From:	Have Your Say Northern Territory
To:	Onshoregas DEPWS
Subject:	Anonymous User completed Carpentaria Pilot Project EP187 Environment Management Plan
Date:	Wednesday, 10 April 2024 3:55:16 PM

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Anonymous User just submitted the survey Carpentaria Pilot Project EP187 Environment Management Plan with the responses below.

Given name

[redacted]

Family Name

[redacted]

Location

DARWIN, NT

Stakeholder type

Community member

Email address

[redacted]

Interest area

Social and cultural
Flora and fauna
Climate change
Human health

Please provide your comments

Hands off our land and seas

Tick this box if you wish for your name and contact details to be confidential

Make my name and contact details private

From:	Have Your Say Northern Territory
To:	Onshoregas DEPWS
Subject:	Anonymous User completed Carpentaria Pilot Project EP187 Environment Management Plan
Date:	Wednesday, 10 April 2024 3:57:55 PM

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Anonymous User just submitted the survey Carpentaria Pilot Project EP187 Environment Management Plan with the responses below.

Given name

[redacted]

Family Name

[redacted]

Location

COCONUT GROVE, NT

Stakeholder type

Community member

Email address

[redacted]

Interest area

Social and cultural
Climate change
Water
Chemicals
Well integrity
Flora and fauna
Waste management
Human health
Regulation and compliance

Please provide your comments

I do not support this. Stop fracking the NT!

From:	Have Your Say Northern Territory
To:	imperial ep187+
Subject:	Anonymous User completed Carpentaria Pilot Project EP187 Environment Management Plan
Date:	Monday, 15 April 2024 10:13:17 PM

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Anonymous User just submitted the survey Carpentaria Pilot Project EP187 Environment Management Plan with the responses below.

Given name

[redacted]

Family Name

[redacted]

Location

ALICE SPRINGS, NT

Stakeholder type

Community member

Email address

[redacted]

Interest area

Water
Climate change
Chemicals
Well integrity
Flora and fauna
Waste management
Human health
Regulation and compliance
Social and cultural

Please provide your comments

My name is [redacted], I am a long term resident of Alice Springs and have been involved in the campaign against fracking for some time. I detest the industry and am disgusted that we are still having to fight this fight. I believe in the interconnectedness of water and life and fear both the extractive and contamination risks posed to groundwater

through hydraulic fracturing as well as the larger scale climate impacts associated with large scale emissions. Contamination of groundwater and the surrounding ecosystem, and the flow on effects that this would cause to both human health and that of our flora and fauna would be disastrous and research has shown that 100% of wells will fail over time. Moreover the wastewater management plan proposes that this contaminated water may be held in open tanks, transferred in trucks, including during the wet season and disposed of in unspecified locations. The project is situated in the catchment areas of the Limmen Bight River catchment to the north and McArthur River to the east, both of which are renowned for flooding in the wet season- It is ludicrous and downright deceptive that the Northern Territory Government claims to have satisfied all of the Pepper Inquiry recommendations, whilst still failing to properly address the storage of toxic wastewater in open ponds and or facilities to treat and dispose of this safely. I believe that the EMP should be rejected or at the very least the project needs to be referred for a full Environmental Impact Assessment and that the federal environment minister Tanya Plibersek needs to signal assessment against the recently expanded water trigger within the Environment Protection and Biodiversity Act. Please consider this with the utmost concern. Sincerely [redacted]

From:	Have Your Say Northern Territory
To:	imperial ep187+
Subject:	Anonymous User completed Carpentaria Pilot Project EP187 Environment Management Plan
Date:	Tuesday, 16 April 2024 4:49:21 PM

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Anonymous User just submitted the survey Carpentaria Pilot Project EP187 Environment Management Plan with the responses below.

Given name

[redacted]

Family Name

[redacted]

Location

RAPID CREEK, NT

Stakeholder type

Community member

Email address

[redacted]

Interest area

Climate change
Flora and fauna
Water
Human health
Social and cultural

Please provide your comments

I am writing to express my concerns about the fracking project in the NT. As a community member living in the NT, and a parent raising children here, I do not trust that all care has been taken in ensuring that fracking is safe now or into the future. I have listened to and read the views of scientists, environmentalists and medical professionals, and I would like to respectfully request that the Carpentaria Gas Pilot Production be refused because the risks are too great and the impacts on the environment and the lives of people have not been assessed adequately. The project should at a minimum: 1. be required to undertake a full Environmental Impact Statement under the Environment Protection Act 2019 (NT),

and 2. be referred to the Federal Environment Minister under the Environment Protection and Biodiversity Conservation Act 1999 for its likely consequences on water resources. Too much is at stake, and land clearing, greenhouse gas emissions, removal of ground water and contamination of surface water are not consequences that can be easily reversed. Thank you for your consideration. Yours sincerely, Catherine Martel

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From:	Have Your Say Northern Territory
To:	imperial ep187+
Subject:	Anonymous User completed Carpentaria Pilot Project EP187 Environment Management Plan
Date:	Tuesday, 16 April 2024 4:53:23 PM

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Anonymous User just submitted the survey Carpentaria Pilot Project EP187 Environment Management Plan with the responses below.

Given name

[redacted]

Family Name

[redacted]

Location

NIGHTCLIFF, NT

Stakeholder type

Community member

Email address

[redacted]

Interest area

Social and cultural
Flora and fauna
Climate change
Water

Please provide your comments

This will be absolutely devastating for the local area, including some of australias longest continuing indigenous cultural centres also the flora and fauna of the local area will be undeniably decimated This is not ok

Tick this box if you wish for your name and contact details to be confidential

Make my name and contact details private

From: [redacted]
To: imperial ep187+
Date: Tuesday, 16 April 2024 5:25:51 PM

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

I am a birdwatcher, a teacher of traditional Aboriginals in the NT from 1966 to 1988, and an opponent of Beetaloo fracking. My name is [redacted]; I have lived in the NT since December 1965.

My two points are below.

For ages politicians and others have been urging Aboriginals to stand on their own feet and taking responsibility for their own lands. The Yanyuwa, Garrwa, Gudanji and Marra people who own the land around Cape Crawford where fracking is planned, have said time and again that they oppose fracking on their land. I stand four square behind these traditional leaders. Some of them I taught at Yirara College in Alice Springs. Aboriginal Rights are a higher priority than short-term gain for a privileged few.

The proposed land-clearing poses a risk to 3 nationally-listed threatened bird species - the Grey Falcon, Painted honeyeater and Gouldian finch - as well as five migratory birds protected under national environment law. The Beetaloo plans will certainly push these protected birds close to the brink.

I plead on behalf of traditional Aboriginal people, and Protected birds.

[redacted]

.

Virus-free.www.avg.com

From: Have Your Say Northern Territory
To: imperial ep187+
Subject: Anonymous User completed Carpentaria Pilot Project EP187 Environment Management Plan
Date: Tuesday, 16 April 2024 5:29:51 PM

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Anonymous User just submitted the survey Carpentaria Pilot Project EP187 Environment Management Plan with the responses below.

Given name

[redacted]

Family Name

[redacted]

Location

GRAY, NT

Stakeholder type

Community member

Email address

[redacted]

Interest area

Social and cultural
Water
Climate change
Chemicals
Well integrity
Other (please specify) - I am concerned about fracking is toxic to aquafers. It's environmentally toxic with flora. In the US a town was fracked that caused earthquakes that didn't happen before, a bath was filled with water, some one struck a match, threw it in the bath casing a fire. Some homes were burnt from water. The flora was dead around the fracked area.
Flora and fauna
Waste management
Human health
Regulation and compliance

Please provide your comments

No Fracking

[redacted]

Short submission guide: Carpentaria Gas Pilot Production

Imperial Oil and Gas, a subsidiary of Empire Energy, has submitted a draft Environmental Management Plan for its proposed Carpentaria Pilot Production, located near Cape Crawford, 130 kms west of Borroloola.

If approved, this would be the first gas fracking production project approved in the Northern Territory. Empire plans to sell the gas to the McArthur River Mine and hopes to start the project in July this year.

Public consultation is open until 19 April 2024 and comments can be emailed to imperial.ep187@nt.gov.au or sent in using the form here.

Make a quick submission asking that the Carpentaria Pilot Production EMP is refused because the impacts and risks of the project are too significant.

You could also ask that the project:

1. **Is required to undertake a full Environmental Impact Statement under the *Environment Protection Act 2019* (NT)**
2. **Is referred to the Federal Environment Minister under the *Environment Protection and Biodiversity Conservation Act 1999* because it is likely to have a significant impact on water resources.**

The proposed project will:

- Drill and frack 10 new wells on four new well pads and use two existing well pads.
- Use 950 million litres of water and millions of litres of chemicals over four years, mostly for fracking
- Only recover 5% of water and chemicals used in fracking, with the rest remaining underground
- Produce 35 million litres of toxic wastewater per well that will need to be disposed of
- Clear 225 hectares of vegetation for well-pads, gravel pits, a gas plant and a water handling station, plus gas and water flowlines.

Here are some points you might like to raise as to why the Carpentaria Pilot Production EMP should be refused:

- The full lifecycle greenhouse gas emissions from the project will be substantial, but Empire doesn't even attempt to quantify them. They acknowledge that emissions from the project would equal approx 475,000 tCO2-e per annum if they flared all the gas, but they do not estimate the downstream emissions if the gas is transported elsewhere via the McArthur River Gas Pipeline, as they propose.
- The company claims it will produce 25 terajoules (TJ) of gas a day, but the McArthur River Pipeline only has capacity for 15TJ a day. There's no mention or explanation of this difference in the draft EMP and no estimation of emissions from flaring the excess gas.

- There are serious risks of flooding leading to pollution and environmental damage, because the project is in the headwaters of two catchments, and crosses Relief Creek and the area around it that floods.
- Wells will be located just outside the 1 in 100 year flood zone, which means they are likely to flood in more extreme events and be at greater risk with climate change.
- The waste management plan proposes that some of the 35 million litres of contaminated fracking wastewater at each well may be held in open tanks, even during the wet season and transferred in trucks to be disposed of in unspecified locations, risking spills and leaks.
- The re-evaluation of the importance of cultural heritage artefacts found at the site in 2022 from what was previously considered “isolated artefacts” to recognition as a site of greater significance indicates the inadequacy of the assessments being conducted for Environmental Management Plans for fracking activities. Cultural sites and landscapes should be fully protected.
- Empire plans to take up to 950 million litres of water from the productive Cambrian Limestone Aquifer system which is facing growing extraction pressure and which is essential to support culture, nature and communities in the area.
- The water licence they intend to apply for equates to roughly 9% of the total volume of groundwater allocated for fracking the Georgina Wiso Water Allocation Plan, and doubles the volume of water entitlements granted to gas companies to date.
- The risks of aquifer connectivity between the deeper aquifers where fracking will occur and shallower aquifers relied on by communities is poorly understood, and there are risks of cross-contamination and depressurisation.
- The proposed clearing would take the total area of clearing approved for fracking to date to 1,200 hectares, and poses a risk to three nationally-listed threatened species are recorded or likely to be present in the area, the Grey Falcon, Painted honeyeater and Gouldian finch as well as five migratory birds protected under national environment law.

  .

Longer Submission guide: Carpentaria Gas Pilot

Imperial Oil and Gas, a subsidiary of Empire Energy, has submitted a draft Environmental Management Plan for its Carpentaria Pilot.

This application is crucial to Empire's plans to proceed with large-scale exploitation of shale gas in the Beetaloo sub-basin, since they plan to sell the gas and be the first to commercialise the basin.

Public consultation is open until 19 April 2024 and comments can be emailed to imperial.ep187@nt.gov.au or sent in using the form here.

The proposed project

- Empire is seeking approval to drill and frack 10 new wells on four new well pads in the eastern Beetaloo sub-Basin, and further use two existing wells on two pads.
- The EMP indicates the project will use 950ML (million litres) of water in total over four years, most of which is needed for fracking. They will apply for a 750ML per year licence to remove this water from the Gum Ridge Formation. This is roughly 9% of the 8GL of water allocated to gas activities in the Georgina Wiso water plan.
- Only 5% of the water they use will be recovered as "flowback" – the rest will stay underground. There will be around 35 million litres of flowback water returned to the surface per well that will need to be transported, stored and then disposed of off-site. Arrangements for this are unclear.
- The project requires clearing of vegetation for well-pads, flow-lines, nine gravel pits, a gas plant, a water handling station, campsite, groundwater bores and a communications satellite dish, totalling around 225 hectares.
- Construction on Carpentaria 4 horizontal drilling is anticipated from late July (there is already a vertical well there)

Make a submission asking that the EMP is refused because the impacts and risks of the project are too significant. Here are some points you might like to raise as to why the Carpentaria Pilot Production should be refused.

Greenhouse emissions

- Empire says it plans to apply to "use the gas on an appraisal basis" meaning that instead of flaring it onsite, they want to secure a connection to the McArthur River mine gas pipeline, use their gas plant to process the gas and sell it into the network.
- The company claims it will produce 25 terajoules (TJ) of gas a day, but the McArthur River Pipeline only has capacity for 15TJ a day. There's no mention or explanation of this difference in the draft EMP, no estimation of emissions from flaring the excess gas or the downstream emissions from burning it.

Culture

- The re-evaluation of the importance of cultural heritage artefacts found at the site in 2022 and previously considered "isolated artefacts" indicates the inadequacy of the

assessments being conducted for Environmental Management Plans for fracking activities.
- This activity should be subject to a full Environmental Impact Statement that explores the cultural values of affected ecology, water and landscapes and gives Traditional Owners power to grant or refuse consent to the proposed activities.

-

Groundwater

- Empire will need to take 950ML (million litres) of water from the Gum Ridge Formation, part of the productive Cambrian Limestone Aquifer (CLA) system which supports culture, nature and communities in the area.
- They will apply for a licence to extract up to 750ML a year, roughly 9% of the total volume of groundwater allocated to petroleum in the Georgina Wiso Water Allocation Plan. If granted, this 750ML licence would effectively double the volume of water entitlements granted to petroleum companies so far.
- The impact of this water removal on the flow of groundwater locally and regionally is largely undescribed.
- Although these aquifers are vast, their recharge is slow and the behaviour of water in them largely unknown, which means the impacts of water depletion is also uncertain.
- Given limited knowledge of the CLA, a full Environmental Impact Statement is required that properly investigates the hydrological properties of the aquifer, its cultural and ecological values and the impact of this water removal on those values.

Surface water

- The project is in the headwaters of two catchments, the Limmen Bight River catchment to the north and McArthur River to the east.
- The pilot project crosses Relief Creek and the area around it that floods. Wells will be located just outside the 1 in 100 year flood zone, which means they are likely to flood in more extreme events.
- Every well will produce “drill-cuttings” that need to be disposed of and which have elevated concentrations of some metals and other elements of concern.
- Every well will also produce 35 million litres of fracking flow back water and the handling of this water creates the risk of spills and accidents that could contaminate soil or surface waters.
- The wastewater management plan proposes that this contaminated water may be held in open tanks, transferred in trucks, including during the wet season and disposed of in unspecified locations.

Wildlife

- Three nationally-listed threatened species are recorded or likely to be present in the area, the Grey Falcon, Painted honeyeater and Gouldian finch as well as five migratory birds protected under national environment law.

- It will clear up to 229 hectares of native vegetation and wildlife habitat, bringing the total cumulative clearing approved in the area for fracking activities to nearly 1,200 hectares.

From: Have Your Say Northern Territory
To: imperial ep187+
Subject: Anonymous User completed Carpentaria Pilot Project EP187 Environment Management Plan
Date: Tuesday, 16 April 2024 6:08:38 PM

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Anonymous User just submitted the survey Carpentaria Pilot Project EP187 Environment Management Plan with the responses below.

Given name

[redacted]

Family Name

[redacted]

Location

KATHERINE, NT

Stakeholder type

Community member

Email address

[redacted]

Interest area

Water
Regulation and compliance

Please provide your comments

Please see attached file.

[redacted]

Re Carpentaria Pilot Production EMP

I am particularly concerned about Empire's plans to take up to 950 million litres of water from the productive Cambrian Limestone Aquifer system which is facing growing extraction pressure and which is essential to support culture, nature and communities in the area. The water licence they intend to apply for equates to roughly 9% of the total volume of groundwater allocated for fracking the Georgina Wiso Water Allocation Plan, and
doubles the volume of water entitlements granted to gas companies to date. The risks of aquifer connectivity between the deeper aquifers where fracking will occur and shallower aquifers relied on by communities is poorly understood, and
there are risks of cross-contamination and depressurisation.

It is easy to write about intended actions in an environmental management plan however, the required commitment to fair and honest dealing to follow through and thoroughly implement commitments to environmental codes of practice is more difficult and as industry track record demonstrates, often dispensed with entirely. The imperative to put financial profit ahead of less profitable and therefore lesser commitments is the first priority of board members to financial investors. As a community who consume or otherwise benefit from the resources produced and allow operations on lands we are responsible for, we are also investors in the company.

In this case the stated degradation of groundwater supply and potential surface water pollution risks are too high to accept. I request that this project is referred to the Federal Environment Minister under the Environment
Protection and Biodiversity Conservation Act 1999 because it is likely to have a significant impact on water resources.

[redacted]
Katherine NT

From:	Have Your Say Northern Territory
To:	imperial ep187+
Subject:	Anonymous User completed Carpentaria Pilot Project EP187 Environment Management Plan
Date:	Tuesday, 16 April 2024 8:23:46 PM

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Anonymous User just submitted the survey Carpentaria Pilot Project EP187 Environment Management Plan with the responses below.

Given name

[redacted]

Family Name

[redacted]

Location

ALICE SPRINGS, NT

Stakeholder type

Community member

Email address

[redacted]

Interest area

Climate change
Water
Social and cultural
Other (please specify) - Concerns about transparency, based on professional experience as consultant in the Petroleum exploration and extraction industry
Regulation and compliance
Waste management

Please provide your comments

I am concerned about impacts on aquifers and future water quality. I could not locate this project amongst current EPBC Act referral. Has this project been referred and assessed for impact on water? If not, it should be. Given the rapid progression of climate change, we have to immediately reduce usage of fossil fuels. Further fossil fuel extraction is detrimental to our climate and undermines efforts made worldwide to halt warming. Gas and petroleum extraction produces problematic waste, such as large amounts of a

wastewater, a mix of water, salt and oil and various chemical substances. These are often held in open basins, which are a death trap to birds. Waste water is a huge environmental hazard, no matter where it is taken. The risk assessments that accompany the EMP are rather arbitrary. I do not agree that the risks are sufficiently managed. I have seen petroleum wells and fracking sites - they are subject to unplanned incidents that result in additional contamination. These incidents are not always reported as they should. I expect that the same will happen here, so the environmental risks are greater than stated in the EMP. I note we have a very promising new law now - the NT Environment Protection Act 2019. Has this project been assessed for its merits under the EP Act? It most definitely should. I believe that it does not meet the environmental standards the EP Act calls for. I note the proponent claims to have consulted Indigenous custodians of the land, however there are concerns amongst Traditional Owners about the project and I am not convinced that they support the

---

Tick this box if you wish for your name and contact details to be confidential

Make my name and contact details private

From:	Have Your Say Northern Territory
To:	imperial ep187+
Subject:	Anonymous User completed Carpentaria Pilot Project EP187 Environment Management Plan
Date:	Tuesday, 16 April 2024 10:54:29 PM

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Anonymous User just submitted the survey Carpentaria Pilot Project EP187 Environment Management Plan with the responses below.

Given name

[redacted]

Family Name

[redacted]

Location

DUNDEE BEACH, NT

Stakeholder type

Landholder/occupier

Email address

[redacted]

Interest area

Social and cultural
Flora and fauna
Water
Waste management
Human health
Chemicals
Regulation and compliance

Please provide your comments

Why is this still going through? Surely there are other ways of economic growth. This will impact tourism, one of the Northern Territory strong sides, in a bad way. And as a territorial, I am not keen on drinking chemically polluted water. This is a very short sighted project and you know it.

Tick this box if you wish for your name and contact details to be confidential

Make my name and contact details private

From: Have Your Say Northern Territory
To: imperial ep187+
Subject: Anonymous User completed Carpentaria Pilot Project EP187 Environment Management Plan
Date: Wednesday, 17 April 2024 6:54:43 AM

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Anonymous User just submitted the survey Carpentaria Pilot Project EP187 Environment Management Plan with the responses below.

Given name

[redacted]

Family Name

[redacted]

Location

PALM BEACH, NSW

Stakeholder type

Community member

Email address

[redacted]

Interest area

Well integrity
Flora and fauna
Waste management
Human health
Regulation and compliance
Water
Climate change
Chemicals
Social and cultural

Please provide your comments

see attachment

[redacted]

Tick this box if you wish for your name and contact details to be confidential

Make my name and contact details private

RE: Carpentaria Gas Pilot - Imperial Oil and Gas Pty Ltd submitted an Environment Management Plan (EMP)

Thank you for the opportunity to provide a response to this proposal.

I am appalled that in this day and age a proposal seeking to destroy habitat, increase fossil fuel production and emissions is being even considered.

The full lifecycle greenhouse gas emissions from this project will be substantial, but Empire doesn't even attempt to quantify them. They acknowledge that emissions from the project would equal approx.. 475,000 tCO2-e per annum if they flared all the gas, but they do not estimate the downstream emissions if the gas is transported elsewhere via the McArthur River Gas Pipeline, as they propose.

The proposed clearing would take the total area of clearing approved for fracking to date to 1,200 hectares, and poses a risk to three nationally-listed threatened species are recorded or likely to be present in the area, the Grey Falcon, Painted honeyeater and Gouldian finch as well as five migratory birds protected under national environment law, along with being the only home of thousands of other individual birds, mammals and fish – when will these come before the profits sought by any company or human individual?

Australia is the sunniest place on earth – why would this be needed for energy? Who really profits or benefits form this – certainly not Australia nor Northern Territorians.

Further points why this proposal should be rejected:

Greenhouse emissions

● Empire says it plans to apply to "use the gas on an appraisal basis" meaning that instead of flaring it onsite, they want to secure a connection to the McArthur River mine gas pipeline, use their gas plant to process the gas and sell it into the network.

● The company claims it will produce 25 terajoules (TJ) of gas a day, but the McArthur River Pipeline only has capacity for 15TJ a day. There's no mention or explanation of this difference in the draft EMP, no estimation of emissions from flaring the excess gas or the downstream emissions from burning it.

Culture

● The re-evaluation of the importance of cultural heritage artefacts found at the site in 2022 and previously considered "isolated artefacts" indicates the inadequacy of the assessments being conducted for Environmental Management Plans for fracking activities.

● This activity should be subject to a full Environmental Impact Statement that explores the cultural values of affected ecology, water and landscapes and gives Traditional Owners power to grant or refuse consent to the proposed activities. assessments being conducted for Environmental Management Plans for fracking activities.

● This activity should be subject to a full Environmental Impact Statement that explores the cultural values of affected ecology, water and landscapes and gives Traditional Owners power to grant or refuse consent to the proposed activities.

Groundwater

● Empire will need to take 950ML (million litres) of water from the Gum Ridge Formation, part of the productive Cambrian Limestone Aquifer (CLA) system which supports culture, nature and communities in the area.

● **They will apply for a licence to extract up to 750ML a year, roughly 9% of the total volume** of **groundwater** allocated to petroleum in the Georgina Wiso Water Allocation Plan. If granted, this 750ML licence would effectively double the volume of water entitlements granted to petroleum companies so far.

● The impact of this water removal on the flow of groundwater locally and regionally is largely undescribed.

● Although these aquifers are vast, their recharge is slow and the behaviour of water in them largely unknown, which means the impacts of water depletion is also uncertain.

● Given limited knowledge of the CLA, a full Environmental Impact Statement is required that properly investigates the hydrological properties of the aquifer, its cultural and ecological values and the impact of this water removal on those values. Surface water

● The project is in the headwaters of two catchments, the Limmen Bight River catchment to the north and McArthur River to the east.

● The pilot project crosses Relief Creek and the area around it that floods. Wells will be located just outside the 1 in 100 year flood zone, which means they are likely to flood in more extreme events.

● Every well will produce “drill-cuttings” that need to be disposed of and which have elevated concentrations of some metals and other elements of concern.

● Every well will also produce 35 million litres of fracking flow back water and the handling of this water creates the risk of spills and accidents that could contaminate soil or surface waters.

● The wastewater management plan proposes that this contaminated water may be held in open tanks, transferred in trucks, including during the wet season and disposed of in unspecified locations.

Wildlife

● Three nationally-listed threatened species are recorded or likely to be present in the area, the Grey Falcon, Painted honeyeater and Gouldian finch as well as five migratory birds protected under national environment law.

● It will clear up to 229 hectares of native vegetation and wildlife habitat, bringing the total cumulative clearing approved in the area for fracking activities to nearly 1,200 hectares – this is completely unacceptable – we should be conserving habitat, not allow it to be destroyed so fossil fuel producers can profit.

Allowing this proposal to pass would be like voting for your own demise.

Voting for this to proceed would be the same as killing all that wildlife yourself.

Allowing any of these wells near any water source, or to be allowed to use any water source, is akin to poisoning, permanently, the drinking water, of the living generations of humans and all other animals – and all those to come.

No ‘Environment Management Plan’ could ever qualify or quantify:

‘’Land clearing and earthworks

Drilling, hydraulic fracture, completion, testing, maintenance, suspension and abandonment of wells

Construction, operation, modification of facilities and gas and wastewater flowlines used to recover petroleum, treat water, and treat gas

Decommissioning and rehabilitation

Drilling and hydraulic fracturing of up to 10 petroleum wells

Associated civil works including:

Up to 24.2 ha of access tracks

Up to 62.1 ha of new and expanded well pads and drill cutting sumps

Up to 57.6 ha of gravel pits

Up to 1.2 ha for camp locations

Other ancillary infrastructure.’’

This is not a plan to manage the environment – this presents a plan to permanently destroy it, for the profit of a few and at great loss to many.

The time as elapsed, a decade ago, for considering such destructive proposals as part of our future.

From: [redacted]
To: imperial ep187+
Subject: Carpentaria proposal
Date: Wednesday, 17 April 2024 9:16:41 AM
Attachments: [redacted]

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Please see attached my concerns regarding the environmental consequences of this project.

[redacted]

Carpentaria Pilot Project EP187 Environment Management Plan

Emailed to: imperial.ep187@nt.gov.au

I am a long-term resident of the Northern Territory and a student at Charles Darwin University studying environmental science. I understand the importance and the fragility of the environment impacted by this project. I would like to express my concerns regarding this project and request that it be rejected in the light of serious environmental risk. At the very least, this project should undergo a full environmental impact statement under the Environment Protection Act 2019. I also request that it is referred to the Federal Environment Minister for review.

My reasons for this are:

- This is the first commercial gas fracking project in the Northern Territory and the NT cannot afford to approve this and get it wrong. The risks of damage and harm from the impacts on land clearing, weed infestation, massive water use and generations of wastewater, and huge greenhouse gas emissions are significant. The risks must be assessed and reduced to an absolute minimum level *if* the project is to proceed.
- The volume of water required for these wells is astounding. Added to other projects' water allocation in the NT, the volume is massive and beyond the experience of any previous water allocations. The quality scientific research to support safety, and outcomes of taking this volume of water from the system is lacking. The risk of contamination of aquifers and the impact on land, wildlife and human habitation is not adequately known. Such water-hungry projects should not be approved in this dry but flood-prone environment.
- The connection between aquifers that life depends on is largely unknown. Effects of underground contaminated water remaining post-fracking are considered minimal in this submission but are not well understood or supported by adequate scientific research to give substantial confidence in the claims.
- Adequate disposal of wastewater is not outlined. The Pepper inquiry specifically noted that contaminated water should remain in enclosed tanks to limit risk to birds and other wildlife. This has not been addressed and does not meet the stated NT Government aim of meeting all 135 recommendations of the Pepper inquiry.
- The full lifecycle greenhouse gas emissions from the project will be substantial, but have not been quantified or adequate offsets proposed. This is another failure to meet the Pepper inquiry requirements to reduce risks.
- While production of 25 terajoules (TJ) of gas a day is claimed, McArthur River Pipeline only has capacity for 15TJ a day. This has not been explained, raising concerns about other potential inaccuracies in the proposal.
- In the wet season, there are serious risks of flooding leading to pollution and environmental damage, because the project is in the headwaters of two catchments, and crosses Relief Creek and the area around it that floods.
- The proposed clearing poses a risk to three nationally listed threatened species which are recorded or likely to be present in the area, the Grey Falcon, Painted honeyeater and Gouldian finch as well as five migratory birds protected under national environment law.
- Weed infestation and dust as a result of land clearing and road construction will forever change the ecosystem of the area with cascading effects on vegetation and wildlife

NT rivers are some of the last remaining wild rivers in the world and the ecosystems they support are extensive, interconnected and vital for a range of industries that bring income into the NT. They are also vital for life in these dry areas, with underground water being the “lungs” for surface beings – wildlife, vegetation and humans.

The water volumes proposed alone, indicate potential for serious environmental impact of this project. In my view this is an unacceptable risk. We cannot afford to get this wrong. Unfortunately, the environmental record of industries in the NT does not inspire confidence in the population, and government regulation is weak. Territorians deserve the very highest level of scrutiny of this project, and the placement of regulatory conditions (as promised in agreeing to all the Pepper inquiry requirements) for it to proceed. I do not believe it is worth the risk to our environment and wish the project not to proceed at all.

From:	Have Your Say Northern Territory
To:	imperial ep187+
Subject:	Anonymous User completed Carpentaria Pilot Project EP187 Environment Management Plan
Date:	Wednesday, 17 April 2024 9:45:33 AM

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Anonymous User just submitted the survey Carpentaria Pilot Project EP187 Environment Management Plan with the responses below.

Given name

[redacted]

Family Name

[redacted]

Location

NIGHTCLIFF, NT

Stakeholder type

Community member

Email address

[redacted]

Interest area

Social and cultural
Water
Flora and fauna
Waste management
Climate change
Human health

Please provide your comments

I submit that that the Carpentaria Pilot Production EMP is refused because the impacts and risks of the project are too significant. The full lifecycle greenhouse gas emissions from the project will be substantial but have not been quantified by Empire Energy, There are serious risks of flooding leading to pollution and environmental damage, because the project is in the headwaters of two catchments, and crosses Relief Creek and the area around it that floods. Given the location of the wells, they are likely to flood in more extreme events and be at greater risk with climate change. A re-evaluation of the

importance of cultural heritage artefacts is required and cultural sites and landscapes should be fully protected. Empire plans to take up to 950 million litres of water from the productive Cambrian Limestone Aquifer system which is facing growing extraction pressure and which is essential to support culture, nature and communities in the area. The water licence they intend to apply for equates to roughly 9% of the total volume of groundwater allocated for fracking the Georgina Wiso Water Allocation Plan, and doubles the volume of water entitlements granted to gas companies to date. The proposed clearing would take the total area of clearing approved for fracking to date to 1,200 hectares, and poses a risk to three nationally-listed threatened species are recorded or likely to be present in the area, the Grey Falcon, Painted honeyeater and Gouldian finch as well as five migratory birds protected under national environment law. At an absolute minimum, the project should be required to undertake a full Environmental Impact Statement under the Environment Protection Act 2019 (NT) and should be referred to the Federal Environment Minister under the Environment Protection and Biodiversity Conservation Act 1999 because it is likely to have a significant impact on water resources.

Tick this box if you wish for your name and contact details to be confidential

Make my name and contact details private

From:	Have Your Say Northern Territory
To:	imperial ep187+
Subject:	Anonymous User completed Carpentaria Pilot Project EP187 Environment Management Plan
Date:	Wednesday, 17 April 2024 2:19:50 PM

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Anonymous User just submitted the survey Carpentaria Pilot Project EP187 Environment Management Plan with the responses below.

Given name

[redacted]

Family Name

[redacted]

Location

MALAK, NT

Stakeholder type

Community member

Email address

[redacted]

Interest area

Social and cultural
Water
Climate change
Flora and fauna
Human health
Waste management
Regulation and compliance
Well integrity
Chemicals

Please provide your comments

I ask that the Carpentaria Pilot Production EMP is refused because the impacts and risks of the project are too significant. Further to this, i ask that the project: 1. Is required to undertake a full Environmental Impact Statement under the Environment Protection Act 2019 (NT) 2. Is referred to the Federal Environment Minister under the Environment

Protection and Biodiversity Conservation Act 1999 because it is likely to have a significant impact on water resources. Here are some examples of why the project should be refused. The full lifecycle greenhouse gas emissions from the project will be substantial, but Empire doesn't even attempt to quantify them. They acknowledge that emissions from the project would equal approx 475,000 tCO2-e per annum if they flared all the gas, but they do not estimate the downstream emissions if the gas is transported elsewhere via the McArthur River Gas Pipeline, as they propose. The proposed clearing would take the total area of clearing approved for fracking to date to 1,200 hectares, and poses a risk to three nationally-listed threatened species are recorded or likely to be present in the area, the Grey Falcon, Painted honeyeater and Gouldian finch as well as five migratory birds protected under national environment law. The waste management plan proposes that some of the 35 million litres of contaminated fracking wastewater at each well may be held in open tanks, even during the wet season and transferred in trucks to be disposed of in unspecified locations, risking spills and leaks. thank you for taking the time to read my submission.

From:	Have Your Say Northern Territory
To:	imperial ep187+
Subject:	Anonymous User completed Carpentaria Pilot Project EP187 Environment Management Plan
Date:	Wednesday, 17 April 2024 2:55:33 PM

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Anonymous User just submitted the survey Carpentaria Pilot Project EP187 Environment Management Plan with the responses below.

Given name

[redacted]

Family Name

[redacted]

Location

WANGURI, NT

Stakeholder type

Community member

Email address

[redacted]

Interest area

Social and cultural
Flora and fauna
Water
Climate change

Please provide your comments

To the NT Government, NT EPA and the Minister for Environment, Climate Change and Water Security, Eva Lawler: I'd like to request that the Carpentaria Pilot Production EMP submitted by Imperial Oil & Gas on 18 March 2024 be refused, as the risk that their proposed activities will leave long-term, irrevocable environmental damage to Country is worryingly high. Moreover, in their EMP, Imperial Oil & Gas have failed to properly assess the full scale of the long-term impacts their project will have. In their EMP, Imperial Oil & Gas/Empire has failed to quantify the downstream emissions if, according to their proposed plan, the gas they extract is transported out of the Barkly via the McArthur River Gas Pipeline. If the NT government is serious about its commitment to

achieving net zero greenhouse gas emissions by 2050, these emissions need to be included in the company's EMP. I'd also argue that further research needs to be made into aquifer connectivity. Despite Imperial's assurances that their wells will not affect the Cambrian Limestone Aquifer above, the fact that only just three years ago scientists from the CSIRO were finding multiple new species of fauna in this very aquifer system proves that we do not know enough to comfortably say that fracking and the use of millions of litres of chemicals in the process will not permanently damage the environment. I would like to request that Imperial complete a full Environmental Impact Statement for the Carpentaria Pilot Project, as outlined under the Environment Protection Act 2019 (NT). I would also like to request that the project is referred to the Federal Environment Minister under the Environment Protection and Biodiversity Conservation Act 1999 for its significant impact on water resources. These are issues that will affect Territorians and Australians in the long-term. It is disappointing that the NT government's approach is short-sighted and lacking in ambition or creativity, rather than looking for ways for Territorians to benefit environmentally and economically in the long term. I kindly ask that you consider the following requests to look further into the project's potential environmental impact above.

Tick this box if you wish for your name and contact details to be confidential

Make my name and contact details private

From:	Have Your Say Northern Territory
To:	imperial ep187+
Subject:	Anonymous User completed Carpentaria Pilot Project EP187 Environment Management Plan
Date:	Wednesday, 17 April 2024 4:49:49 PM

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Anonymous User just submitted the survey Carpentaria Pilot Project EP187 Environment Management Plan with the responses below.

Given name

[redacted]

Family Name

[redacted]

Location

NIGHTCLIFF, NT

Stakeholder type

Community member

Email address

[redacted]

Interest area

Flora and fauna
Waste management
Human health
Regulation and compliance
Well integrity
Chemicals
Climate change
Water
Social and cultural

Please provide your comments

I am asking that the Carpentaria Pilot Production EMP is refused because the impacts and risks of the project are too significant. I am asking ask that the project: 1. Is required to undertake a full Environmental Impact Statement under the Environment Protection Act 2019 (NT) 2. Is referred to the Federal Environment Minister under the Environment

Protection and Biodiversity Conservation Act 1999 because it is likely to have a significant impact on water resources. These are some of the reasons why the Carpentaria Pilot Production EMP should be refused: ● The full lifecycle greenhouse gas emissions from the project will be substantial, but Empire doesn't even attempt to quantify them. They acknowledge that emissions from the project would equal approx 475,000 tCO2-e per annum if they flared all the gas, but they do not estimate the downstream emissions if the gas is transported elsewhere via the McArthur River Gas Pipeline, as they propose. ● The company claims it will produce 25 terajoules (TJ) of gas a day, but the McArthur River Pipeline only has capacity for 15TJ a day. There's no mention or explanation of this difference in the draft EMP and no estimation of emissions from flaring the excess gas. ● There are serious risks of flooding leading to pollution and environmental damage, because the project is in the headwaters of two catchments, and crosses Relief Creek and the area around it that floods. ● Wells will be located just outside the 1 in 100 year flood zone, which means they are likely to flood in more extreme events and be at greater risk with climate change. ● The waste management plan proposes that some of the 35 million litres of contaminated fracking wastewater at each well may be held in open tanks, even during the wet season and transferred in trucks to be disposed of in unspecified locations, risking spills and leaks. ● Empire plans to take up to 950 million litres of water from the productive Cambrian Limestone Aquifer system which is facing growing extraction pressure and which is essential to support culture, nature and communities in the area. ● The water licence they intend to apply for equates to roughly 9% of the total volume of groundwater allocated for fracking the Georgina Wiso Water Allocation Plan, and doubles the volume of water entitlements granted to gas companies to date. ● The risks of aquifer connectivity between the deeper aquifers where fracking will occur and shallower aquifers relied on by communities is poorly understood, and there are risks of cross-contamination and depressurisation. ● The proposed clearing would take the total area of clearing approved for fracking to date to 1,200 hectares, and poses a risk to three nationally-listed threatened species are recorded or likely to be present in the area, the Grey Falcon, Painted honeyeater and Gouldian finch as well as five migratory birds protected under national environment law. The re-evaluation of the importance of cultural heritage artefacts found at the site in 2022 from what was previously considered "isolated artefacts" to recognition as a site of greater significance indicates the inadequacy of the assessments being conducted for Environmental Management Plans for fracking activities. Cultural sites and landscapes should be fully protected.

From:	Have Your Say Northern Territory
To:	imperial ep187+
Subject:	Anonymous User completed Carpentaria Pilot Project EP187 Environment Management Plan
Date:	Wednesday, 17 April 2024 6:13:27 PM

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Anonymous User just submitted the survey Carpentaria Pilot Project EP187 Environment Management Plan with the responses below.

Given name

[redacted]

Family Name

[redacted]

Location

CLONCURRY, QLD

Stakeholder type

Community member

Email address

[redacted]

Interest area

Social and cultural
Flora and fauna
Water
Climate change

Please provide your comments

The effects of fracking are not completely known. We can look at the American areas where a fracking has been continuing to see some of the problems which have been occurring there. The northern territory is an area that should be protected and an ecosystem that is fragile , and also impacts on the Northern Territory ecosystem echo nationwide Greenhouse emissions ● Empire says it plans to apply to “use the gas on an appraisal basis” meaning that instead of flaring it onsite, they want to secure a connection to the McArthur River mine gas pipeline, use their gas plant to process the gas and sell it into the network. ● The company claims it will produce 25 terajoules (TJ) of gas a day, but the McArthur River Pipeline only has capacity for 15TJ a day. There’s no mention or

explanation of this difference in the draft EMP, no estimation of emissions from flaring the excess gas or the downstream emissions from burning it. TThe capacity is not there? How will it be managed? What emissions will be produced? Culture ● The re-evaluation of the importance of cultural heritage artefacts found at the site in 2022 and previously considered “isolated artefacts” indicates the inadequacy of the assessments being conducted for Environmental Management Plans for fracking activities. ● High tou tourism and cultural importance area has been full and informed involvement by all the cultural stakeholders ? This activity should be subject to a full Environmental Impact Statement that explores the cultural values of affected ecology, water and landscapes and gives Traditional Owners power to grant or refuse consent to the proposed activities. ● Groundwater The great artisian basin is the water source for most of inland Australia. Do not want to damage the groundwater further. It is already impacted by PA FAS and by the large water licenses. Already in place the impact of this further usage has not been properly assessed ● Empire will need to take 950ML (million litres) of water from the Gum Ridge Formation, part of the productive Cambrian Limestone Aquifer (CLA) system which supports culture, nature and communities in the area. ● They will apply for a licence to extract up to 750ML a year, roughly 9% of the total volume of groundwater allocated to petroleum in the Georgina Wiso Water Allocation Plan. If granted, this 750ML licence would effectively double the volume of water entitlements granted to petroleum companies so far. ● The impact of this water removal on the flow of groundwater locally and regionally is largely undescribed. ● Although these aquifers are vast, their recharge is slow and the behaviour of water in them largely unknown, which means the impacts of water depletion is also uncertain. ● Given limited knowledge of the CLA, a full Environmental Impact Statement is required that properly investigates the hydrological properties of the aquifer, its cultural and ecological values and the impact of this water removal on those values. Surface water As demonstrated by the recent flood events and the ones that have happened in previous recent years this area could be subject to extreme flooding of surface waters impact on the surface water by mining and racking activities will impact a large area of Australia In a negative fashion. ● The project is in the headwaters of two catchments, the Limmen Bight River catchment to the north and McArthur River to the east. ● The pilot project crosses Relief Creek and the area around it that floods. Wells will be located just outside the 1 in 100 year flood zone, which means they are likely to flood in more extreme events. ● Every well will produce “drill-cuttings” that need to be disposed of and which have elevated concentrations of some metals and other elements of concern. ● Every well will also produce 35 million litres of fracking flow back water and the handling of this water creates the risk of spills and accidents that could contaminate soil or surface waters. ● The wastewater management plan proposes that this contaminated water may be held in open tanks, transferred in trucks, including during the wet season and disposed of in unspecified locations. Wildlife ● Three nationally-listed threatened species are recorded or likely to be present in the area, the Grey Falcon, Painted honeyeater and Gouldian finch as well as five migratory birds protected under national environment law. ● It will clear up to 229 hectares of native vegetation and wildlife habitat, bringing the total cumulative clearing approved in the area for fracking activities to nearly 1,200 hectares.

From:	Have Your Say Northern Territory
To:	imperial ep187+
Subject:	Anonymous User completed Carpentaria Pilot Project EP187 Environment Management Plan
Date:	Wednesday, 17 April 2024 7:45:19 PM

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Anonymous User just submitted the survey Carpentaria Pilot Project EP187 Environment Management Plan with the responses below.

Given name

[redacted]

Family Name

[redacted]

Location

TOOWOOMBA, QLD

Stakeholder type

Community member

Email address

[redacted]

Interest area

Social and cultural
Water
Human health
Climate change

Please provide your comments

Impacts from this proposed project are so significant that thorough analysis is needed from all sections of society . Also an Environmental impact study is essential. The project should be 1. required to undertake a full Environmental Impact Statement under the Environment Protection Act 2019 (NT) 2. referred to the Federal Environment Minister under the Environment Protection and Biodiversity Conservation Act 1999 because it is likely to have a significant impact on water resources.

From:	Have Your Say Northern Territory
To:	imperial ep187+
Subject:	Anonymous User completed Carpentaria Pilot Project EP187 Environment Management Plan
Date:	Wednesday, 17 April 2024 7:52:55 PM

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Anonymous User just submitted the survey Carpentaria Pilot Project EP187 Environment Management Plan with the responses below.

Given name

[redacted]

Family Name

[redacted]

Location

ALICE SPRINGS, NT

Stakeholder type

Community member

Email address

[redacted]

Interest area

Social and cultural
Flora and fauna
Water
Waste management
Climate change
Human health
Chemicals
Well integrity

Please provide your comments

I request that the project: Is required to undertake a full Environmental Impact Statement under the Environment Protection Act 2019 (NT) Is referred to the Federal Environment Minister under the Environment Protection and Biodiversity Conservation Act 1999 because it is likely to have a significant impact on water resources. I do not want the proposed project as it will: Drill and frack 10 new wells on four new well pads and use two

existing well pads. Use 950 million litres of water and millions of litres of chemicals over four years, mostly for fracking Only recover 5% of water and chemicals used in fracking, with the rest remaining underground Produce 35 million litres of toxic wastewater per well that will need to be disposed of Clear 225 hectares of vegetation for well-pads, gravel pits, a gas plant and a water handling station, plus gas and water flowlines. These are the reasons why the Carpentaria Pilot Production EMP should be refused: The full lifecycle greenhouse gas emissions from the project will be substantial, but Empire doesn't even attempt to quantify them. They acknowledge that emissions from the project would equal approx 475,000 tCO2-e per annum if they flared all the gas, but they do not estimate the downstream emissions if the gas is transported elsewhere via the McArthur River Gas Pipeline, as they propose. The company claims it will produce 25 terajoules (TJ) of gas a day, but the McArthur River Pipeline only has capacity for 15TJ a day. There's no mention or explanation of this difference in the draft EMP and no estimation of emissions from flaring the excess gas. There are serious risks of flooding leading to pollution and environmental damage, because the project is in the headwaters of two catchments, and crosses Relief Creek and the area around it that floods. Wells will be located just outside the 1 in 100 year flood zone, which means they are likely to flood in more extreme events and be at greater risk with climate change. The waste management plan proposes that some of the 35 million litres of contaminated fracking wastewater at each well may be held in open tanks, even during the wet season and transferred in trucks to be disposed of in unspecified locations, risking spills and leaks. The re-evaluation of the importance of cultural heritage artefacts found at the site in 2022 from what was previously considered "isolated artefacts" to recognition as a site of greater significance indicates the inadequacy of the assessments being conducted for Environmental Management Plans for fracking activities. Cultural sites and landscapes should be fully protected. Empire plans to take up to 950 million litres of water from the productive Cambrian Limestone Aquifer system which is facing growing extraction pressure and which is essential to support culture, nature and communities in the area. The water licence they intend to apply for equates to roughly 9% of the total volume of groundwater allocated for fracking the Georgina Wiso Water Allocation Plan, and doubles the volume of water entitlements granted to gas companies to date. The risks of aquifer connectivity between the deeper aquifers where fracking will occur and shallower aquifers relied on by communities is poorly understood, and there are risks of cross-contamination and depressurisation. The proposed clearing would take the total area of clearing approved for fracking to date to 1,200 hectares, and poses a risk to three nationally-listed threatened species are recorded or likely to be present in the area, the Grey Falcon, Painted honeyeater and Gouldian finch as well as five migratory birds protected under national environment law

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Make my name and contact details private

From:	Have Your Say Northern Territory
To:	imperial ep187+
Subject:	Anonymous User completed Carpentaria Pilot Project EP187 Environment Management Plan
Date:	Wednesday, 17 April 2024 8:05:13 PM

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Anonymous User just submitted the survey Carpentaria Pilot Project EP187 Environment Management Plan with the responses below.

Given name

[redacted]

Family Name

[redacted]

Location

GOOLMANGAR, NSW

Stakeholder type

Community member

Email address

[redacted]

Interest area

Water
Social and cultural

Please provide your comments

Thankyou for the opportunity to make this submission. I am against the Carpentaria Pilot Project EP187 Environment Management Plan and ask that it is refused permission to proceed as it would be catastrophic for the environment and the health of the community. I ask that the project: 1. Is required to undertake a full Environmental Impact Statement under the Environment Protection Act 2019 (NT) 2. Is referred to the Federal Environment Minister under the Environment Protection and Biodiversity Conservation Act 1999 because it is likely to have a significant impact on water resources. There are serious risks of flooding leading to pollution and environmental damage, because the project is in the headwaters of two catchments, and crosses Relief Creek and the area around it that floods. The re-evaluation of the importance of cultural heritage artefacts found at the site in 2022 from what was previously considered “isolated artefacts” to recognition as a site of greater

significance indicates the inadequacy of the assessments being conducted for Environmental Management Plans for fracking activities. Cultural sites and landscapes should be fully protected. The risks of aquifer connectivity between the deeper aquifers where fracking will occur and shallower aquifers relied on by communities is poorly understood, and there are risks of cross-contamination and depressurisation. The proposed clearing would take the total area of clearing approved for fracking to date to 1,200 hectares, and poses a risk to three nationally-listed threatened species are recorded or likely to be present in the area, the Grey Falcon, Painted honeyeater and Gouldian finch as well as five migratory birds protected under national environment law.

From:	Have Your Say Northern Territory
To:	imperial ep187+
Subject:	Anonymous User completed Carpentaria Pilot Project EP187 Environment Management Plan
Date:	Wednesday, 17 April 2024 9:37:27 PM

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Anonymous User just submitted the survey Carpentaria Pilot Project EP187 Environment Management Plan with the responses below.

Given name

[redacted]

Family Name

[redacted]

Location

PARAP, NT

Stakeholder type

Community member

Email address

[redacted]

Interest area

Flora and fauna
Water
Waste management
Climate change
Human health
Chemicals

Please provide your comments

I oppose fracking in the NT because I am concerned about the effect it will have on the natural environment and the health of our population.

From:	Have Your Say Northern Territory
To:	imperial ep187+
Subject:	Anonymous User completed Carpentaria Pilot Project EP187 Environment Management Plan
Date:	Wednesday, 17 April 2024 10:16:47 PM

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Anonymous User just submitted the survey Carpentaria Pilot Project EP187 Environment Management Plan with the responses below.

Given name

[redacted]

Family Name

[redacted]

Location

BRINKIN, NT

Stakeholder type

Community member

Email address

[redacted]

Interest area

Social and cultural
Water
Climate change
Chemicals
Well integrity
Flora and fauna
Waste management
Human health
Regulation and compliance

Please provide your comments

I am writing to urge you to refer this project to the federal Environment Minister under the Environment Protection and Biodiversity Conservation Act, and to require an Environmental Impact Statement under the NT Environment Protection Act. The environmental and cultural damage that will be caused by this proposal is unacceptably

high. The harm to human and ecosystem health that will be caused by contaminated aquifer water is unacceptably high. The risks of flooding at well sites compound the dangers of wide-scale pollution, but even in a best-case scenario, the proponent's plans to leave contaminated water in the open storage tanks during the wet season will lead to large amounts of toxic wastewater escaping into the environment. The fugitive emissions from this project will be significant, and are not adequately addressed in the Environmental Management Plan. Nor are the project’s scope 3 emissions, which will also be extremely high. As with all gas projects in the NT, the primary victims of the damage done by this proposal will be Aboriginal. Allowing this project to proceed without referring it for further assessment would reflect not only a disregard for the public in general, but a particular, racist disregard for the health of Country. The 1200 hectares of proposed clearing will directly impact several federally protected species, including the Gouldian finch. This clearing must be referred under the EPBC Act.

From: [redacted]
To: imperial ep187+
Cc: [redacted]
Subject: Submission - Imperial Oil and Gas Pty Ltd - IMP5-1: Carpentaria Pilot Project EP187 EMP
Date: Thursday, 18 April 2024 9:56:30 AM
Attachments: [redacted]

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Good morning,

Please find attached Environment Centre NT's submission on the Imperial Oil and Gas Pty Ltd - IMP5-1: Carpentaria Pilot Project EP187 Environment Management Plan.

Kind regards,

[redacted] | W http://www.ecnt.org.au/
GPO Box 2120, Darwin NT 0801 | Unit 3/98 Woods Street, Darwin Northern Territory – Australia

Environment Centre NT
protecting nature | living sustainably | creating a climate for change

To support the Environment Centre please visit www.givenow.com.au/environmentcentrent
We acknowledge the Traditional Owners, The Larrakia people, on whose land we meet, live and work. We pay our respects to their elders past, present and emerging. We acknowledge Australia's First Nations never ceded sovereignty of their lands, seas and waters.

Environment Centre NT
protecting nature | living sustainably | creating a climate for change

18 April 2024

Petroleum Operations Unit
PO Box 3675
Darwin NT 0801

By email: imperial.ep187@nt.gov.au

To Petroleum Operations Unit,

Imperial Oil and Gas Pty Ltd - IMP5-1: Carpentaria Pilot Project EP187 Environment Management Plan

The Environment Centre NT (ECNT) is the peak community sector environment organisation in the Northern Territory of Australia, raising awareness amongst community, government, business and industry about environmental issues, holding government to account over environmental governance, and supporting community members to participate in decision-making processes and action.

Thank you for the opportunity to provide a comment on the draft EMP of Imperial Oil and Gas Pty Ltd (**proponent**) for assessment under the *Petroleum (Environment) Regulations 2016* (**Imperial EMP**).

The EMP proposes a scope of activities on exploration permit (EP) EP 187. The EMP includes the following activities:

- Land clearing and earthworks
- Drilling, hydraulic fracture, completion, testing, maintenance, suspension and abandonment of wells
- Construction, operation, modification of facilities and gas and wastewater flowlines used to recover petroleum, treat water, and treat gas
- Drilling and fracking 10 new wells on four new well pads in the eastern Beetaloo sub-Basin and the use of two existing wells on two well pads
- Decommissioning and rehabilitation
- Drilling and hydraulic fracturing of up to 10 petroleum wells
- Associated civil works including:
    - Up to 24.2 ha of access tracks
    - Up to 62.1 ha of new and expanded well pads and drill cutting sumps
    - Up to 57.6 ha of gravel pits
    - Up to 1.2 ha for camp locations
    - Other ancillary infrastructure.

Environment Centre NT submits that the Imperial EMP should be rejected because it does not comply with the Petroleum Act or Petroleum Environment Regulations.

ECNT's arguments are below.

Greenhouse gas emissions

Imperial states they plan to apply to "use the gas on an appraisal basis" meaning that instead of flaring it onsite, they want to secure a connection to the McArthur River mine gas pipeline, use their gas plant to process the gas and sell it into the network.

The Territory Labor government made a commitment to the Northern Territory public to implement recommendation 9.8 of the Pepper Inquiry which states:

> *That the NT and Australian governments seek to ensure that there is no net increase in the life cycle GHG emissions emitted in Australia from any onshore shale gas produced in the NT*[1].

This proposal presents a practical test of the government's commitment to recommendation 9.8. The proponent is seeking to sell and profit from fracked gas and so this amounts to the first Beetaloo production programme. Imperial have estimated scope 1 emissions from the Carpentaria pilot production programme to be 475 000 tC02-e annually. The Pepper Inquiry recommendation 9.8 made no distinction between upstream and downstream emissions, rather the clear implication is that any emissions (including scope 1, 2 and 3) released in Australia from Beetaloo gas must be offset to ensure there is no net increase in emissions. To approve this project without the proponent having a plan to offset the full 475 000 tC02-e would amount to a failure to deliver on the government's commitment to implement Peper Inquiry recommendation 9.8.

Imperial claim that their scope 1 emissions would be reduced to 30 000 tC02-e annually if the company receives approval to sell portions of the gas rather than flare it. However, we have concerns that the scope 1 emissions will in fact be higher than their estimates, given the company claims it will produce 25 terajoules (TJ) of gas a day when the McArthur River Pipeline only has capacity for 15TJ a day. There is no mention or explanation of this difference in the draft EMP and there is no estimation of emissions from flaring the excess gas or the downstream emissions from burning it. The EMP should not be approved given the inadequacy in explaining these discrepancies.

We note Imperial are arguing that due to their plans to sell a portion of the gas, their proposal does not trigger the Large Emitters Policy nor the Emissions Offset Policy. However, as outlined above the pipeline to the proposed customer lacks the capacity to transport the full 25TJ and so there is a question of whether more robust calculations might mean the threshold of 100 000 tC02-e as laid out in these policies might in fact be triggered. In addition, the plan to sell a portion of the gas has not been approved and so remains a hypothetical scenario. It is also possible that the proposal to sell gas may constitute a variation to the existing Native Title agreement under the Native Title Act, meaning the proponent may have to seek and negotiate a variation with Native Title holders. Again, demonstrating that the plan to sell gas is far from assured. Therefore, the full 475 000 tC02-e must be considered and assessed as being scope one emissions under the Large Emitters and GHG Offset Policy given the level of uncertainty around the stated plans to sell a portion of the gas.

The EMP also contains scant information on the decommissioning plan or post closure monitoring and there is no mention of ongoing monitoring in relation to methane leaks post-closure. In relation to water and post closure monitoring the EMP merely states:

> The decommissioning processes for the wells will include ongoing groundwater monitoring in down-gradient production /monitoring bores at all well sites once the petroleum wells and well sites are decommissioned to ensure that there is no impact on groundwater quality from the Activity.

[1] Justice Rachel Pepper 'Scientific Inquiry into Hydraulic Fracturing: Summary' pp 35.

There is no mention of frequency of monitoring, nor any mention of how long monitoring will continue for. This is another failing of the proposal and demands further detail on what post-closure monitoring activity will occur to ensure the public are not left with the burden of funding the ongoing monitoring and management of decommissioned well sites.

The EMP also fails to adequately outline the impacts and risks associated with this project and how they will be managed and mitigated. It is merely a plan for proposed activities including inputs and outputs. It does not attempt to assess environmental risk as an EMP should. In relation to emissions there is no assessment of how this proposal will contribute to or hinder the government's target of net zero by 2050. We submit that the EMP should not be approved without an assessment of impacts to the net zero emissions target, and this should be assessed in term of cumulative impacts across all Imperial projects.

Cultural impacts

The re-evaluation of the importance of cultural heritage artefacts found at the site in 2022 and previously considered "isolated artefacts" indicates the inadequacy of the assessments being conducted for Environmental Management Plans for fracking activities.

The EMP activities should be subject to a full Environment Impact Assessment under the Environment Protection Act to explore the cultural values of affected ecology, water and landscapes and to provide Traditional Owners an opportunity to grant or refuse consent to the proposed activities.

Groundwater extraction

The EMP indicates the project will use 950ML (million litres) of water in total over four years, most of which is needed for fracking. They will apply for a 750ML per year licence to remove this water from the Gum Ridge Formation. This is roughly 9% of the 8GL of water allocated to gas activities in the Georgina Wiso water plan and if granted, this 750ML licence would effectively double the volume of water entitlements granted to petroleum companies so far.

The impact of this water removal on the flow of groundwater locally and regionally is largely undescribed in the EMP. Although these aquifers are vast, their recharge is slow and the behaviour of water in them largely unknown, which means the impacts of water depletion is also uncertain.

Given limited knowledge of the CLA, a full Environmental Impact Statement is required that properly investigates the hydrological properties of the aquifer, its cultural and ecological values and the impact of this water removal on those values.

The EMP concludes that the extraction of 750ML/year (almost 10% of the allocation for all petroleum activities within the project area) 'is not considered to have a significant impact on groundwater'. It makes this conclusion based on the amount extracted falling within the Estimated Sustainable Yield in the Georgina Wiso Water Allocation Plan.[2] The EMP does not engage in any deeper analysis on the impacts of groundwater extraction, which is inaccurate. In making groundwater licensing decisions, the Water Act requires the consideration of a number of factors, the Estimated Sustainable Yield being only one factor.[3] These factors include any adverse impacts of

[2] EMP, p 136.
[3] Water Act, s 90(1).

extraction of the water and wastewater facilities. There are a number of groundwater dependent ecosystems within close proximity to the project area (see map on page 97 of the EMP). The assessment of groundwater dependent ecosystems on page 232 of the EMP describes the GDEs but does not analyse or assess any risk or impacts to the GDEs from the EMP activities. The EMP must not be approved without an assessment of the impact of groundwater extraction proposed to support the EMP activities, including on factors like groundwater dependent ecosystems.

Further, the EMP states that some years, the activity may exceed the estimate. In fact, it estimates a total use of 950ML/year when breaking down the water use for each type of activity (see Table 3.9-1).[4] The EMP should not be approved without clarity and environmental impact analysis relating to the proposed groundwater extraction.

Environment Centre NT commissioned two expert reports by water experts Matthew Currell and Christopher Ndehedehe regarding the risk of significant impacts of fracking on water resources (**Attachments 1 and 2**). The reports address:

- The impacts of increased water in this region could have significant impacts on water resources and ecosystems, species and culture that these water resources support.
- There is a lack of scientific certainty regarding the groundwater resources in the region which mean that the likelihood and extent of impacts of these projects is currently unknown, and that caution should be exercised.

In January 2024, these experts along with Professor Sue Jackson, released a peer-reviewed article drawing on the above research, entitled "Risks in the current groundwater regulation approach in the Beetaloo region, Northern Territory, Australia" (**Attachment 3**).

We have attached these reports to our submission. We submit that the EMP should not be approved without a comprehensive environmental impact assessment regarding the impact of the EMP activities, including groundwater extraction at the rates proposed, on the environment.

Environment Centre NT further submits that the potential impacts of this project, in combination, and in the context of, other existing and proposed developments in the area, satisfy the criteria for 'significant impacts' under the *Significant Impact Guidelines 1.1*. We submit that the Northern Territory government should refer this project for assessment under the EPBC Act under the water trigger controlling provisions.

Surface water impacts

The project is in the headwaters of two catchments, the Limmen Bight River catchment to the north and McArthur River to the east. The pilot project crosses Relief Creek and its surrounding floodplains. The wells will be located just outside the 1 in 100 year flood zone, which means they are likely to flood in more extreme events, increasing contamination risk.

Every well will produce "drill-cuttings" that need to be disposed of and which have elevated concentrations of some metals and other elements of concern. Every well will also produce 35 million litres of fracking flow back water and the handling of this water creates the risk of spills and accidents that could contaminate soil or surface waters. The wastewater management plan proposes that this contaminated water may be held in open tanks,

[4] EMP, p 137.

transferred in trucks, including during the wet season and disposed of in unspecified locations. These potential for, and extend of, risks to surface water and the species and culture they sustain have not been explored in this EMP. Environment Centre NT submits that this EMP should not be approved until these risks have been addressed, mitigated or managed.

Wastewater

Only 5% of the water used in the hydraulic fracturing process will be recovered as "flowback" – the rest will stay underground, posing significant risks of chemical contamination. The attached Currell and Ndehedehe reports detail the interconnectivity of the aquifers in the Beetaloo Basin and the risks associated with contamination. There are also uncertainties surrounding inter-aquifer connectivity which must be addressed in order to understand the extent of potential contamination from fracking fluids in the Beetaloo Basin.

There will be around 35 million litres of flowback water returned to the surface per well that will need to be transported, stored and then disposed of off-site. The EMP states that Imperial will install up to 60km of wastewater and gas gathering networks utilising low-pressure (less than 1,670 kPa MAOP) high-density Polyethylene (HDPE) flowlines. These will be designed to transfer large volumes of water/wastewater safely and efficiently between well pads and the WHS and to gather gas for transfer to the CGP.

Evidence from fracking activities in the US demonstrate is common with surface spills occurring in as many as many as 16% of hydraulicly fractured wells in the US.[5] This risk of surface contamination is further heightened in the Northern Territory given the high rainfall totals during the wet season months and that many of the well sites are located on floodplains which could inundate wastewater holding ponds and disperse fracking fluids. This is compounded by the NT Government's failure to implement the Fracking Inquiry recommendation that there should be no wastewater stored in open water storages[6], which was specifically intended to address this threat.

In ECNT's views, the construction of wastewater flowlines are very risky and untested in a Northern Territory context. Further, it is clear to ECNT that this petroleum activity is not actually covered by the Code of Practice. In ECNT's view, references to "pipelines" in the Code of Practice relate to gas pipelines, with have standards and risks that are specific to this infrastructure (for example, addressing methane leaks). Imperial has sought to rely on a standard for coal seam gas, but this standard may not be appropriate for Northern Territory conditions, and in any case is not incorporated into the Code of Practice which is, by definition, intended to cover all petroleum activities. In ECNT's view, constructing and operating wastewater flowlines as proposed in the Imperial EMP does not comply with the Code of Practice, and to authorise the EMP would breach s58(ab) of the Petroleum Act.

There are considerable risks associated with the wastewater flowlines, including potential contamination of surface and groundwater (including the surrounding, interconnected aquifers and streams) if they crack, split or leak. The proposed flowlines cross numerous waterways and risk erosion where the pipelines are buried, as well as movement that could affect their integrity. The EMP does not detail any details regarding leak detection in

[5] Lauren A. Patterson, Katherine E. Konschnik, Hannah Wiseman, Joseph Fargione, Kelly O. Maloney, Joseph Kiesecker, Jean-Philippe Nicot, Sharon Baruch-Mordo, Sally Entrekin, Anne Trainor, and James E. Saiers 'Unconventional Oil and Gas Spills: Risks, Mitigation, and State Reporting Requirments' *Environmental Science & Technology* **2017** *51* (5), 2563-2573.
[6] Justice Rachael Pepper 'Scientific Inquiry into Hydraulic Fracturing in the Northern Territory' (2018) pp. 156.

wastewater flowlines, posing an unacceptable risk to the surrounding environment. This information is crucial to ensuring that any risks associated with operating flowlines can be mitigated and managed by the applicant to an acceptable level. The EMP should not be approved until this information has been provided and assessed.

There is little to no information about decommissioning of the wastewater flowlines in the Imperial EMP, which may pose a significant environmental and operational risk for pastoralists. There are serious questions about the composition of the flowback/wastewater and the risk it poses to the environment in the event of a fracture or leak. In this regard, Imperial has not complied with recommendation 7.10 of the Pepper Inquiry, which requires the composition of flowback water for its existing fracking wells to be publicly disclosed. There are significant questions about the composition and therefore risk profile of any wastewater or produced water at the new site, including its potential for reuse. The construction of wastewater flowlines should not be approved without knowledge and disclosure of the composition of Imperial's wastewater and its safety, consistent with the recommendations of the Pepper Inquiry.

The Wastewater Management Plan does not detail how and where waste will be disposed of offsite. The EMP should consider whether facilities exist which are capable of managing waste in an environmentally safe way.

Land clearing

Three nationally-listed threatened species are recorded or likely to be present in the area, the Grey Falcon, Painted honeyeater and Gouldian finch, as well as five migratory birds protected under the *Environment Protection Biodiversity Conservation Act 1999*. The EMP involves the clearing of up to 229 hectares of native vegetation and wildlife habitat, bringing the total cumulative clearing approved in the area for fracking activities to nearly 1,200 hectares.

Australia is in a deforestation and biodiversity crisis. We are the only developed nation included as a global deforestation hotspot.[7] Land clearing is currently the greatest threat to biodiversity in Australia and land clearing rates are increasing in the Northern Territory, including for the fracking industry. The Northern Territory has witnessed a threefold increase in land clearing approvals between 2018 and 2022, with few legal mechanisms and policy frameworks available for a strategic or integrated approach to landscape management. Clearing native vegetation destroys habitat for native animals, fragments the wider ecosystem and can contribute to the spread of invasive weeds and feral animals, exacerbating the impacts of other threatening processes.

Considering the number of matters of national environmental significance that may occur in the project area, and considering the project could impact biodiversity values, air and water pollution and water levels, the project should at a minimum, be referred for assessment under the EPBC Act. The Federal and Northern Territory government must ensure that projects that involve land clearing that could significantly impact listed threatened species and migratory birds are referred for assessment under the EPBC Act. Environment Centre NT submits that the Northern Territory government should refer this project for assessment under the EPBC Act.

Attachments

[7] The Wilderness Society, 'Deforestation in Australia'.

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1. **Attachment 1 -** [redacted], The Cambrian Limestone Aquifer, Northern Territory: Review of the Hydrogeology and Management Rules to Ensure Protection of Groundwater Dependent Values', (December 2022).

2. **Attachment 2 -** [redacted] Strategic Regional Environmental and Baseline Assessment - Expert Review – Groundwater, (October 2023).

3. **Attachment 3 -** [redacted], "Risks in the current groundwater regulation approach in the Beetaloo region, Northern Territory, Australia" (February 2024).

For more information, please contact [redacted]

[redacted]
Freshwater Campaigner

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Climate Campaigner

The Cambrian Limestone Aquifer, Northern Territory: Review of the Hydrogeology and Management Rules to Ensure Protection of Groundwater Dependent Values

[redacted]

Environment Centre NT

[1]School of Engineering, RMIT University
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Executive Summary

This report presents a concise review of the hydrogeology of the Cambrian Limestone Aquifer (CLA) in the Northern Territory (NT), and the ecological and cultural values sustained by its groundwater. It examines risks to these values associated with different approaches to the assessment of groundwater license applications in the CLA, including using the Top End and Arid Zone contingent rules, which apply in areas without a Water Allocation Plan (WAP), and other approaches proposed in draft WAPs (e.g., Georgina-Wiso). The report concludes with recommendations about appropriate methods and safeguards to protect the CLA's groundwater and the values it sustains, in line with recommendations of the Pepper Inquiry. The major focus is the areas of the CLA where WAPs are in progress – Flora Tindall, Mataranka and Georgina Wiso.

The Cambrian Limestone Aquifer (CLA) ranges from <50 m to over 400 m thick, covering much of the NT. The aquifer comprises inter-layered limestone and mudstone. Groundwater occurs largely within secondary porosity (fractures and karst features). The CLA is overlain by younger Cretaceous rocks; where these are absent, recharge to the aquifer and/or discharge to surface water occur. Below the CLA sits the Beetaloo sub-basin, a sequence of Proterozoic sedimentary rocks that host saline groundwater, oil and gas. The CLA occurs in three basins - Daly, Wiso, and Georgina. There is cross-basin connectivity between the equivalent limestone units within these.

Local recharge within each CLA basin appears to exceed rates of throughflow between adjacent basins, based on environmental tracer data and modelling. Throughflow remains poorly quantified but appears nonetheless to be a significant part of the water balance. There are also indications of vertical inter-aquifer connectivity - e.g., deep groundwater below the CLA contributing to spring flows at Mataranka Thermal Pools (in addition to CLA groundwater). Recharge to the CLA occurs by diffuse percolation of rainfall in areas where Cretaceous cover is thin or absent, at rates generally between <1 and 30 mm/yr, increasing from south to north. There is also evidence of recharge at higher rates (>100 mm/yr), associated with karst features (e.g., sinkholes). Discharge of groundwater to the surface appears to be limited to small but environmentally and culturally significant areas, where it sustains vitally important groundwater dependent ecosystems (GDEs).

Groundwater from the Tindall Limestone flows to the surface via springs, wetlands, and the channels of the Roper and Flora rivers and associated tributaries. These groundwater flows support significant vegetation communities and aquatic ecosystems within spring pools, groundwater-dependent sections of streams, and downstream waterbodies. Fauna drink from groundwater-fed pools and terrestrial vegetation utilises groundwater where the CLA water table is shallow. GDEs are also found within the aquifer matrix, i.e., stygofauna, including crustaceans, within caves and cavities in the rock. These groundwater dependent sites, waters, fauna, and vegetation and are of great cultural significance to Aboriginal peoples of the region. Aboriginal peoples' oral accounts highlight the interconnectedness of the region's groundwater, surface water and landscape, and both human and non-human living communities, as well as ancestral beings.

WAPs are not currently in place for the region encompassing the CLA and Beetaloo sub-basin, but are expected to be finalized in 2022-23, in accordance with recommendations from the Pepper Inquiry. A draft WAP for the Georgina-Wiso region is currently open for public review. Current rules for groundwater licensing where WAPs are not finalized use the Top End and Arid Zone contingent rules, to set caps on groundwater extraction rates for consumptive use in a given area. The Top End rules allow for allocation of groundwater licenses up to a fraction (20%) of estimated recharge. This approach is broadly in line with other groundwater management jurisdictions in Australia and worldwide, which calculate a Sustainable Yield as a fraction of recharge and/or discharge with the intention of balancing extraction with a need to maintain long-term groundwater access and limit impacts on GDEs. It should be noted however, that this method and/or the value of 20% may not always achieve these aims, due to complicated re-distribution of water balances in response to groundwater extraction. It remains unclear whether extracting 20% of recharge in aquifers

currently classified as Top End (such as the Tindall Limestone) would have unacceptable consequences for GDEs. Preliminary analysis indicates significantly reduced flows to the Roper River could result, which would be particularly noticeable during dry periods.

The Arid Zone rules, which apply to the south of a line delineating northward and southward flowing surface water catchments of the NT, contain two clauses relevant to groundwater. The first states that licensed extractions should have no detrimental impacts on GDEs; the second allows for depletion of 80% of total pre-development groundwater storage, over a 100-year timeframe. These two aspects of the rules are contradictory. It is not possible for the first aim to be achieved if the second part is permitted. In accordance with the conclusions of the Pepper Inquiry, using storage volumes to calculate sustainable yields is not in line with ecologically sustainable development and risks harm to groundwater dependent values. Aquifers should not be described in terms of total storage when considering sustainable yields or 'safe' extraction rates. It is the water flows to and from the aquifer sustaining other aspects of the water cycle and dependent values (e.g., flows to springs, rivers and vegetation) that are most important in assessing sustainable yield. These flows are normally very small in comparison to the total water in an aquifer's storage; hence, extracting even small proportions of overall storage can have significant water cycle consequences (e.g., reduced baseflows and/or loss of groundwater dependent ecosystems).

The Arid Zone contingent allocation rules appear to be one of the only cases in Australia where a storage-based approach is applied to the determination of a 'sustainable' yield. If this approach were to be adopted in WAPs covering the CLA and Beetaloo sub-basin and/or remains in use more generally, it would allow for unsustainable development of groundwater, with serious potential consequences for groundwater dependent ecosystems, cultural values and water users. In the Daly Basin/Tindall Limestone section of the CLA, where the Mataranka springs and Roper River occur, extraction at rates that cause long-term storage depletion would endanger these and other important GDEs, by reducing spring discharge, river baseflow and water table levels.

The current draft WAP for the Georgina Wiso region proposes an estimated sustainable yield (yearly extraction cap) of 262.6 GL/year, estimated to be 40% of long-term averaged recharge. It is unclear how or why the value of 40% of recharge was determined to represent a sustainable level of extraction. In the Georgina and Wiso Basins, knowledge of the water balance, hydrogeology and groundwater dependent ecosystems are currently not sufficient to fully understand the effects of such extraction. The recharge estimate used to derive the ESY is model-derived and has considerable uncertainty. It is nearly double the value derived from earlier runs of the same model, and higher than some field-based estimates, meaning the ESY may constitute a larger fraction of recharge than assumed. The current data also indicate that recharge is considerably lower than the long-term average in most years (and may be negligible under the typical climate), except for rare events where rainfall (and recharge) far exceeds the rolling long-term average. Such periods have likely occurred only three or four times over the past century. The vast majority of estimated recharge to the Georgina and Wiso basins is associated with a single event in 1974. The recurrence interval for such recharge events, and details of their mechanism remain unknown. Therefore, under the proposed ESY, in most years, significant aquifer overdraft (extraction far exceeding recharge) would be permitted. Such overdraft may occur for many consecutive years (or decades), before the next episodic recharge event occurs.

Drawdown associated with consecutive years (or decades) of aquifer overdraft in the Georgina and Wiso basins would endanger stygofauna communities and reduce cross-basin discharge fluxes within the CLA, e.g., to the Tindall Limestone aquifer (upon which key GDEs noted above depend). Currently, groundwater discharge mechanism(s) from these two basins is poorly understood. There may be additional groundwater dependent ecosystems within or close to the edge of the plan area sustained by CLA groundwater (such as springs in the western Wiso Basin, or un-mapped deep-rooted vegetation communities). These GDEs may suffer reduced access to groundwater for extended periods between recharge events due to extraction at the proposed ESY, threatening

their survival. Water quality risks, such as migration of saline water into fresher parts of the aquifer, and potential aquifer integrity issues associated with concentrated extraction in particular regions have also received limited or no attention in the draft WAP. Better characterization of GDEs, recharge and discharge mechanisms and rates, and more comprehensive assessment of these risks are urgently required before appropriate management rules can be adopted to ensure the Georgina-Wiso WAP does not lock in negative impacts on environmental and cultural values.

Sustainable management of groundwater extraction throughout the CLA should adopt a management approach in line with contemporary best practice, that sets:

1) **Volumetric extraction rate limits** which in the long-term ensure:
   A) groundwater flows and levels do not decline in such a way as to compromise the health of the groundwater dependent ecosystems, water quality and aquifer integrity. This requires careful analysis of recharge and discharge flux rates, environmental dependencies on these flows, and the extent of 'capture' and drawdown caused by pumping at different rates.
   B) the renewability of groundwater resources, ensuring prevention of long-term storage depletion and/or detrimental capture of surface flows - recognising the value of the Roper River, Mataranka springs and other GDEs supported by the CLA.

2) **Clearly defined and well monitored groundwater level thresholds**, determined to be the elevations required to sustain environmental and cultural values of groundwater dependent sites and ecosystems – including through the maintenance of throughflows between the CLA basins. When these levels are approached or crossed, reductions in groundwater pumping should be triggered, in line with level-based management approaches adopted in other parts of Australia and internationally. Trigger levels must be set appropriate distances from environmental assets seeking to be protected to account for time-lags.

Setting both a cap on total extractions in declared management zones, along with a series of water level thresholds and buffer zones to protect GDEs, would be in line with international best practices, if implemented alongside a robust monitoring program. Further, any rules developed to allow trading of groundwater should restrict the trade of extraction permits into areas close to high value GDEs. Together, these measures would ensure protection of key values supported by the CLA's groundwater. This management approach should be informed by a continuing program of inter-disciplinary science and community consultation, focusing on groundwater requirements of GDEs, and modelling to determine relationships between flows to these, extraction volumes, gradients, and time.

Knowledge gaps which should be addressed urgently include better qualitative and quantitative information on inter-basin and inter-aquifer flows (topics currently being investigated), better quantification of flows from the CLA and other aquifers to springs and streams (including those that have been less studied than Mataranka Thermal Pools and the Roper River), and eco-hydrological studies (including more extensive stygofauna surveys). These studies should determine the groundwater levels, flow rates and quality required to sustain key environmental and cultural values, as well as possible downstream consequences of reduced spring flows, river baseflows and groundwater throughflows of various magnitudes. Understanding what community stakeholders consider to be acceptable risks and impacts, and making public all relevant supporting scientific data and analysis informing WAP rules, should form part of the process of determining extraction rate caps and triggers. There is also a need to consider climate change and variability, with mechanisms to account for this built into long-term integrated water resources management.

Keywords: Groundwater sustainability, Cambrian Limestone Aquifer, Groundwater Recharge, Sustainable Yield, Groundwater Dependent Ecosystems, Cultural Value of Water, Northern Territory.

Cover Image: Pandanus species at Bitter Springs, Elsey National Park, Northern Territory, Australia. Source: Wikimedia Commons.

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Introduction

This report, prepared at the request of Environment Centre NT, is designed to provide a concise, up-to-date review of literature and technical information about the Cambrian Limestone Aquifer (CLA), and current groundwater policies in the Northern Territory, in order to:

a) Consider the adequacy of current groundwater licensing arrangements under the *Water Act* – with a specific focus on the use of the Top End and Arid Zone contingent rules in water planning, and other proposed management rules in draft Water Allocation Plans

b) Make recommendations regarding the determination of sustainable yields and other management rules for Water Allocation Plans, and other relevant policies governing groundwater licensing within the CLA and Beetaloo sub-basin.

Recent groundwater licensing decisions and challenges to these[1] highlight that there is ongoing debate regarding the above issues, and a need for clear, scientifically informed analysis of the most appropriate mechanism(s) to ensure protection of groundwater dependent environmental, cultural, and economic values. The Pepper inquiry into Hydraulic Fracturing in the NT highlighted significant risks associated with the groundwater licensing arrangements in place at the time of the inquiry; these arrangements have remained largely un-changed since then. Recent licensing decisions signal an intent to apply the Arid Zone contingent rules (or similar management approach) over a larger geographic extent than has previously occurred, warranting thorough review of the potential risks and implications of this. Draft water allocation plans also include other methods to determine estimated sustainable yields within plan areas, based on recharge rates (which may or may not be protective of groundwater-supported values). This report delves into these issues and other knowledge gaps highlighted in the Pepper Inquiry and makes recommendations attempting to address these.

Appendix A lists the four main tasks/questions ECNT requested be addressed in this report. The subsequent structure of the report (in four sections) corresponds with these four topics. Subsequent to the commissioning of the report, ECNT also requested that the proposed groundwater management rules put forward in the draft Georgina Wiso WAP – released to the public in November, 2022 (Northern Territory Government, 2022a), be analysed and discussed (and this is done throughout the report).

The report draws upon literature that includes both technical work commissioned by or conducted within Northern Territory government agencies, as well as peer-reviewed scientific literature, including reports by national science agencies (e.g. CSIRO and Geoscience Australia) and academic institutions (e.g., relevant peer-reviewed journal papers).

[1] E.g., NT Land Corporation, application KG08988; Fortune, groundwater extraction licence WDPCC10000

1. Hydrogeology of the Cambrian Limestone Aquifer

a) Thickness, structure and properties

The Cambrian Limestone Aquifer (CLA) is an extensive carbonate aquifer underlying much of the Northern Territory to the north of Alice Springs and south of Katherine, encompassing most of the Barkly Tableland and Sturt Plateau. The aquifer system occurs within three major sedimentary basins; Daly, Georgina and Wiso (Fig. 1). The division between these three basins hosting the CLA corresponds with the presence of basement highs in the underlying rocks (at the basins' edges), above which the CLA aquifers thin and occur relatively close to the surface (e.g., Fig. 2). These basement highs are not complete hydrogeological or hydraulic boundaries; as such, there is some connectivity between the basins, with groundwater flowing from the southern two (Georgina and Wiso) providing inflows to the northern basin (Daly), in accordance with regional groundwater flow gradients (Tickell and Bruwer, 2017; Evans et al., 2020; Oberprieler et al., 2021). The primary limestone aquifer units of the CLA have different names within the three basins (Table 1):

Table 1: Major Cambrian Limestone Aquifer (CLA) units across the three major sedimentary basins (after Tickell and Bruwer, 2017; Bruwer and Tickell, 2015 and Evans et al., 2020).

Basin	**Name of main CLA aquifer units (Upper & Lower)**	**Comment on usage/aquifer potential**
Daly	Jinduckin Formation/Oolloo Dolostone (upper)	A minor aquifer that is thin or absent in much of the basin
	Tindall Limestone (lower)	Major CLA aquifer in the Daly Basin. Equivalent to Gum Ridge Formation (Georgina) and Montejinni Limestone (Wiso)
Georgina	Anthony Lagoon Formation (upper)	Locally high-yielding aquifer, utilized for stock watering
	Gum Ridge Formation (lower)	Thick, extensive and locally high-yielding limestone aquifer, less utilized than Anthony Lagoon Formation due to depth, but considered prospective as a water source
Wiso	Hooker Creek Formation (upper)	Local confining layer and/or aquifer depending on lithology.
	Montejinni Limestone (lower)	Major CLA aquifer in the Wiso Basin. Equivalent to Tindall & Gum Ridge Formations

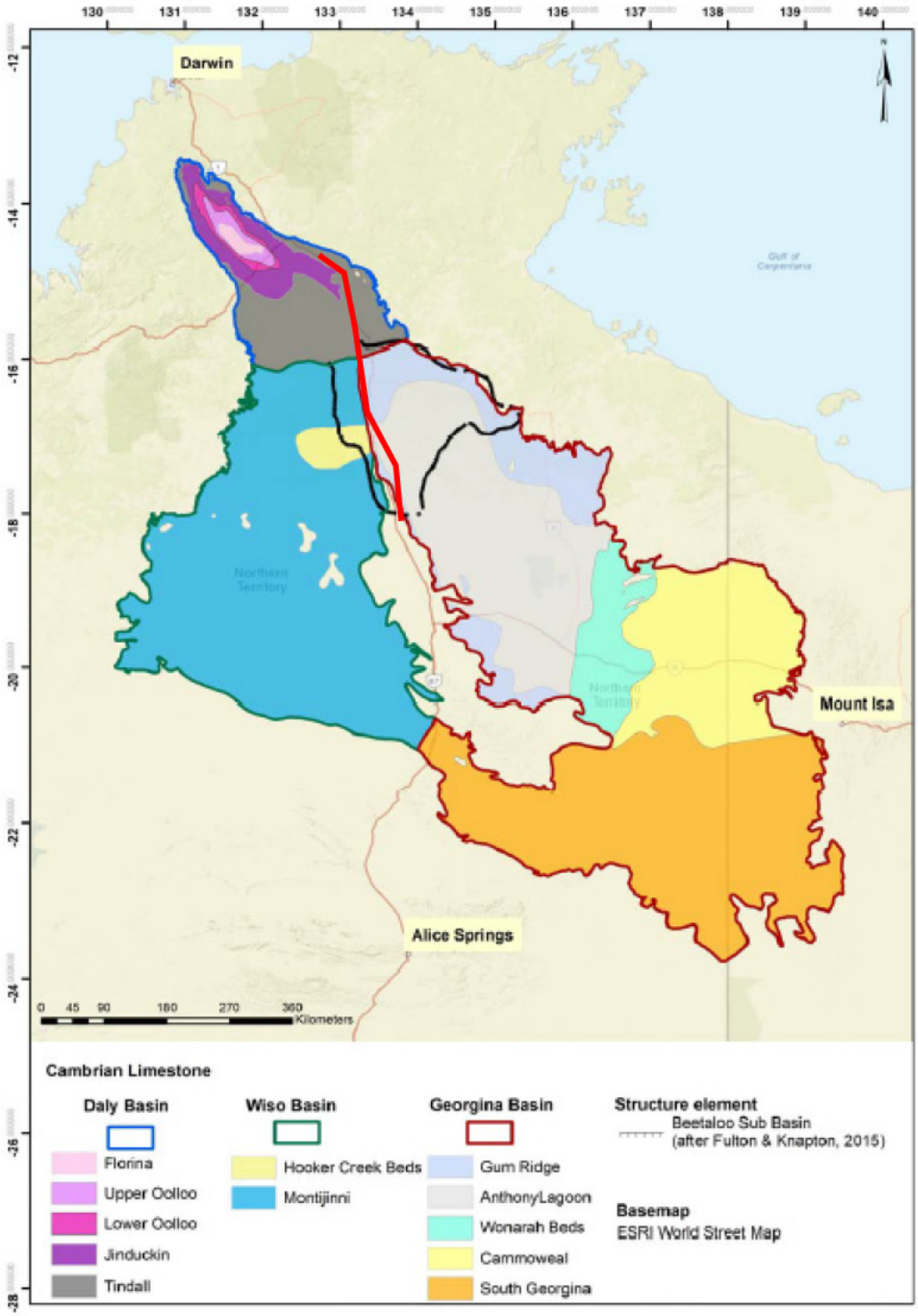


Figure 1: Map showing the three sedimentary basins hosting the Cambrian Limestone Aquifer (CLA) along with the outcrop geology. Modified from Deslandes et al., 2019. Red line shows approximate cross section location for Figure 2 (from Bruwer and Tickell, 2015).

The CLA has outcrops or sub-crops near the surface over significant areas in all three basins (notably at Mataranka, and the southern Wiso and Georgina Basins) but it is generally buried beneath younger sedimentary rocks from the Cretaceous period (Knapton, 2020). There is a time gap of approximately 400 million years between the Cambrian and Cretaceous rocks, and the boundary between the CLA and Cretaceous comprises a weathered erosional surface developed during this time. Significant karst features (sinkholes, caves and other secondary

porosity) also developed in the limestone. The boundary permits diffuse leakage of rainfall recharge to the CLA, where the Cretaceous cover is thin (Bruwer and Tickell, 2015).

The CLA is underlain by older Cambrian volcanic rocks (e.g., the Antrim Plateau basalts), and below this, Proterozoic sedimentary rocks, including those of the Beetaloo Sub-basin (e.g., the Roper Group) which host extensive oil and gas deposits (Evans et al., 2020). Together, the Cretaceous, Cambrian, and Proterozoic geological units form a thick sequence (up to 5 km) of stacked sedimentary rocks, including multiple aquifer and aquitard units. The extent of vertical connectivity between the CLA and underlying rocks is a focus of recent and current research programs, as recommended by the Pepper Scientific Inquiry - e.g., through the Strategic Regional Environmental Baseline Assessment (SREBA) program. The most recent reports from these programs note that inter-basin and inter-aquifer connectivity occur, but are generally still not well characterized (Lamontagne et al., 2021; Frery et al., 2022). These studies have found evidence from environmental tracers and geophysics of deep groundwater flow reaching shallow aquifers and/or the surface, e.g., at Mataranka springs (Lamontagne et al., 2021).

Aquifer thickness and structure

The CLA ranges in thickness from approximately 20 to 80 m above basement highs where it outcrops or sub-crops near the surface (including near the Roper River and Mataranka springs), to over 400 m at its thickest extent within the Georgina Basin, comprising the Anthony Lagoon and Gum Ridge formations (Tickell and Bruwer, 2017). Throughout most of the Daly, Georgina and Wiso basins, the CLA ranges between approximately 100 to 300 m thick and can be described as a semi-confined to unconfined aquifer. An example cross-section showing the Tindall Limestone and Gum Ridge Formations (lower CLA units in the Daly and Georgina basins, respectively), overlying and underlying geological units across the Daly/Georgina boundary, is shown below:

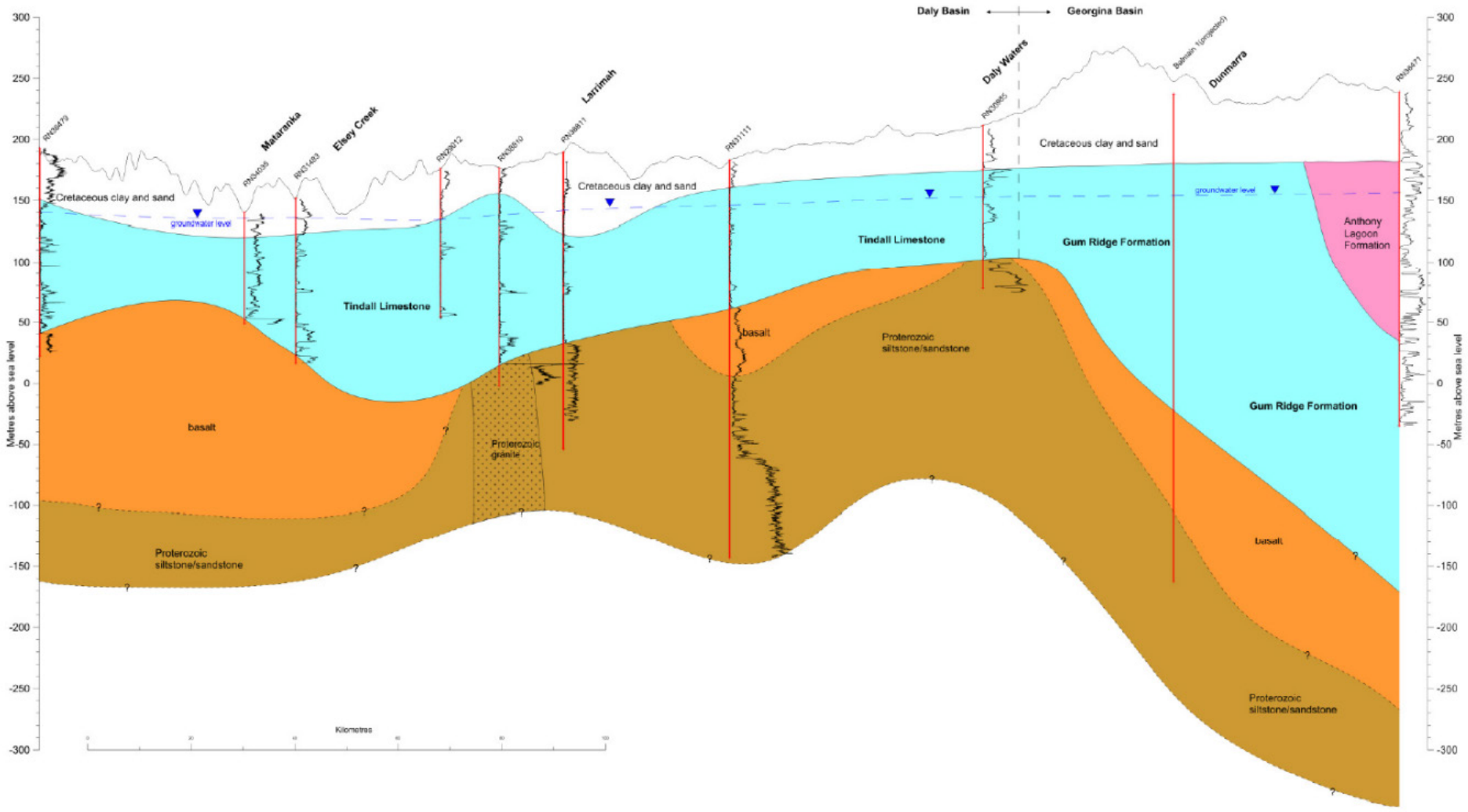


Figure 2: Cross section of the southern Daly and northern Georgina Basin, showing estimated thickness of the CLA, Cretaceous cover, and underlying Cambrian and upper Proterozoic rocks (From Bruwer and Tickell, 2015). Approximate cross section location indicated on Fig. 1.

Aquifer properties

A program of pumping tests has been carried out to assess the CLA's potential bore yields and hydraulic properties in the Daly and Georgina basins. This has determined that aquifer transmissivity values – which determine how much groundwater can be readily extracted and the extent of drawdown in response to pumping - range between relatively low values (~5 m^2/day) up to very high values (over 45,000 m^2/day). These data are summarized in Table 2:

Basin	**Unit**	**Range of transmissivity values (m^2/day)**	**Estimated groundwater storage capacity (GL)**
Daly	Tindall Limestone (lower)	100 to 47,400	28,200 to 56,400
Georgina	Anthony Lagoon Formation (upper)	13 to 8200	1,766,000 to 3,532,000 GL
	Gum Ridge Formation (lower)	5 to 3100	52,500 to 157,500 GL
Wiso	Hooker Creek Formation (upper)		
	Montejinni Limestone (lower)	3 to 9480	

Table 2: Summary of estimated aquifer transmissivity values for main CLA units (after Bruwer and Tickell, 2015; Tickell and Bruwer, 2017; Knapton, 2020).

Transmissivity values of above ~500 m^2/day are generally considered permeable and prospective for development of an aquifer as a water resource[2]. As such, significant portions of the CLA would be considered high-yielding. However, transmissivity values are highly variable throughout the region, e.g., in areas of the Georgina Basin where the Anthony Lagoon Formation comprises low-permeability siltstone (between limestone layers) bores are low-yielding with T values < 50 m^2/day. Knowledge of aquifer hydraulic parameters within the Wiso Basin (e.g., Montejinni Limestone) is relatively limited (see Table 2), as a significant program of pumping tests and related studies has not (to our knowledge) been reported.

Storage capacity

Various estimates of the total amount of groundwater in storage within the CLA have been given, as noted in Table 2. These estimates should be interpreted with caution for two reasons:

1. The CLA is not a 'standard' porous medium (with uniform distribution of void space in which groundwater can be stored). Instead, much of the porosity is secondary, relating to karstic features (sinkholes, dolines) and fracturing. How much water in storage is available for extraction is unlikely to be well described by these bulk estimates. For example, effective porosity values of up to 40% (cited in Tickell and Bruwer, 2017) for the Gum Ridge Formation may over-estimate the availability of water that can be readily extracted.

[2] For example, see Science Direct topic entry under Transmissivity: https://www.sciencedirect.com/topics/earth-and-planetary-sciences/transmissivity

2. Aquifers should not be described in terms of their total storage when considering sustainable yields or 'safe' extraction rates (this topic is covered in detail in Sections 2 and 3 of this report). It is the water flows to and from an aquifer sustaining other aspects of the water cycle and dependent values (e.g., groundwater flows to streams, springs and other aquifers), that is the most important factor in assessing the sustainable yield from an aquifer (not storage volume) (Theis, 1940; Alley et al., 1999; Ponce, 2007). These flows are normally very small in comparison to the total water in an aquifer's storage; extracting even small proportions of overall storage can have significant water cycle consequences (e.g., reduced baseflows and/or loss of groundwater dependent ecosystems). Viewing the aquifer as a single connected 'bucket' of stored water that can be extracted without impacting the broader water-cycle, risks serious harm to water users and the environment (Alley et al., 2002; Bierkens and Wada, 2019).

b) The water balance of the CLA and connections to the broader water cycle

Groundwater Recharge

Groundwater recharge - defined as water that crosses the water table, adding to groundwater stored in an aquifer (Healy, 2010) may take place through a range of mechanisms, e.g., diffuse rainfall infiltration across a wide area vs. focused recharge below specific landscape features; continuous recharge vs. episodic 'event-based' recharge. Direct recharge – i.e., rainfall percolation below the soil zone to the water table, to the CLA is thought to be restricted to areas where the Cretaceous rocks covering the aquifer are thin or absent (Fig. 3). Other recharge mechanisms that have been identified include macropore flow (through large surface cracks) stream and lake water leakage, including surface water losses to karstic features (e.g., sinkholes and dolines) (Bruwer and Tickell, 2015; Tickell and Bruwer, 2017; de Caritat et al., 2019; Deslandes et al., 2019). The latter mechanisms are not well quantified throughout the CLA, though recent environmental tracer sampling by Deslandes et al (2019) allowed for approximate quantification of diffuse (rainfall seepage) and preferential (sinkhole) recharge in certain areas (see Table 3). Based on tritium data, point-based diffuse recharge rates were estimated to be between ~1mm/yr and 30 mm/year, generally increasing from south to north, in accordance with increasing rainfall and decreasing ET rates, while preferential recharge through sinkholes was estimated to occur at significantly higher rates (>100 mm/year) in local areas. Crosbie and Racchakonda (2021) derived similar overall recharge estimates based primarily on chloride data, while De Caritat et al (2019) also identified areas of the Wiso Basin where leakage from surface water bodies (Lake Woods and Newcastle Waters Creek) is the predominant recharge source. They noted Tarrabool Lakes to be a significant recharge feature to the Georgina Basin.

Bruwer and Tickell 2015 estimated recharge to the Daly Basin CLA (Tindall Limestone) to be approximately 330 GL/yr, based on water table fluctuations, Chloride mass balance, and numerical modelling. All these methods are acknowledged to have issues/uncertainties, but the use of multiple lines of evidence provides some level of confidence in the magnitude of the estimates. Tickell and Bruwer, 2017 used chloride data from precipitation and groundwater to estimate recharge to the two major CLA units in the Georgina Basin (Gum Ridge and Anthony Lagoon Formations). These were estimated to be approximately 1 to 10 mm/year on a point basis, which is approximately 0.2 to 3% of yearly rainfall. Quantifying these estimated rates across the extent of the basin's major recharge areas (see Fig. 3

below), results in overall recharge estimates of approximately 20 to 180 GL/year for the Gum Ridge Formation, and 50 GL/year for Anthony Lagoon Formation (Table 4).

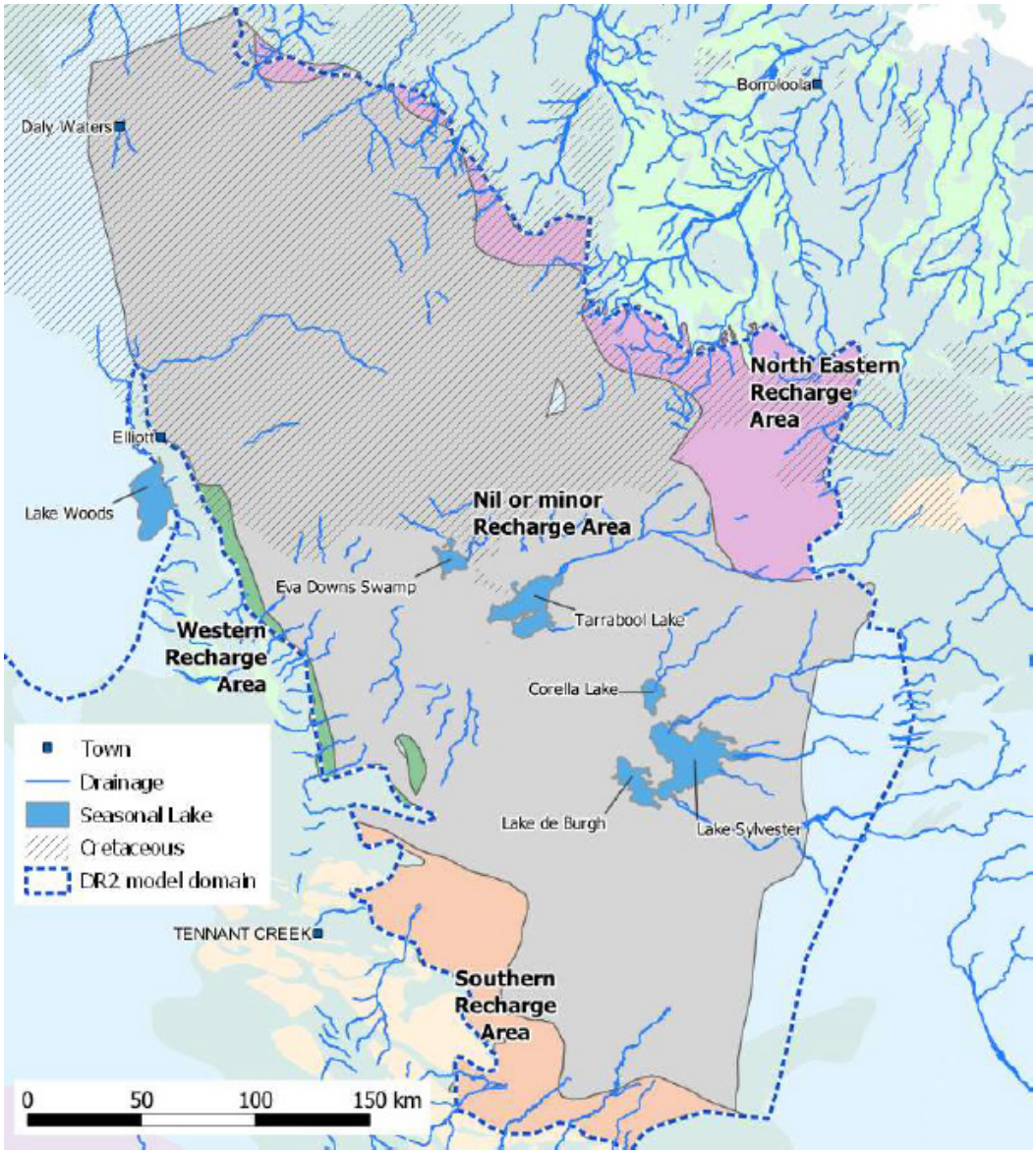


Figure 3 – Mapped or inferred groundwater recharge areas for the Georgina Basin (From Knapton et al., 2020, after Tickell and Bruwer, 2017).

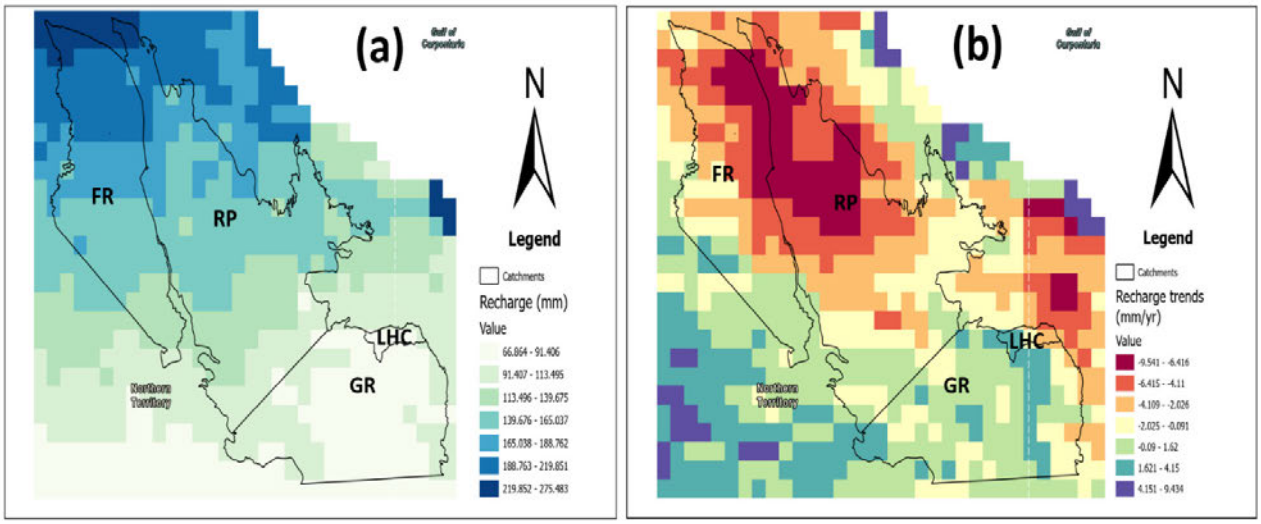
Knapton et al., (2020) reviewed earlier estimates of recharge in the CLA to inform coupled surface-groundwater modelling using MIKE-SHE and FEFLOW. MIKE-SHE estimates recharge based on rainfall, evapotranspiration, vegetation and soil properties (allowing incorporation of preferential flow through macropores). Based on this approach, Knapton et al (2020) estimated recharge to the Georgina basin to be ~315 GL/yr, considerably higher than field-based estimates of Tickell and Bruwer (2017). Sanford (2002), Scanlon et al. (2002) and others have noted that caution is required when using numerical models and/or water balance estimates (with recharge calculated as the residual of other water balance terms) to estimate groundwater recharge. As a generally small part of the water budget, there are significant uncertainties with such estimates, and ground-truthing with field data is essential. Recharge in the Mataranka zone of the Daly Basin was estimated by Knapton (2020) at ~177 GL/year, in line with earlier estimates by Bruwer and Tickell (2015).

Hydrograph analysis in the Georgina Basin (Tickell and Bruwer, 2017) shows that recharge to the southern CLA aquifers (Georgina and Wiso basins) is mostly associated with rare, intensive wet periods, when 5-year moving average rainfall exceeds the long-term average. Major water table rises, indicating significant recharge, have been recorded only twice since monitoring began; in the mid-1970s and early 2000s. Recharge is likely to be well below the long-term average in most years, but substantially above long-term averages only during such rare wet events.

The recently released draft Georgina Wiso WAP estimates recharge rates to the Georgina and Wiso Basins to be approximately 660 GL/year; i.e., significantly higher than the previous model-based estimates outlined in Table 3. The 660 GL/year value is based on updated coupled surface water-groundwater modelling - the same model reported in Knapton, (2020). The estimate is however nearly double the recharge reported for the Georgina Basin in the previously documented modelling. This is likely due to the use of the most recent 50 year-period of data (1970 to 2020, a relatively wet period), as opposed to the full length of available climate records – Knapton, (2020) used the longer period of 1900 to 2019 climate data. Notably, the majority (two thirds) of the recharge contributing to the overall total over the revised modelled conducted for the draft WAP occurred during 1974, an extremely wet year which saw an estimated 21,280 GL of recharge. There is very little data to indicate the mechanism or geographic extent of this large, episodic recharge event, nor any indication as to how frequently such events may recur. As such, the estimation of average recharge in the draft WAP, is very heavily dependent on a single recharge event nearly fifty years ago, for which data are mostly lacking. This is critically important when assessing whether extracting a fraction of the averaged recharge rate derived using the model – e.g., 40%, as proposed in the plan – can be considered appropriate as a sustainable yield (see further discussion in section 2 and 3 below).

In recent years, estimation of groundwater recharge has also been attempted using satellite remote sensing methods, in particular the Gravity Recovery and Climate Experiment (GRACE), launched by NASA in 2002. The use of these data is still generally considered to require careful ground-truthing, as there are multiple sources of uncertainty and potential error (e.g., Chen et al., 2016). In the Murray Darling basin and elsewhere, the agreement between satellite and in-situ data from monitoring bores suggests GRACE data can track groundwater dynamics (e.g., Rateb et al., 2020; Chen et al., 2016) with limited uncertainties compared to outputs from models and other sources (see Scanlon et al., 2002). Estimation of recharge and/or groundwater storage changes with GRACE is only feasible over large geographical areas, as the satellite data have limited local-scale resolution.

Preliminary analysis in this report shows that the large scale of the CLA allows for meaningful use of GRACE to examine recharge rates and water balance trends (Figure 4 and Table 3). Annual recharge in the Daly Basin was estimated from GRACE data for 2003-2016 based on the difference between maximum groundwater depth observation in a particular year and the shallowest observation in the following year. Soil moisture, derived from the Global Land Data Assimilation System model (GLDAS-Noah), was subtracted from the overall GRACE signal for terrestrial water storage change. Preliminary recharge estimates using this method resulted in high rates (> 200 mm/yr) in the northern Flora River catchment, reducing gradually towards the south, and slightly reducing over time (Fig. 4b). Recharge in the Gregory River catchment ranged from 66-90 mm/yr and appeared to be slightly increasing with time. The recharge estimates broadly align with those proposed by Deslandes et al., (2019) and chloride mass balance data by Crosbie and Rachakonda (2021), though they are higher than previous estimates.



FR-Flora River; RP-Roper River; GR-Gregory River; LHC-Lawn Hill Creek

Figure 4 – Spatial patterns of annual groundwater recharge in four catchments of the Cambrian Limestone Aquifer estimated from the Gravity Recovery and Climate Experiment satellite (2003-2016). (a) Shows the average annual recharge and (b) the trends in annual recharge during the period. Data sourced and processed by C. Ndehedehe

This preliminary analysis indicates that, notwithstanding uncertainties relating to estimates of soil moisture, GRACE can be used as an independent line of evidence for recharge to the CLA, and to examine its responses to climate variability and water extraction. In the CLA, recharge is primarily being driven by annual rainfall and possibly also the strongly annual temporal patterns of surface water extent (de Caritat et al., 2019).

Table 3: Summary of recharge estimates for the CLA

Study	Basin/Unit(s)	Point-based recharge rate estimates (mm/year)	Volumetric recharge rate (CLA)	Method(s) used
Deslandes et al., 2019	Southern Daly (Tindall), Northern Georgina (Anthony Lagoon & Gum Ridge Fm),	1 to 25 mm/yr (diffuse, increase south to north); 140 to 190 mm/yr (preferential	Not quantified	Tritium, Chloride mass balance (recharge rate); CFCs, SF6 and noble gases

	Northern Wiso (Montejinni Lstone)	recharge through sinkholes)		(qualitative insights)
Bruwer and Tickell, 2015	Daly Basin / Tindall Limestone	8.7 to 28.5 mm/yr (in areas of shallow/exposed CLA)	Approx. 330 GL/yr (possible range from 286 to 722 GL/yr).	Water table fluctuations, Chloride mass balance, water balance, model
Tickell and Bruwer, 2017	Georgina Basin / Anthony Lagoon Formation	0.9 to 12.2 mm/yr (areas of shallow/ exposed CLA)	20 to 179 GL/yr (Gum Ridge Fm) 51 GL/yr (Anthony Lagoon Fm)	Chloride mass balance
Crosbie and Rachakonda, 2021	Entire CLA	5 to 156 mm/yr including: 5 to 18 mm/yr (Georgina); 9 to 31 (Wiso); 49 to 156 (Daly) (5^{th} to 95^{th} percentiles)		Chloride mass balance, constrained using baseflow separation and remote sensing data
Knapton et al., 2020	Georgina Basin & Daly Basin		315 GL/yr (Georgina); 177 (Daly)	Coupled ground-surface water modelling
Northern Territory Government, 2022a	Georgina & Wiso Basins		608.4 GL/yr (Georgina); 48 GL/yr (Wiso) (Additional estimates compiled in background report – NTG, 2022b)	Coupled ground-surface water modelling
This study (preliminary estimates only)	Daly Basin (Flora, Roper, Gregory River catchments)	174 mm, 87 mm, 84, and 144 mm for the Flora River, Gregory River, Lawn Hill Creek and Roper River catchments.	Not quantified	GRACE satellite data

Groundwater flow patterns

Regionally, groundwater flows from the southern parts of the Barkly Tableland, Sturt Plateau and Wiso Tableland (within the Georgina and Wiso basins) to the north, following the gentle decline in topography (Fig. 4). Flow patterns within the Daly Basin continue this northerly-directed flow-path within the Tindall Limestone, towards the Roper River and Mataranka Springs on the east of the basin, and towards the Flora River and associated springs on the western side of the basin (e.g., Top Springs). In the Daly Basin, there is also flow from the northern margins (near Katherine) towards the south, with groundwater flows again converging upon and discharging to the Mataranka Springs and Roper River (Fig. 4). At the northern extent of the Daly Basin, there is further northward-directed groundwater flow in the Tindall Limestone, which discharges into the Daly River through many springs (Fig. 4).

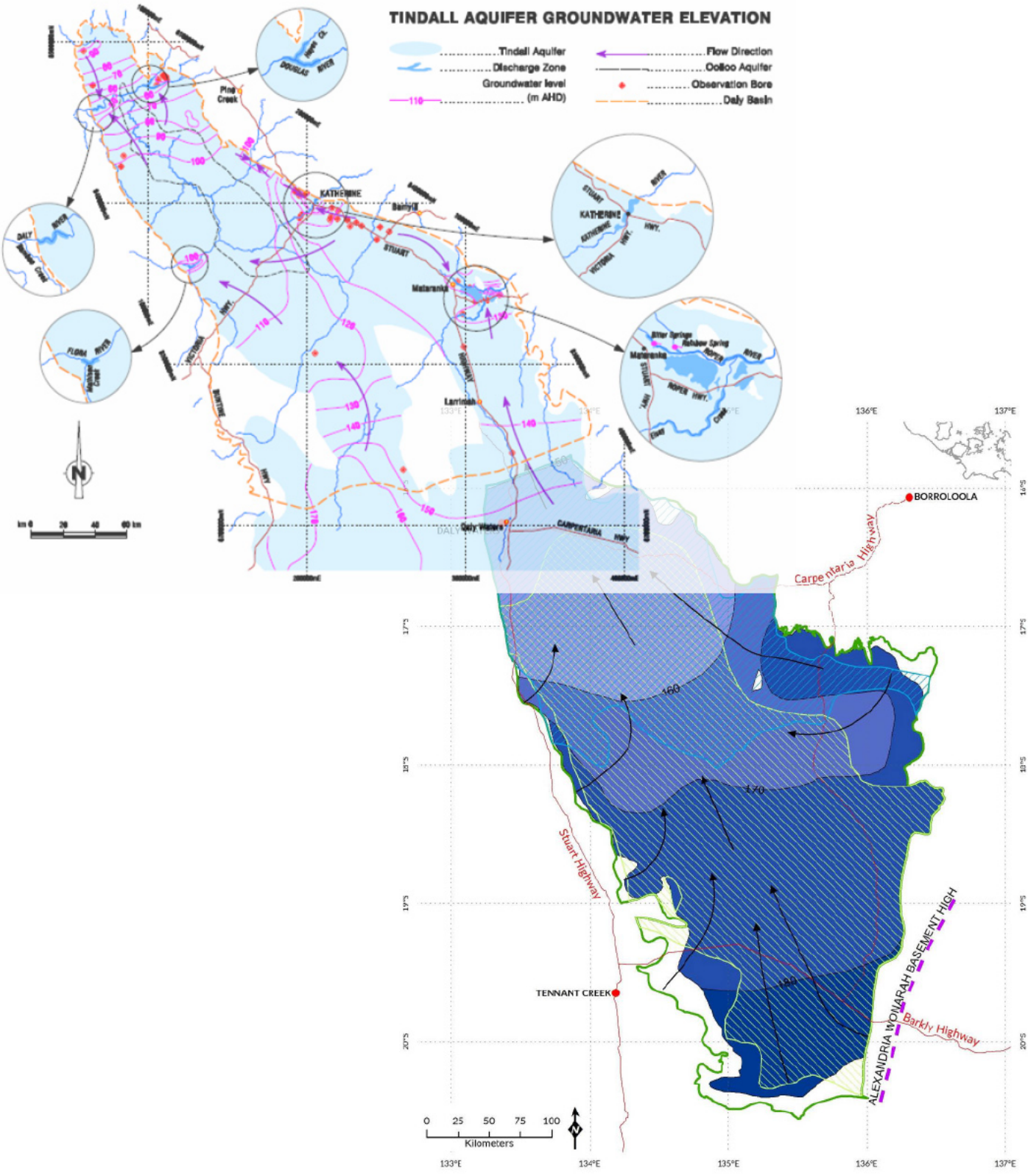


Figure 4 – Composite map of approximate groundwater level contours in equivalent Cambrian limestone aquifer units across the Georgina Basin (bottom image) and Daly Basin (top image). Maps from Tickell (2007) and Bruwer and Tickell (2015).

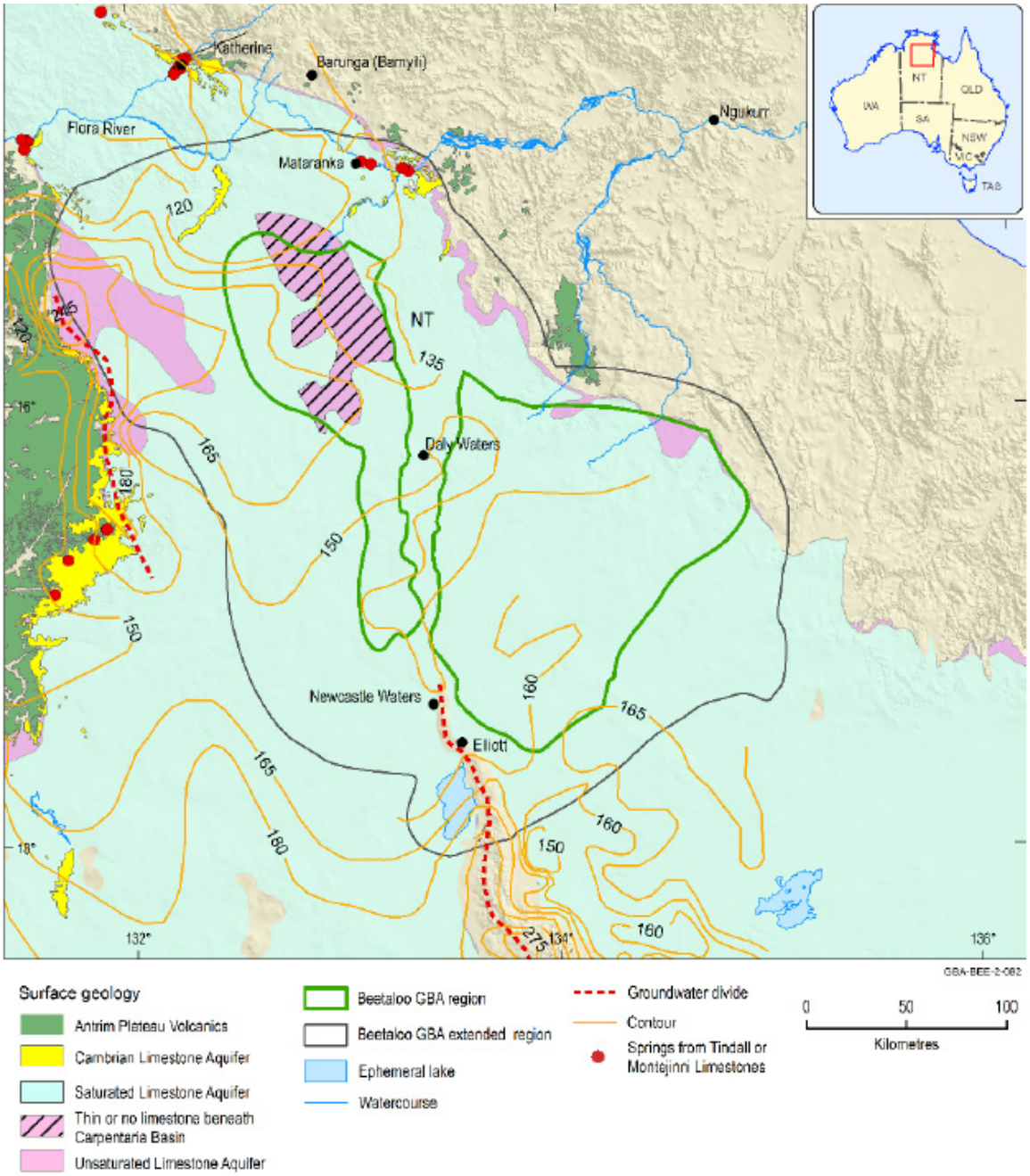


Figure 5: Approximate water level contours: Montejinni Limestone, Wiso Basin and Tindall Limestone, southern Daly Basin, with Beetaloo sub-basin indicated. From: Evans et al., (2020).

Throughflow between different CLA units in the three basins

The extent of connectivity along regional groundwater flowpaths, i.e., the amount of throughflow from the Georgina and Wiso basins into the Daly Basin along its southern boundary, and the importance of such throughflow (as opposed to more localized recharge), in sustaining fluxes and levels in the Tindall Limestone, remains a major knowledge gap (Evans et al., 2020). This has significant implications for how the CLA is likely to respond to groundwater extraction in different regions - i.e., the extent of localized vs. regional impacts. The groundwater contour patterns mapped and shown in Fig. 4 and Fig. 5 indicate that groundwater flow in the main CLA units continues from the northern extents of the Georgina and Wiso Basins into the Daly Basin, i.e., throughflow from the southern basins into the Daly. The mapping of stygofauna assemblages recently by Rees et al (2020) and Oberprieler (2021) indicated that there is a high degree of connectivity within the CLA across the three basins - if this was not so, more localized endemic stygofauna communities would be expected. This is further supported by similarities in the hydrochemistry of groundwater along flow paths that cross the basin boundaries (Evans et al., 2020).

Tickell and Bruwer (2017) note that despite the equivalence between the Tindall Limestone and Gum Ridge Formation across the Daly/Georgina basin boundary and regional flow directions, recharge and flow patterns are somewhat different in the two basins, and localised recharge and flow within each basin are also important:

> "There is a notable difference in the flow pattern in the Gum Ridge Formation compared to that in the Tindall Limestone, its equivalent in the Daly Basin. In the latter case, where the Formation outcrops along the basin margin, flow is parallel to the margin and groundwater discharges to streams which are generally perpendicular to the margin. In the Georgina Basin, groundwater levels are too deep to discharge to streams, so the flow pattern is basin-wards from the margins and then to the north-west." (Tickell and Bruwer, 2017)

On the basis of pumping test data, hydraulic gradients and aquifer geometry, Tickell and Bruwer (2017) estimated throughflow from the Georgina Basin (Gum Ridge Formation) to the Daly Basin (Tindall Limestone) to be approximately 2 GL/year. Knapton (2020) proposed somewhat larger estimates of groundwater throughflow from the Georgina to Daly basin, with 1.6 to 16 GL/yr transferring as throughflow (Figure 6). This is still a relatively small contribution to the Tindall Limestone's water balance in comparison to rainfall recharge within the basin itself (Table 4), however it may be important for sustaining water levels and flows through the Daly Basin. Carbon isotope dating also points to somewhat complicated relationship between groundwater flow patterns, recharge, and inter-basin connectivity:

> "From carbon isotopes, Suckow et al. (2018) noted that apparent groundwater ages became younger northward along an inferred regional flow path trend, from the Georgina Basin to Daly Basin. This is the opposite of what is usually expected, which is that groundwater becomes older along a confined flow path. One explanation for the apparent carbon age trend is that recent recharge is occurring in the northern part of the trend, with older groundwater at the southern end of the flow path in the Georgina Basin. Other interpretations and complicating factors, put forward by Suckow et al. (2018) are: there is not a continuous regional flow path (flow paths are more localised), unknown processes are influencing the carbon isotope results, or that flow velocity is high enough along the flow path that not enough time is available for significant radioactive decay to occur in carbon isotopic system." (Evans et al., 2020).

Knapton (2020) summarised a basic water balance for the Georgina & Daly basins, encompassing throughflow and estimates of groundwater discharge to the Roper River and Mataranka Springs, as outlined in Figure 6. Groundwater contour mapping shows that groundwater flow divides between and within the three basins are important controls on flow patterns and inter-basin connectivity, and that these are controlled by topography and geological structure (e.g., faulting); particularly in the Wiso Basin, where flow towards Top Springs on the western basin margin is important in addition to the northward directed flows into the Daly Basin towards the Flora River (Fig. 5).

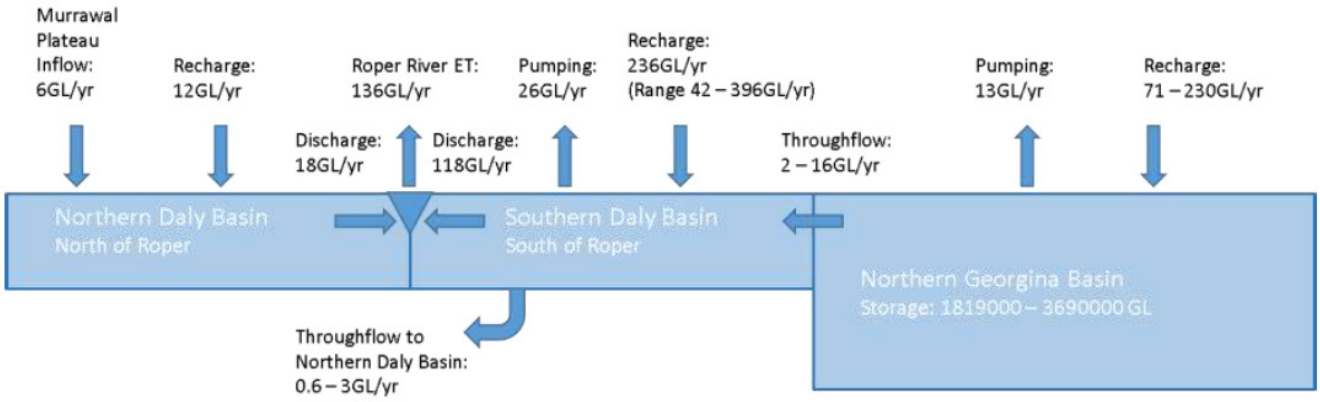


Figure 6: Indicative water balance for the Roper River basins encompassing estimated recharge, discharge and throughflow rates. From Knapton, (2020).

Groundwater discharge

Discharge of groundwater from the Tindall Limestone within the Daly Basin occurs to the Roper River and its southern tributaries – e.g., Elsey Creek, via springs (including Mataranka Thermal Pools) and diffuse discharge to the river channel along a significant length within the upper catchment (Figure 7). These flows make up a very significant proportion of the Roper and its tributaries' flow in the upstream section of the catchment, and support important Groundwater Dependent Ecosystems and cultural values (Jolly et al., 2004; Karp, 2008; Barber and Jackson, 2011; Bruwer and Tickell, 2015; Lamontagne et al 2021). CLA groundwater discharge to the surface has been estimated to be approximately 3 to 4 m^3/second downstream of the Mataranka springs (Knapton 2006; Fulton and Knapton, 2015), equating to approximately 260 to 345 ML/day, encompassing flow from both north and south (Evans et al., 2020). Springs along the Flora River on the western side of the Daly Basin receive approximately 2.3 m^3/second of discharge at the end of the dry season and the river is estimated to gain approximately 2 to 5 m^3/second of flow from the Tindall Limestone (see Evans et al., 2020, citing Knapton, 2006). Further information about the flows from the CLA to the surface and the values they sustain are discussed in further detail in section 1c, below.

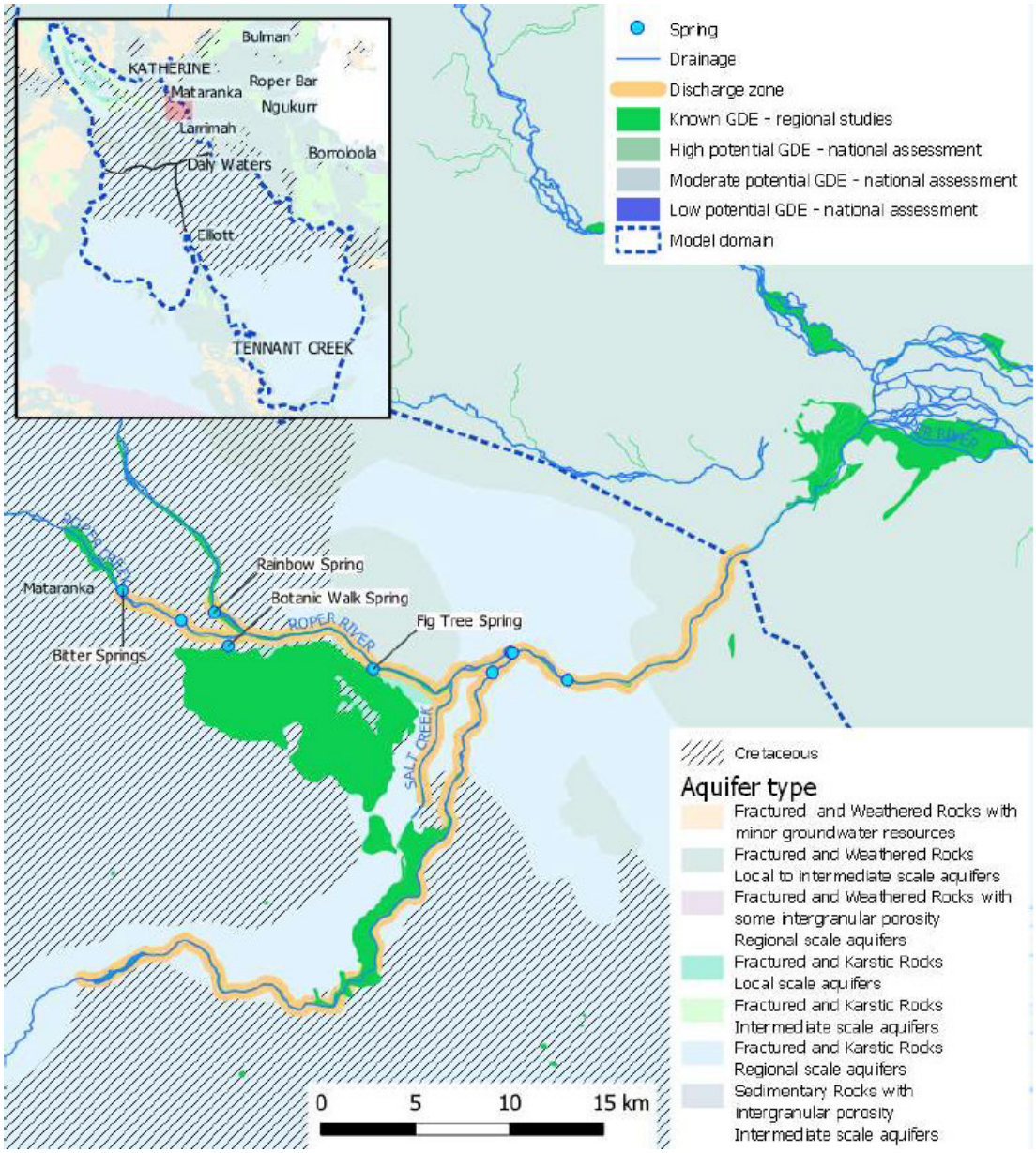


Figure 7 – Mapped locations of groundwater dependent ecosystems receiving discharge from the CLA in Mataranka region (From: Knapton, 2020). The major tributary to the south is Elsey Creek.

Additional groundwater discharge from the CLA is associated with evapotranspiration by groundwater dependent vegetation, in areas of shallow water table (Knapton, 2020).

In the Georgina Wiso basin, there is very limited understanding of groundwater discharge mechanisms. The draft Georgina Wiso basin WAP hypothesises that groundwater outflow from the CLA in these two basins only takes place through (relatively small volumes) of groundwater throughflow to the Daly Basin to the north, with no additional groundwater discharge through ET or groundwater flows to springs and other surface features. This is premised on the assumption that CLA groundwater levels are uniformly deep below ground level (difficult to assess currently, due to a lack of comprehensive monitoring bore coverage), and that vegetation communities are not able to access groundwater from deep water tables. This matter requires further careful analysis. The idea that recharge to the aquifer is not balanced by comparable amounts of groundwater discharge would be unusual for a large, relatively un-developed aquifer system. Typically, aquifers that have limited groundwater extraction are thought to come to a long-term equilibrium where recharge + inflow is approximately balanced by discharge + outflow (Theis, 1940; Alley et al., 1999).

Evans et al., (2020) note that CLA groundwater may provide flows that sustain Top Springs on the western side of the Wiso basin; however, field studies are lacking to verify this or

determine the rate(s) of discharge. The water level mapping presented by Evans et al., (2020) and other Bioregional Assessment reports also indicates that there are areas where CLA groundwater levels are likely to be within 20 m of the surface. Whether there are deep-rooted vegetation communities that are adapted to utilise such groundwater (e.g., *Acacia* species able to grow deep tap-roots, Lamoureux et al., 2016) is not known. Further field evidence is clearly needed to resolve the above issues and determine where and how much groundwater discharge occurs from the Georgina and Wiso basins, and what values are sustained by these flows.

Timescales of flow and aquifer response times

The timescales of groundwater flow between recharge and discharge areas within the CLA are not well known, nor is it well understood how long the system may take to reach a new equilibrium in response to significant disturbance, such as a major and rapid increase in groundwater extraction rates, or a step-change in the regional climate conditions. Analysis of basin time-constant (τ) as per equation 1 below, is one way to approach this question (Schwartz et al., 2010; Currell et al., 2016). Numerical modelling can also estimate these time-dependent responses and lags.

$$\tau = \frac{L^2 S_S}{K}$$

$$\tau_{step} = \frac{L^2}{D_h}$$

Where L = length of the flow system, K = hydraulic conductivity [L/T], Ss = Specific Storage (dimensionless), Dh = Hydraulic diffusivity (transmissivity/storativity) [L^2/T]. Value of τ (in units of time) represent approximate period required for a groundwater flow system to re-equilibrate following a major hydrological change/disturbance. After Currell et al., 2016.

Based on preliminary analysis of aquifer dimensions and hydraulic properties (Table 2), time constants on the order of 500 to 50,000 years would apply to the Georgina and Daly Basin flow systems (assuming a continuous, connected flow path across the length of the basin(s), see Fig. 4). The aquifer system(s) would be expected to take hundreds to tens of thousands of years to reach a new steady-state (where inflows and outflows reach a stable equilibrium) following a major hydrological change. This does not mean that increasing rates of groundwater extraction in the short term would take this length of time to impact on groundwater levels and discharge to the surface - such impacts would begin to manifest immediately close to the points of extraction and spread over time throughout the system as it re-equilibrates. Rather, τ values indicate the timescale required for the full effects of a major hydrological change to manifest. These concepts are discussed further in Section 2. In the numerical model for the Daly basin used by Bruwer and Tickell (2015) to assess potential impacts of increased groundwater extraction on Roper River baseflow, it took approximately 300 years for a new steady state to be reached, following a new wellfield extracting 20% of estimated recharge. Decreases in discharge to the river began to occur rapidly, exceeding 15% within 25 years. This timeline is consistent with earlier modelling by Knapton (2004).

Radiocarbon and other environmental tracer data in Deslandes et al., (2019) also give an indication of timescales of recharge, throughflow and discharge in the CLA (Figure 8); however, caution must be applied in the estimation of 'age' of groundwater, as groundwater isotopic data appear not to follow a clear horizontal and/or vertical flowpath (such as a piston flow or exponential piston flow model, for which calculation of groundwater velocities can be achieved). Most ^{14}C results from groundwater samples in the CLA range from 10 to 100 percent modern carbon (where 100 pmC represents modern/recent recharge), and also contain tritium (albeit at relatively low concentrations) 'excess air' and modern gases such as SF6. The detection of these 'young' groundwater age tracers indicates active recharge throughout much of the region, which possibly overprints groundwater 'ageing' along regional flowpaths (Deslandes et al., 2019).

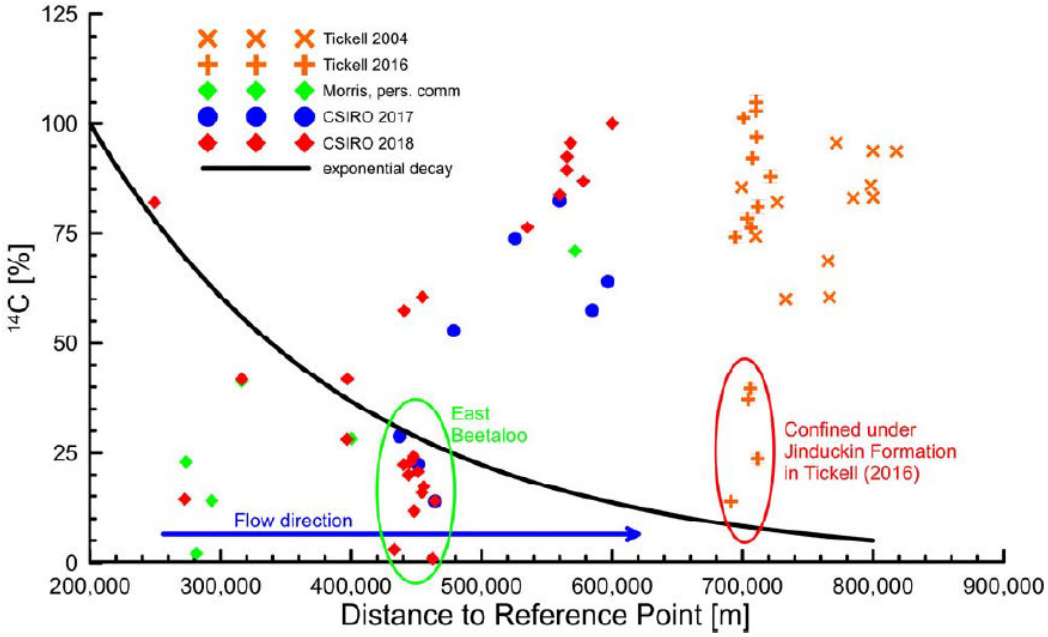


Figure 8: Summary of radiocarbon data from the CLA, from Deslandes et al., (2019).

c) The dependencies on the key groundwater systems from hydrological, environmental and cultural perspectives.

In the Daly Basin, discharge of water from the Tindall Limestone to the Roper River is a significant proportion of the river's flow in the upper catchment, and supports important Groundwater Dependent Ecosystems (Karp, 2008; Bruwer and Tickell, 2015; Evans et al., 2020; Lamontagne et al 2021). These groundwater flows sustain the river and its tributaries through dry periods – i.e., the river is fully dependent on groundwater following periods of low rainfall. Discharge from the CLA is also the predominant source of water sustaining the Mataranka Springs, which flow to the Roper River in its headwaters. Karp, (2008) explained:

> "The springs in the Roper start from the upstream junction of the Waterhouse River and Roper Creek (which join to become the Roper River) and extend east to the edge of the limestone basin. This region is the most significant in terms of groundwater and surface water interactions with the Mataranka Basin providing much of the base-flow in the Roper River."

Locations of the Waterhouse River, Roper Creek and downstream section of the Roper River are shown in Figure 9; essentially this region is the beginning of the Roper River catchment, and thus discharge from the Tindall Limestone provides permanent flows at the source of the river, which sustain all downstream sections. Figure 7 also shows mapped areas of groundwater discharge in this area.

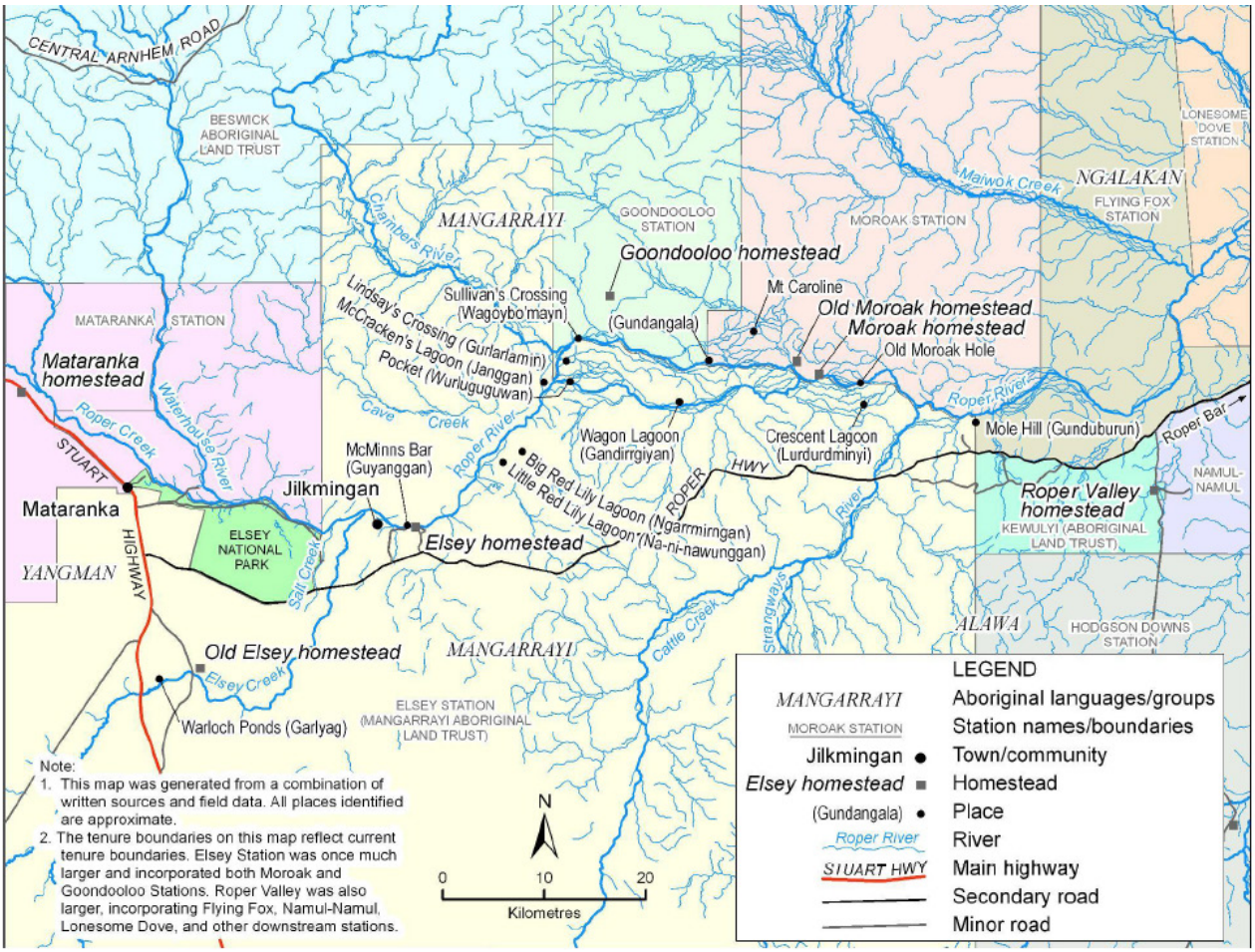


Figure 9: Detailed map of sites in the upper Roper River catchment (from Barber and Jackson, 2012).

Karp (2008) showed that the zone where the Roper River crosses the Tindall Limestone and receives discharge from the aquifer is associated with a sharp increase in river flows, which then decline gradually moving downstream, implying limited additional baseflow inputs to the river:

> "Clearly the karstic springs in the Tindall aquifer provide significant flow to the river in the Mataranka Basin with the rate of increased flow being high in this region. Similarly, immediately downstream of the Basin, the subsequent decrease in flow is significant and is associated with losses to swamps and wetlands such as Red Lily Lagoon and 57 mile Waterhole"

Karp (2008) further stressed the dependence of the river (including downstream sections) on Tindall Limestone groundwater discharge and management implications of this dependence:

> "Analyses of data collected during a comprehensive survey in October 1980 show only small changes in water quality in the non-tidal sections of the Roper River extending some 200 kilometres from the junction of Roper Creek and Waterhouse River to Roper Bar (Figure 4.13). **This suggests that during the dry season, the limestone aquifers in the Mataranka basin provide the main supply of water flow in the Roper River. Thus, the management of the groundwater resources in the Mataranka Basin is crucial to the viability of the downstream reaches of the Roper River**."

Source(s) of groundwater discharge to springs

Recent research by Lamontagne et al (2021) used environmental tracers to better define the sources of groundwater discharge for individual springs within the Mataranka Thermal Pools (springs) complex. This research identified that there is flow from the CLA both from northern and southern flow systems within the Tindall Limestone aquifer (see Fig. 4) and a component of deeper flow (probably from the Antrim Plateau Volcanics) and shallow, recent recharge, in different springs (see locations in Fig. 10):

> "Major ions, Sr, $^{87}Sr/^{86}Sr$, $\delta^{18}O$-H^2O, δ^2H-H_2O, ^3H, ^{14}C-DIC were consistent with regional groundwater from the Daly and Georgina basins of the CLA as the sources of water sustaining the major springs (Rainbow and Bitter) and one of the minor springs (Warloch Pond). However, 3H = 0.34 TU in another minor spring (Fig Tree) indicated an additional contribution from a young (probably local) source. High concentrations of radiogenic 4He (> 10–7 cm3 STP g–1) at Rainbow Spring, Bitter Spring and in nearby groundwater also indicated an input of deeper, older groundwater. The presence of older groundwater within the CLA demonstrates the need for an appropriate baseline characterisation of the vertical exchange of groundwater in Beetaloo Sub-basin ahead of unconventional gas resource development."

This indicates some level of inter-aquifer connectivity between the CLA and underlying units, either locally (i.e., just at the Mataranka Springs due to local structural geology) and/or regionally. This topic remains a knowledge gap and current research is examining the extent of inter-aquifer connectivity more extensively (Evans et al., 2020).

Locations of groundwater discharge

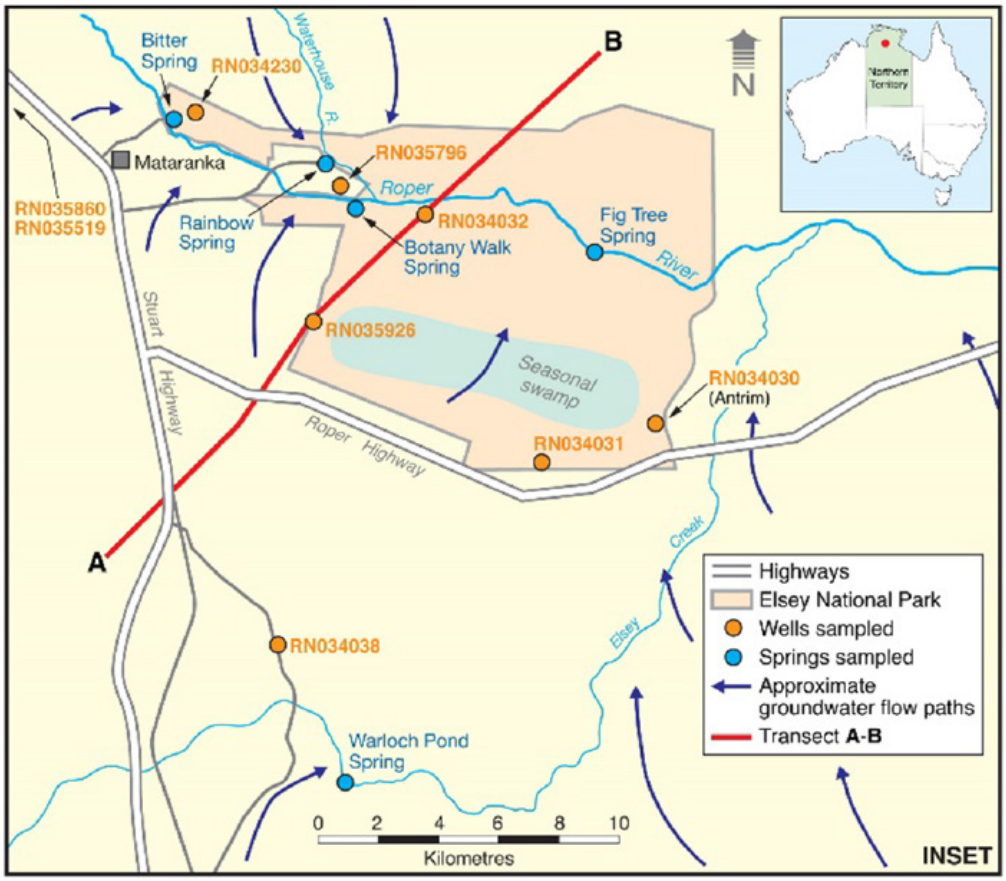
Most visible groundwater discharge to the Roper River from the CLA occurs into wetlands and spring pools located within Elsey National Park (Fig. 7; Fig. 9), which then flow to the Roper River. Discharge via the main river channel itself also occurs (Karp, 2008); evidence of this includes tufa (calcium carbonate deposits from discharging karst groundwater) along the riverbanks, and major ion chemistry in the springs and river which match CLA groundwater (Karp, 2008). Elsey Creek, which flows into the Roper River from the south, is also sustained by CLA discharge, including from Warloch Pond Spring (Lamontagne et al., 2021). Venting of groundwater discharge to permanent waterholes (e.g. Longreach waterhole) along Elsey Creek has also been identified. Additional tributaries of the upper Roper from the south are also likely sustained by Tindall Limestone groundwater (Fig. 7; Short, 2020).

Springs also provide flow to the Flora River on the western side of the Daly Basin – this is the regional groundwater discharge zone for the CLA northwards out of the Wiso Basin (Fig. 4). Top Springs on the western side of the Wiso basin (See Fig. 5) are also thought to be sustained by discharge from the CLA (Evans et al., 2020). There appear to be less data and less extensive investigation of mechanism of discharge, rates of flow, environmental and cultural values, and vulnerability of these springs, in comparison to Mataranka Springs – a major knowledge gap which should be addressed for the determination of management rules in the Georgina-Wiso WAP.

Groundwater salinity

Water quality in the CLA is variable, with salinities ranging from below 500 mg/L to over 10,000 mg/L. Groundwater is generally considerably fresher in the northern (higher recharge) regions of the CLA and tends to be more saline in the south. Tickell and Bruwer (2017) mapped groundwater salinities for the Georgina Basin and found little correlation with bore/aquifer depth. This indicates that zones of saline water may inter-mingle with or occur close to fresher groundwater, with associated implications for water quality (e.g., creating a risk of salinization if extraction rates in high quality groundwater bores occur close to saline groundwater zones).

Figure 10: Location of Mataranka Thermal Pools within Elsey National Park (Lamontagne et al., 2021).



Ecological and cultural significance of the Roper River, Mataranka Springs & GDEs

The Roper River and Mataranka springs are of high cultural significance for Aboriginal peoples of the region, as documented by Barber and Jackson (2011), Barber and Jackson (2012) and others (e.g., Merlan, 1982). The region is also associated with significant ecological values (Faulks, 2001; Duong and Stokeld, 2021), which are part of the cultural landscape managed under customary law by Traditional Owners:

> "From an Indigenous perspective, the country and the places it contains are active participants in the life of human beings, responding to events and actions in the world, particularly the actions of those people with whom it is strongly connected ancestrally. Therefore an important first step in the proper management of both land and water is appropriate conduct by human beings." (Barber and Jackson 2011).

Barber and Jackson interviewed Aboriginal peoples of the Roper region, and their views help to give a sense of the central and fundamental importance of water in their lives and culture:

> "Water is life, gives life to the land. It feeds the environment, keeps country cool and healthy. We don't like to damage country. Its good for fishing, swimming, camping. We use it for teaching too- cultural stories, bedtime stories, camping beside the river. Its our heritage. We need it to visit, enjoy life. M.H.
>
> If there was no water, all the life would be dead. The animals would be gone if the river dried out. R.S.
>
> Water is needed for the animals and the sacred areas. Water for the country and the people. D.D.
>
> We are dependent on that river. J.R.

> Water is for healing. The water runs out at the crossing. When we get sick, we go and drink the water. M.R
>
> There is a spring close to Beswick community. That water never dies, it will always be there. It gives us water to drink, and for the animals too. J.M."

In the context of early steps in the water planning process, Barber and Jackson (2011) further documented how the Indigenous peoples of the area understand the connectivity between groundwater and surface water, and the importance of upstream flows of these waters for everyone downstream:

> "We are upstream, we are the point of origin. We are guardians for the downstream people and they are the guardians for us. The Elsey mob are getting us involved because we are upstream. They've got the surface water for us, and we've got the underground water for them. The ownership of the two goes hand in hand." A.M.

In line with other accounts of the integral role played by water within living cultural landscapes that connect Aboriginal peoples with their ancestors and other living entities, the cultural significance of water is about more than a collection of 'sacred sites' in a landscape, which may nonetheless play special roles in Indigenous beliefs, ceremonies and Dreaming stories, but cannot describe in full the significance of above and below-ground waters connecting and sustaining the lands collectively termed 'Country' (Ah Chee, 2002; Marshall, 2017; Moggridge, 2020). Nonetheless, the sites discussed below represent important localities featuring in Aboriginal hunting and fishing patterns, stories, songs and ceremonies:

Red Lily Wetlands: Barber and Jackson (2012) document the importance of the Red Lily Lagoons (approximately 20 km downstream of Salt Creek and the eastern extent of Elsey National Park – see Fig. 9), both culturally and economically to the Indigenous peoples of the Roper valley. They documented how the pre-colonial practice of constructing weirs to restrict flows along small tributaries of lagoons was used by Aboriginal people to keep the lagoons filled with water as the dry season progressed, allowing the hunting season to continue for longer and over a more extensive area than could otherwise occur. Eventually this practice was stopped at Red Lilly in the mid-20th Century, as the managers at downstream Roper Station successfully argued in court that it damaged their livelihood by restricting downstream river flows (Barber and Jackson, 2012). Traditional owners continued the practice in other nearby areas (see Barber and Jackson, 2012).

Barlyurra: "Barlyurra is a site complex rather than a specific site. It straddles the Roper River in the vicinity of Red Lily lagoon and upstream. It includes the sites Warrwarrag, Garawi Yirrij, Wa-gardjag, Ngalarrg, Na-Yumbunggan, and Lunjan. The members of the Barlyurra group are affiliated with these sites through the Wijwij, or possum, dreaming. Amy Dirngayg told a story of the possum making a hair belt. There is also a snake dreaming, the detail of which is secret to men and therefore the subject of restricted evidence. Na-Yumbunggan is a ceremony ground for men's ceremony, although Jessie Roberts said that the presence of tourists using the river has caused the cessation of ceremonies on that site. The area is Bangariyn-Ngarrijbalan country, which meets with Gamarra-Burrala country somewhere to the west of Guwarlmbarlg." (Commonwealth of Australia 1990: 107, cited in Barber and Jackson, 2011).

Waterholes & permanent springs: As documented by McGrath (cited in Barber and Jackson 2011), waterholes were a critical part of the Aboriginal economy and a setting for major ceremonies. They were sites of intense conflict during colonization of the northern frontier.

> 'There is a heavy concentration of sites along the Roper River, where permanent water is available. Other sites tend to be associated with permanent waterholes in the

ephemeral waterways. There is no neat pattern of Dreaming tracks associated with sites. Rather, Dreaming tracks intertwine. (Commonwealth of Australia 1997:113)"

"Much of this country is well watered and well provided with trees. The Mangarrayi pride themselves on their association with the riverine country along the Roper and other bodies of water within their country. (Merlan 1982:146)"

An example of the significance of one such site was documented in Barber and Jackson, 2011:

"The first site visited by the Dreaming on the claim area is Gorowan, on Salt Creek. The Dreaming then visited Na-Burl (Elsey Falls), Murrwale and Barlmarrag, all on the Roper River. Between Murrwale and Barlmarrag is a waterhole, into which the Garawi jumped and in which it submerged. It travelled underground to the north and re-emerged at Nganawirdbird. This is a place of great significance. It consists of a large sinkhole and limestone cave at the top of a hill. Inside, various limestone features have been painted; they represent the internal organs of the plains kangaroo. The site is on the register of the national estate, pursuant to the Australian Heritage Commission Act 1975. p108."

Barber and Jackson (2011) also document how the ancestral being, known as the Rainbow Serpent, is understood by Aboriginal peoples to populate the Dreaming landscapes of the Roper region - as in many other Indigenous peoples' Dreaming stories Australia wide. The serpent is associated with the underground water flows that connect different parts of the country and keep certain places supplied with permanent water, as told by Bill Harney, Wardaman elder:

"The spring him fill up with water from the ground, so now him dry [dry season]… that river still runnin' from that spring. Him bin that spring all the time. Important because that Rainbow Serpent they sit down there longa spring every time … When him dry you know that the spring gotta have him water because that Rainbol [regional Aboriginal Kriol term for Rainbow Serpents] there." Cooper and Jackson 2008:27.

The serpent connects the peoples and waters of landscapes that are very distant from the Katherine/Mataranka area, as far as Borroloola on the Gulf of Carpentaria:

"The story of the Walalu, Stranger Rainbow Serpent is very important and very sacred…The Walalu is sometimes called Yankarra, which is Yanyuwa [language] for "the Stranger", he is called this because he came from such a long way away and, once he moves through Garrwa and Yanyuwa country he keeps moving all the way into Marra country, he moves through Alawa and Mangarrayi country, and finishes his journey at the Mataranka hot springs which is far to the west." (Yanyuwa families et al. 2003).

Water and its aquatic species figure prominently in Indigenous peoples' beliefs and stories (e.g. conception stories) regarding birth, death and connection between ancestral spirits/beings and living people, animals and plants:

"Birth is important too. The couple bear a child and that child comes out from the spring. The kids come from the water. It's the same story, even when we die. The water is a way that adopted kids come into that country. They get born into there, and they are automatically part of that country. The spirits greet us." M.R and M.H. cited in Barber and Jackson (2011) p19.

"The returning wanggij in some cases is described as incorporeal, but sometimes it may come in the form of an aquatic species, like a fish, since the Mangarrayi believe

> that children emerge from water. Although the wanggij is said to look for its father, it may first be recognized by someone else. (In the instances I was told of, this was always by a close patrilineal relative; one woman caught her brother's child as a barramundi, as is now evidenced by the fact that the hook, which tore its mouth, left a scar that the child bears".

Large (particularly riparian) trees: As outlined in Jackson and Barber (2013), Merlan (1982) recorded how Indigenous peoples of the upper Roper believe that large trees – often located near important water sites – embody individuals from current or recently deceased generations:

> "Trees do have the name. Name of that person. The ones which grow in special places. When we see the Dreaming tree, we know not to touch that. Don't put a fence line through there, put it around it." (R.R.)

This links living Aboriginal people to 'both the lines of descent and to the totemic creatures who created the land' (Jackson and Barber, 2013, p.11).

Ecological values and conservation management

Faulks (2001) conducted an ecological assessment of the Roper River and sub-catchments, and found generally stable riverbeds, limited disturbance of river corridors, creeks, rivers channel, and bank habitats in very good or condition, despite widespread evidence of some disturbance by exotic animals. Exotic vegetation was also found to be widespread. Vegetation found to be dependent on the groundwater flows to the Roper River, its tributaries, and springs (Mataranka Thermal Pools) include communities of *Livistona rigida* (palms) which has restricted distribution in the Top End region and thus considered to be of high ecological significance (Faulks, 2001). These palms require shallow, steady water tables (i.e., < 2 m below surface) before they become stressed and vulnerable to fire. Faulks summarized the findings of earlier surveys of the vegetation of Elsey National Park by Lucas and Manning (1989):

> "The riparian vegetation adjacent to the Roper River within Elsey National Park was described as being diverse, both floristically and structurally. *Pandanus aquaticus*, *Terminalia erythrocarpa*, *Melaleuca* spp., *Eucalyptus camaldulensis* and *Livistona rigida* form dense stands along the river banks. Lush communities of *Livistona rigida* as well as *Ficus platypoda* were associated with springs." (Faulks, 2001).

Knapton (2009) summarised GDEs of the Roper River region, noting the importance of groundwater in sustaining Mataranka Thermal Pools, Red Lily Lagoon, Flying Fox Creek, Mainoru River and Wilton River. In addition to the *Livistona* palm communities, riverbank vegetation, including *Melaleuca argentea* and *Barringtonia acutangular* are thought to almost exclusively utilize groundwater (i.e., they are obligate GDEs). Large *Livistonia* palm and melaleuca communities occur along Elsey Creek and in the vicinity of springs in Elsey National Park and other sections of the Roper River channel. Riparian vegetation communities associated with the permanent water provided by CLA discharge are relatively small in terms of land area, but serve as critically important habitat for animal species – both local and migratory (Woinarski et al., 2000).

Remote-sensing based mapping by Short (2020) further identified distinct regions of groundwater-dependent terrestrial vegetation in Mataranka, using normalized difference moisture and vegetation indices (NDVI/NDMI). Vegetation that persists during dry periods, due to perennial access to groundwater, was identified at permanent water bodies and in areas away from river corridors, which correlated with zones of high (shallow) water tables (Fig. 7).

Stygofauna communities - fauna which live within aquifers, are another type of GDE that widely occur and for which knowledge and data are gradually growing worldwide. A stygofauna survey was conducted in the CLA within the region encompassing the Beetaloo sub-basin and Roper River system, in response to this being identified as a key knowledge gap in the Pepper inquiry. The results are reported by Rees et al., (2020) and Oberprier et al (2021). The surveys identified a diverse range of stygofauna species occurring in the CLA dominated by crustaceans, including the blind shrimp *Parisia unguis*. The widespread occurrence of specific stygofauna across great distances in the CLA is consistent with a high level of connectivity throughout the aquifer system (as opposed to stygofauna which exhibit a greater level of short-range endemism, which indicate localized evolution and habitat conditions). Identified species showed relatively little correspondence with stygofauna communities documented in other regions such as Western Australia, where stygofauna surveys have covered a larger and relatively diverse range of settings (Rees et al., 2020).

2. Risks to groundwater dependent ecosystems and associated values from current allocation rules (storage-based estimates of sustainable yield)

The predominant risks associated with an increase in groundwater extraction rates from the CLA are:

i. Reduced flows of groundwater to the Roper River, Mataranka Thermal Pools and other streams, springs and wetlands of the region. If these groundwater discharge flows and/or CLA groundwater levels were to decline below key thresholds, complete loss of springs and baseflow to rivers may occur. This would lead to the loss of vegetation communities and animal habitat, and incalculable loss and damage to the cultural values associated with both specific sites (e.g., springs, waterholes, and wetlands) and the health of 'country' and Aboriginal culture from a holistic point of view (see section 1c). Stygofauna may also lose their habitat if extensive drawdown occurs in regions of the aquifer they inhabit.

ii. Interference to existing water users and water supplies in the region. For example, a significant drop in groundwater elevations in the CLA may lead existing extraction bores used for stock/pastoral water supply to lose pressure or (in extreme cases) run dry. This is particularly significant in the Daly Basin, where there are already quite a number of pastoral bores utilising CLA groundwater. Significant loss of dry season river flows in the upper Roper River would lead to a reduction in downstream river flows, affecting downstream surface water users. In dry periods, this could (for example) result in saltwater ingress affecting the Ngukurr Aboriginal Community (Jolly et al., 2004; Zaar, 2009). Non-consumptive uses of water (e.g. tourism, fishing and hunting) may also be impacted, with flow-on economic effects and impacts on Indigenous customary uses.

Depletion of significant volumes of storage within an aquifer are also associated with other irreversible negative consequences such as:

- land subsidence and compaction of the aquifer matrix: In limestone terrains this can lead to collapse structures (e.g. sinkholes) at the surface. Aquifer compaction can also impact on aquifer properties, e.g., reducing transmissivity and future groundwater storage capacity (Ojha et al., 2018). This typically affects unconsolidated sediments but has also been documented to impact carbonate aquifers of similar type to the CLA (Laroque et al., 1998).

- Degradation of water quality, through drawing in poorer quality water from layers adjacent, above or below the CLA. It is known that the salinity of groundwater can be variable in different parts of the CLA – for example with TDS concentrations exceeding 10,000 mg/L in parts of the Georgina Basin (Tickell and Bruwer, 2017), but there is currently limited assessment of risks of migration of saline water bodies into fresher parts of the aquifer system under the influence of groundwater extraction.

The rest of this section reviews current water policies in the Northern Territory and assesses the extent to which the above consequences are likely to occur under these policy settings if there is a significant increase in demand for groundwater from industries such as irrigated agriculture and shale gas. Section 3 outlines management approaches that can ensure protection of the groundwater dependent values and avoid these negative consequences.

The Northern Territory Water Allocation Planning Framework

Under the Northern Territory Water Act, water licensing is conducted based on rules set out in Water Allocation Plans for each region. However, large areas of the NT, including the area encompassing most of the CLA and Beetaloo Sub-basin, do not yet have declared water

allocation plans. Only 28% of licenses in the NT occur within areas with a declared WAP (O'Donnell et al., 2022). In accordance with recommendation 7.7 of the Pepper Inquiry, it is understood that the NT Government is currently working on Water Allocation Plans that will encompass the CLA's major sub-zones (Mataranka, Flora Tindall, Georgina Wiso), with the goal of releasing these in 2022-23. Currently, the only publicly available WAP draft is the Georgina-Wiso plan (Northern Territory Government, 2022a).

In the absence of a water allocation plan, the current policy governing groundwater licensing is the Northern Territory Water Allocation Planning Framework, which defines two separate zones of the Territory - Top End and Arid Zone. Within these two zones, different rules apply governing the amount of groundwater that can be extracted from a given aquifer.

In the Top End Zone:

> 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 Arid Zone:

> 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.

These rules are the basis for calculating an "estimated sustainable yield" (ESY) in a given region. Surface water extractions are also subject to different rules within the two zones.

It is unclear what rules will be adopted in the different water allocation plans currently in development. For example, it is unclear how an ESY (overall cap on licensed extractions for a given region) will be determined, and what additional groundwater management rules (e.g., mechanisms such as trigger levels to protect groundwater dependent ecosystems) will apply within the water allocation plan areas. From available minutes on the public record, and statements by the NT government, it appears that the Top End, Arid Zone or other rules that calculate ESYs based on a percentage of aquifer storage, may be used as a basis for developing the plans. For example, minutes of the Mataranka Tindall Water Advisory Committee[3] indicate that it has been proposed that the Arid Zone rules be applied to the Tindall Limestone near Larrimah, despite this region being north of the Top End/Arid Zone boundary (i.e., within the Top End zone).

The draft Georgina-Wiso WAP appears to have adopted an approach that bases the ESY on a fraction of the average groundwater recharge (similar to the Top End rule), however the fraction of recharge is substantially higher than for the Top End rule, and there are considerable issues which call the methodology used to develop the proposed ESY into question (see the section on Recharge above, and further discussion below in section 3).

The Top End/Arid Zone delineation

Figure 10 shows the current boundary between the Top End and Arid Zones, based on a technical report completed by the NT Water Resources Division in 2020[4]. The line essentially relies upon surface water catchment boundaries – with northward flowing catchments forming the Top End, and inland-flowing catchments forming the Arid Zone. The report reviews additional climate and hydrological datasets (e.g., soil moisture, evapotranspiration,

[3] https://depws.nt.gov.au/__data/assets/pdf_file/0008/1049453/mataranka-tindall-wac-meeting-11-minutes-and-appendices.pdf

[4] Classification of the Top End and Arid Zone for Northern Territory water resources. Water Resources Division Technical Report 55/2020.

runoff, deep drainage), which also broadly correspond with a transition in climate and hydrological conditions across the line (e.g., the 600 mm/year mean rainfall contour). However, this average rainfall contour does not align with an accepted definition of arid, which generally defines arid zones as having less than 250 mm rainfall per year (Holzapfel, 2008). This applies only to the south of Tennant Creek in the NT. It is also noted in the report, that the boundary line does not represent a distinct or meaningful boundary with respect to the aquifers and groundwater flow systems of the Northern Territory:

> "It is acknowledged that aquifer boundaries rarely align with surface water catchments. However, it is not practical to determine a boundary based on aquifers when there can be a large degree of uncertainty in where a boundary might be defined. Aquifer boundaries, where they have been mapped, may be subject to change by tens to hundreds of kilometres with improved information. By contrast, surface water catchment boundaries are easily defined and readily derived from high-quality (high spatial resolution) national scale elevation data. Once defined, surface water catchment boundaries are not likely to change in the future and are a much better basis upon which to set a boundary such as the Top End/Arid Zone boundary."

Based on the line delineated in the Technical Report (Fig. 11, Fig. 12), the entire Daly Basin, encompassing the Tindall Limestone, and northern Wiso and Georgina basins are within the Top End zone. Figure 12 shows draft boundaries for different water allocation plan districts. The Flora Tindall, Mataranka and northern Georgina Wiso WAP areas are within the Top End zone, while the southern Georgina Wiso WAP area (encompassing most of this WAP area) sit within the Arid Zone. Noting that (as outlined in section 1b), recharge to the Tindall Limestone within the boundaries of the Daly Basin is substantial and appears to exceed throughflow from the Georgina Basin, it is doubtful that the use of Arid Zone rules anywhere within the Daly Basin accords with the notion that the CLA is a 'low recharge high storage' aquifer (see Table 3 and Fig. 4). Hence, even if the Arid Zone rules were to be considered an appropriate management regime for such aquifers (this topic is addressed further below), their use within the Daly Basin would be questionable.

Basis of the Top End/Arid Zone rules

Limited information was identified to explain the original rationale for dividing the Northern Territory into the two zones for the purposes of water management. However, testimony to the Australian Senate in 2003 by the former NT Water Controller, Mr Ian Smith, gives an indication of the basis:

> "The simplest way to explain the allocation framework [as it applies in the Top End zone] is that we seek to retain at least 80 per cent of river flows and 80 per cent of the ground water resource for environmental use. Thereby, in a planning sense and in our licensing procedures, we are looking to license up no more than 20 per cent of the available river flow anywhere in a catchment and, essentially, no more than 20 per cent of the ground water recharge. In a ground water balance sense and in a regional sense, that means that we are retaining at least 80 per cent of the discharge to the environment from ground water systems."

With respect to the Arid Zone rules Mr Smith commented:

> "The behaviour of our aquifers is different in the south than in the north. Our recharge mechanisms are fundamentally different and are much lower, but we have much larger storage. Our policy for aquifers in the southern two-thirds is to

permit mining of the resource over at least 100 years, but our mining at this stage is limited to 80 per cent of the aquifer storage at the start of extraction.[5]"

The rationale for allowing up to 80% of storage to be depleted from aquifers in the Arid Zone may derive partly or in whole from an understanding of the water needs of the township of Alice Springs - where groundwater supplies domestic water to one of inland Australia's largest communities. Groundwater recharge to the aquifer supplying Alice Springs is very limited (estimated to be approximately 750 ML/year) and current allocations (approximately 11,000 ML/year) far exceed this recharge, resulting in long-term depletion of storage in the aquifer (DLRM, 2016). The Arid Zone contingent rules allow this over-draft of the aquifer, in the interests of sustaining water for the township's essential needs. The application of the same rules elsewhere in the NT needs to carefully consider this context – i.e., overdraft of groundwater to supply essential water to a major township is different to applications to extract water at unsustainable rates for economic development. The current WAP still limits depletion of storage in the Amadeus Basin to 25% (not 80%) over 100 years (DLRM, 2016).

[5] Rural and Regional Affairs and Transport References Committee Senate transcript 18/11/2003: https://parlinfo.aph.gov.au/parlInfo/search/display/display.w3p;query=Id:committees/commsen/7147/0004

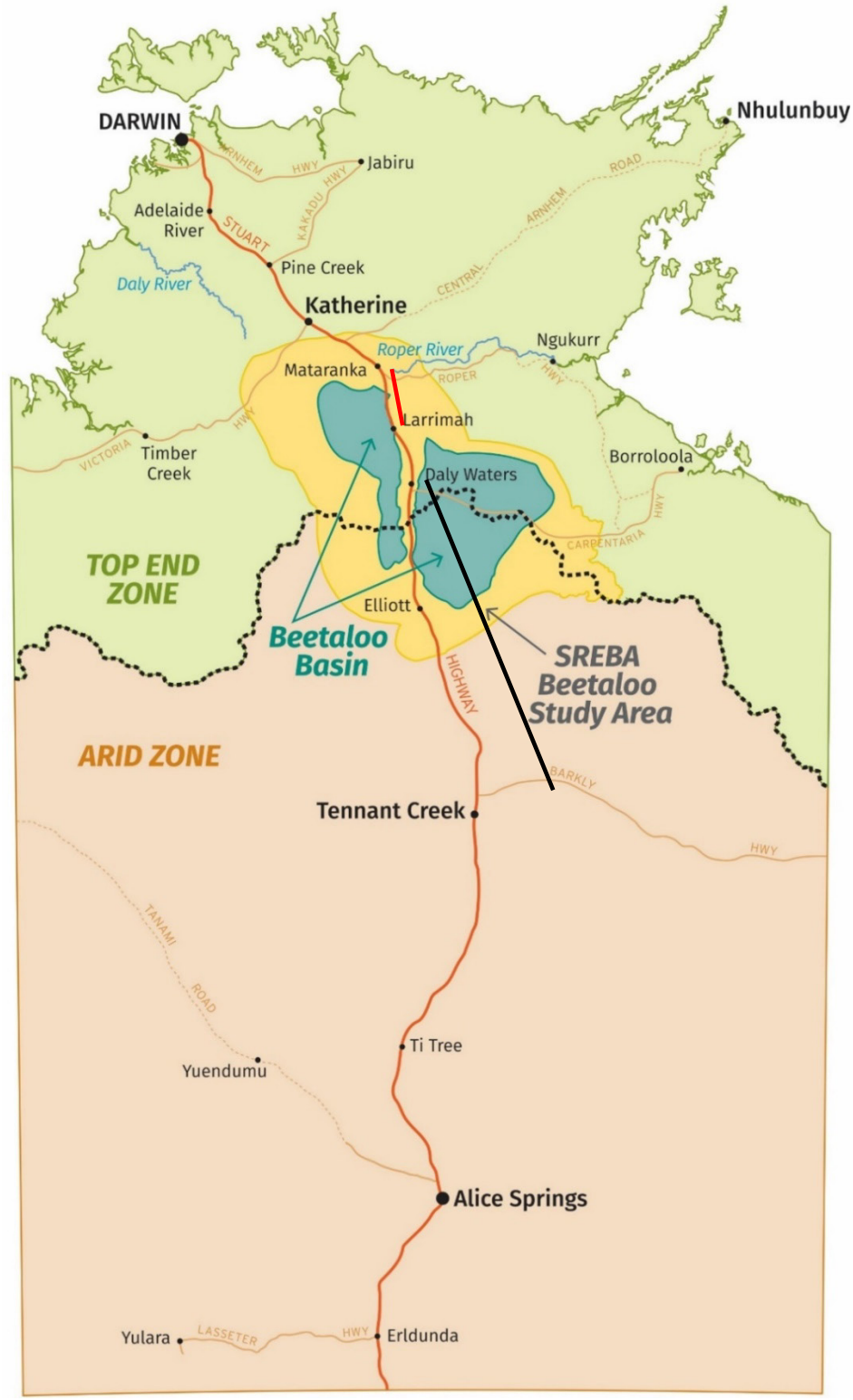


Figure 11: The Top End and Arid Zone boundary, as defined in the Northern Territory Water Allocation Planning Framework, also showing Beetaloo sub-basin and SREBA study area. Red and black lines show approximate locations for Fig. 15. Image credit: First Class Communications.

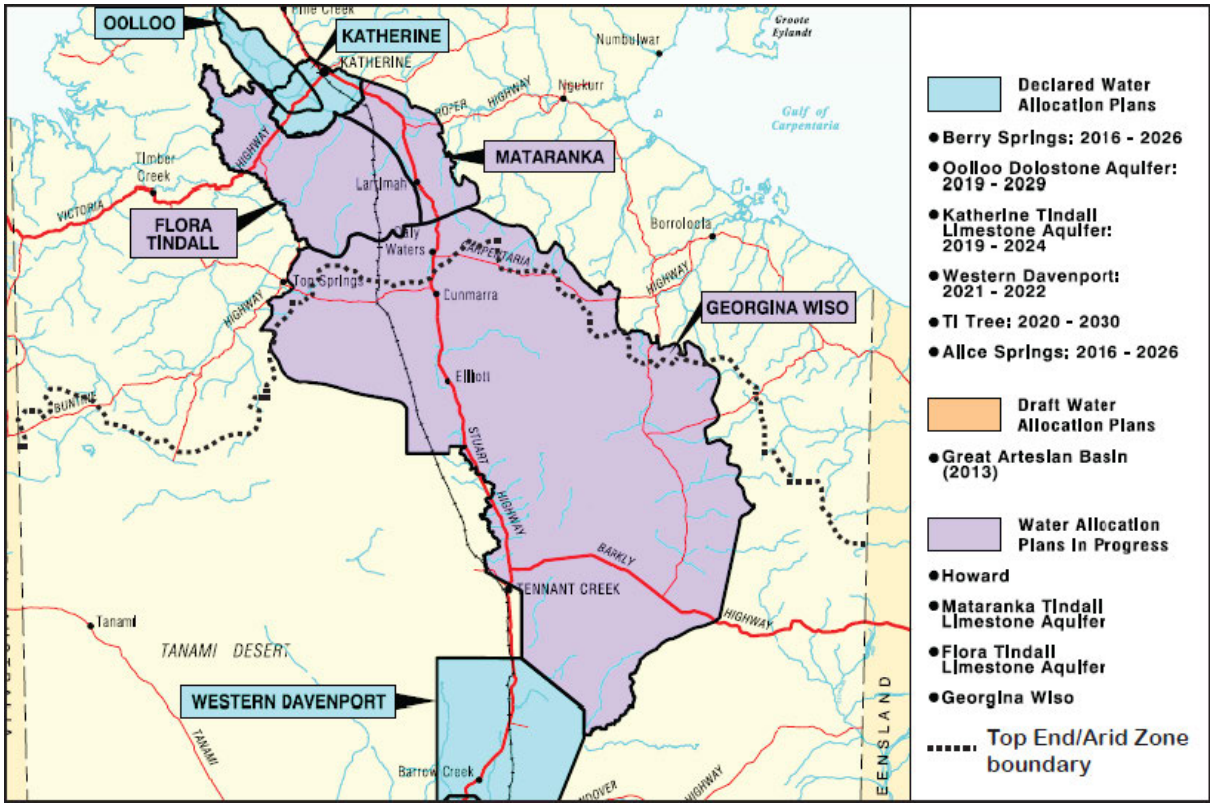


Figure 12: Map of water allocation plan districts where water allocation plans are currently being developed (as of October 2022), with current Arid Zone/Top End boundary marked.

Recent expert opinion on the Top End/Arid Zone rules

The Pepper inquiry reviewed the NT Water Allocation Planning Framework and found that the use of the Arid Zone contingent rules (for onshore gas or any other extractive use) would: '..essentially permit 'mining' of the groundwater resources and would be ecologically unsustainable'. Recommendation 7.7 of the inquiry stated that Water Allocation Plans should be developed for the northern and southern Beetaloo sub-basin with the following principles:

- The new northern Sub-Basin water allocation plan provides for a water allocation rule that restricts the consumptive use to less than that which can be sustainably extracted without having adverse impacts on other users and the environment; and
- The southern Sub-Basin water allocation plan prohibits water extraction for any onshore shale gas production until the nature and extent of the groundwater resource and recharge rates in that area are quantified.

In a recent groundwater licence application near Larrimah that was initially granted to the Northern Territory Land Corporation, but then withdrawn, the Water Resources Review Panel concluded that the use of different allocation rules in the northern and southern parts of the CLA (which, as outlined in Section 1, are to some degree hydraulically connected), is problematic:

> "The application of a significantly different allocation criteria of 20% of storage available for consumptive use (Top End Zone) to 80% of storage available for consumptive use (Arid Zone) to different portions of an aquifer system with high geologic and hydraulic connectivity is not consistent with proper groundwater management. It is not logical to have significantly different allocation criteria in neighbouring management areas for a hydraulically and geologically continuous aquifer, especially if it important to maintain throughflow and natural discharge to the Roper River."

The panel also agreed with the opinion expressed by the Director of Water Planning and Engagement at the time that:

> "Drawing down storage by 80% as proposed by the contingent allocations in the NT WAP Framework will not provide for the environmental and cultural water requirements supported by the aquifer. The lowering of the height of the upper surface of the aquifer after 100 years of extraction has the potential to reverse the hydraulic gradient removing through flow to areas near the southern side of the Roper River and cause water to flow in the opposite direction towards Larrimah.[6]"

These opinions accord with the most up-to-date literature and science on the topics of aquifer responses to groundwater extraction, prevention of aquifer depletion, protection of GDEs, and sustainable groundwater management approaches to achieve these aims (Alley et al., 2002; Ponce, 2007; Gleeson et al., 2012; Doody et al., 2019; Bierkens & Wada, 2019; Walker et al., 2021). These topics are discussed further below.

Problems with the use of a percentage of storage as a basis for sustainable yield

The concept of a Sustainable Yield in the management of groundwater resources has developed over the past hundred or more years. This has occurred in line with evolving views on sustainable water and other resource management, increasing understanding of the interconnections between groundwater and other parts of the water cycle, and awareness of the ecological and cultural values sustained by groundwater flows.

Early concepts regarding the sustainability of groundwater usage began with the 'Safe Yield', which corresponded with the idea that if groundwater extraction did not exceed annual recharge to an aquifer, the aquifer would be protected against long-term storage depletion, thereby allowing ongoing access to the resource into the future (Lee, 1915; Todd, 1959).

It was subsequently shown that this was an overly simplistic way to define 'safe' or 'sustainable' groundwater yield, most importantly because it does not account for the critical role played by groundwater discharge in maintaining surface flows to streams, springs, and connected ecosystems (Theis, 1940, Alley et al., 1999, Seward, 2006), and the ways that these flows, as well as recharge itself, may be changed significantly by groundwater pumping. Groundwater is simply one part of the water cycle, during which it is stored for a period in an aquifer, on its way between infiltrating the land surface (as percolating rainfall) and reaching the oceans or atmosphere via discharge to streams, submarine groundwater or evapotranspiration. As such, extracting the annual recharge flowing into an aquifer deprives the downstream environment (within and/or external to the aquifer), of these flows, which may cause unacceptable environmental, social, cultural and/or economic impacts.

C.V. Theis's seminal work "On the source of water derived from wells" (1940), demonstrated how aquifers and their connected surface waters respond to groundwater extraction in a combination of three ways:

1. The amount of water in storage within the aquifer is reduced (storage depletion)
2. Additional recharge will be drawn into the aquifer from the surface (if it is available in the form of excess or 'rejected recharge')
3. The amount of groundwater discharge to the surface (e.g., baseflow to streams and flow to springs and wetlands) will be reduced

Alley et al (1999) summarised these changes pictorially (reproduced as Fig. 13 below). The second and third changes to the pre-existing water balance are collectively termed 'Capture' by most hydrologists (following Theis). This reflects the fact that this water, which would

[6] Water Resources Review Panel, *Re: Controller's Decision to Grant Groundwater Extraction Licence TLAM10002*, 17 May 2021.

otherwise be available as flows to the surface at some point in time, is re-directed to the pumping wells, meaning the surface is ultimately deprived of it (Theis, 1940).

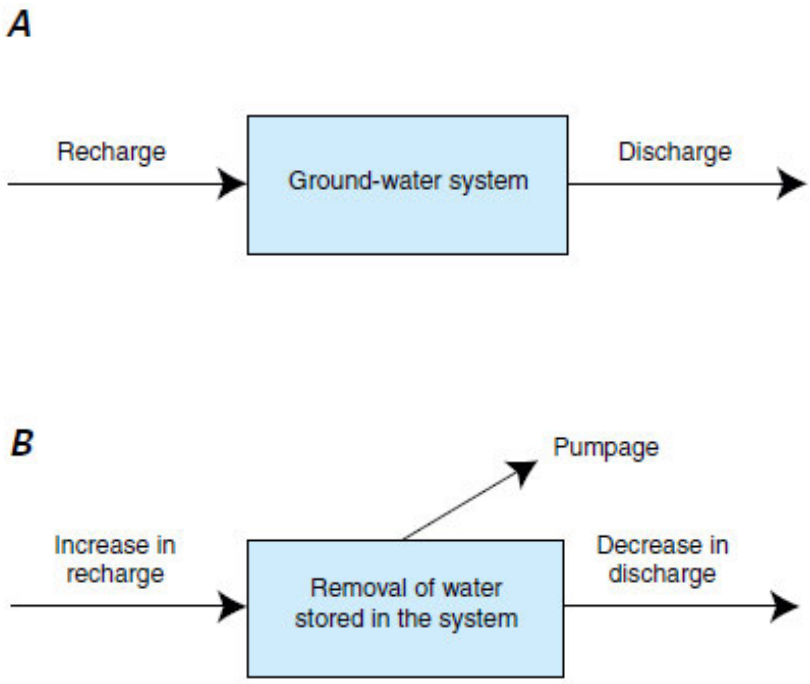


Figure 13: Conceptual diagram representing the three changes which occur (in some combination) when extraction of groundwater disturbs an existing water balance. From Alley et al., (1999).

It has become widely accepted (and demonstrated in modelling studies) that in the long-term, the majority of groundwater extraction is balanced by Capture – i.e., pumping a particular volume over time will result in an equivalent reduction in water discharging from the aquifer. For example, modelling by Konikow and Leake (2014) showed that in the United States, much of the water extracted within major groundwater pumping districts ultimately reduces baseflows to streams. As such, establishing the importance of these baseflows and acceptable levels of impact to these, should be a top priority for sustainable groundwater management.

As pointed out by Theis (1940), depletion of storage is generally an important response of an aquifer to pumping in the early phases of extraction; however, in the long term, Capture will inevitably become the dominant source of water to wells, as the inter-connected groundwater-surface water system approaches a new equilibrium water balance. While in many cases the timescale to reach this point of equilibrium is very long (e.g., Bredehoeft and Durbin, 2009), and in the interim, significant fractions of the pumped water may be derived from storage depletion, the setting of sustainable yield volumes should ultimately focus on determining where the loss(es) of groundwater discharge will occur (and any additional recharge drawn into the aquifer from the surface), and how important these waters are from environmental, economic, and socio-cultural perspectives (Alley et al., 1999, Seward, 2006; Ponce, 2007; Pierce et al., 2013). Direct impacts of storage depletion (e.g., drawdown to the point that GDEs can no longer access groundwater) must also be considered.

The determination of recharge rates is still an important pre-requisite for assessing sustainable groundwater extraction; setting sustainable yields as a fraction of recharge is a way to ensure ongoing access to groundwater into the future, and allows analysis of whether extraction at different rates can be considered ‘renewable’ or ‘non-renewable’ (Bierkens and Wada, 2019). This is in line with current thinking about the sustainable use of natural resources, according to the principle of inter-generational equity (World Commission on

Environment and Development, 1987). Further, recharge is often similar to natural discharge from an aquifer. Thus, setting extraction rates as a fraction of recharge in an aquifer or groundwater 'catchment' will generally limit (but not entirely prevent) reductions in groundwater discharge to springs and streams from that aquifer. However, at least equal or arguably greater focus should be on determining the rates of discharge of groundwater to groundwater dependent streams, springs, wetlands, vegetation and fauna, and the extent to which water sustaining these will be intercepted or reduced by pumping at a given extraction rate. This must be reflected both in the policy rules for setting sustainable yields, and in the focus of scientific work undertaken to define what this should be for a given aquifer/region.

The NT contingent water allocation rules and sustainable yields

The Arid Zone contingent rule (with respect to groundwater) encompass two components:

a) No deleterious effect on GDEs
b) Aquifer storage can be 'depleted' by up to 80% of initial storage volume on a 100-year timeframe

These two parts of the rule may seem to be distinct criteria for assessing the sustainability of groundwater extraction; however, they are strongly inter-dependent and, in systems which receive limited recharge (where the rule is applied), contradictory. In settings where recharge is small relative to storage, extracting 80% of the storage volume will inevitably result in the loss of groundwater flows to connected surface water systems and other GDEs. GDE health depends upon the maintenance of aquifer water levels above thresholds which allow groundwater discharge to springs and baseflow to rivers, ET by vegetation, and to support stygofauna inhabiting the subterranean space of the aquifer. Maintaining GDEs also depends upon the maintenance of flux rates to surface discharge points. This is *related* to maintenance of aquifer water levels, but often in a non-linear way (as illustrated in Fig. 14):

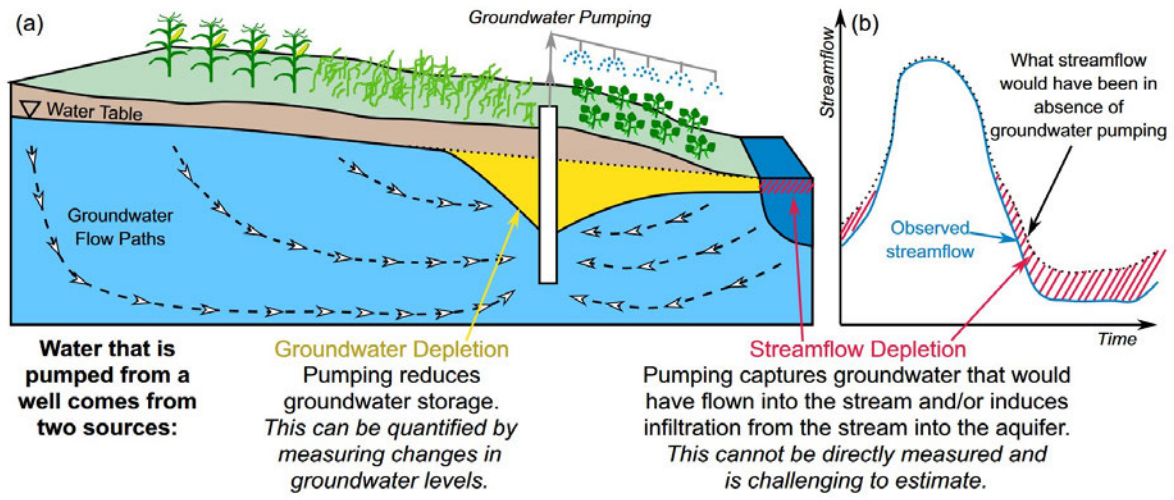


Figure 14 - Example showing how groundwater extraction causes a combination of groundwater storage depletion, and reduction in flows from the aquifer to streams or other surface GDEs, through 'Capture'. From Zipper et al. (2022).

As discussed above, in the long term, most groundwater extraction is balanced by a reduction in the amount of groundwater discharge to the surface or near surface (i.e., GDEs). This may be facilitated by a reduction in throughflow rates between adjacent aquifers (as would apply in the case in the CLA across the Georgina/Daly and Wiso/Daly boundaries) as well as through reduction in flux rates near the GDE(s). If a GDE is fully dependent on groundwater, and there aren't other available sources of 'Capture' to balance extraction, the reduction in flux may result in a 1:1 reduction in water availability to the ecosystem (Hatton and Evans, 1998).

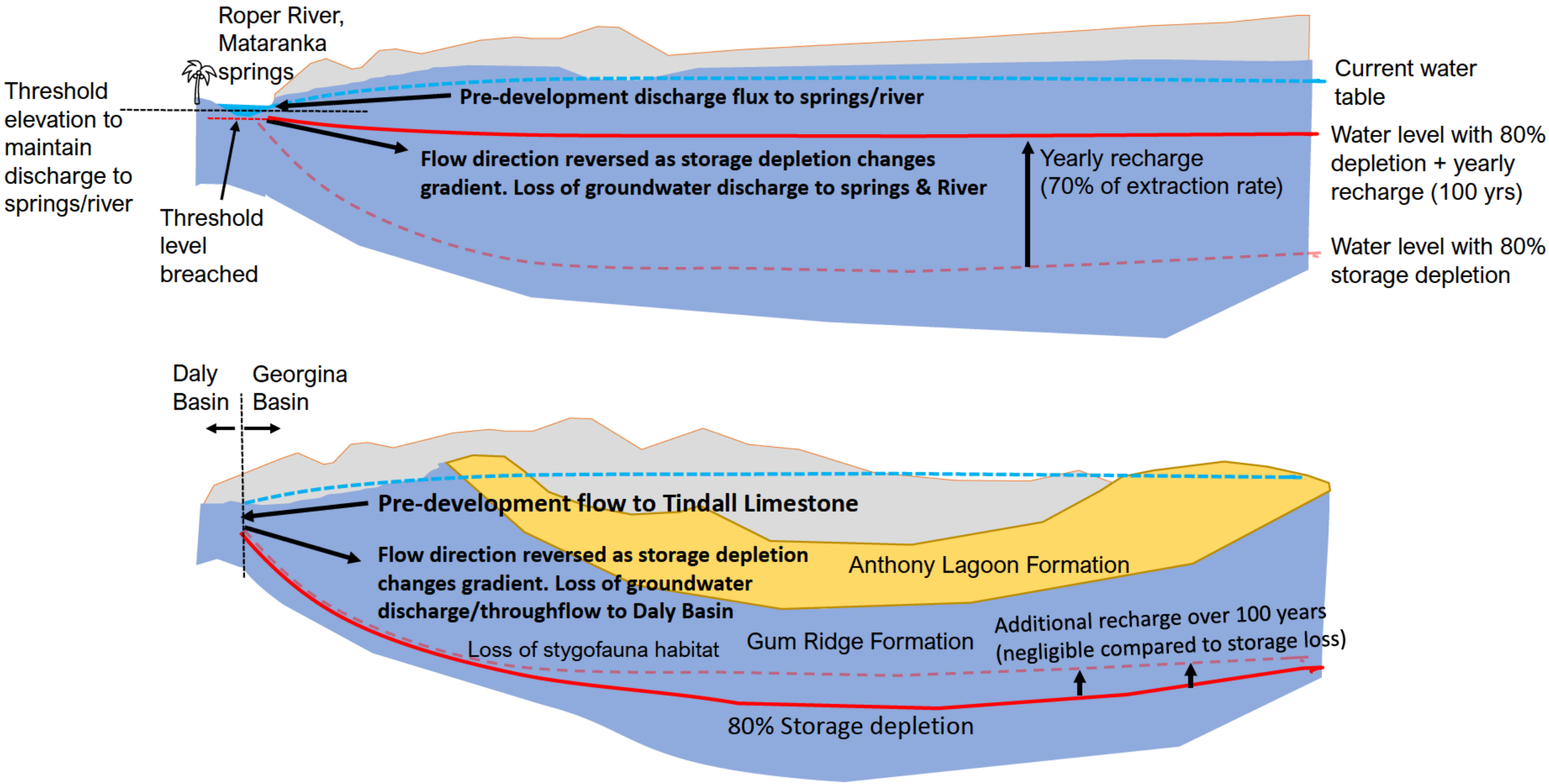
The depletion of water in storage that occurs during the early phases of groundwater extraction - which, in large aquifer systems with long response times, may continue for hundreds or thousands of years, will inevitably cause changes to groundwater levels and flow gradients. |GDEs may be lost entirely as a result of these changes. This can occur by one or both of the following:

a) The groundwater levels at the point of discharge reduce below a threshold elevation (usually the land surface height or root zone depth), which causes groundwater flows to the (near) surface at this point to cease, thereby depriving the GDE of water completely (Figure 15)

b) The groundwater flow gradients change in direction, to the point that groundwater from the aquifer in question no longer flows in the direction of the GDE, and flux from the aquifer to the GDE ceases (again, depriving it of water) – Fig. 14 & 15. This mechanism can cause the loss of springs and baseflow without causing any significant drop in the groundwater *levels* at the point of discharge (e.g., Currell, 2016; Fig. 15). This is why GDE management programs dependent on maintaining water levels only, without also considering effects of pumping on hydraulic gradients and flow rates towards the ecosystem (and setting a cap on rates of extraction accordingly), may be ineffective at protecting GDEs (Noorduijn et al., 2019). Note that throughflow between basins - such as the flows from the Georgina Basin into the Daly Basin, which replenish groundwater along its southern boundary, would be reduced by such changes to groundwater flow gradients (Fig. 15b).

The depletion of even a small amount of the water in storage in an aquifer will change groundwater levels and flow gradients and risk either or both of a) and b). In a case where 80% of the storage volume is depleted, and the recharge rate is small relative to overall storage, it is almost certain that both will occur, as shown conceptually in Figure 15.

Regarding the proposed estimated sustainable yield in the draft Georgina-Wiso WAP (calculated as 40% of recharge, averaged over a 50-year period): As discussed in section 1b, it is likely that in most years this extraction rate would far exceed recharge (as recharge is rare and episodic), and that this situation may persist for many consecutive years or decades. In this scenario, a significant level of storage depletion is likely to occur in between major recharge events. The flow-on effects of such periods of storage depletion – e.g. on throughflows to the Tindall Limestone, groundwater quality, or GDEs (which are to date poorly characterized , remain unknown.


Roper River, Mataranka springs
Threshold elevation to maintain discharge to springs/river
Threshold level breached
Pre-development discharge flux to springs/river
Flow direction reversed as storage depletion changes gradient. Loss of groundwater discharge to springs & River
Yearly recharge (70% of extraction rate)
Current water table
Water level with 80% depletion + yearly recharge (100 yrs)
Water level with 80% storage depletion
Daly Basin
Georgina Basin
Pre-development flow to Tindall Limestone
Flow direction reversed as storage depletion changes gradient. Loss of groundwater discharge/throughflow to Daly Basin
Anthony Lagoon Formation
Loss of stygofauna habitat
Gum Ridge Formation
Additional recharge over 100 years (negligible compared to storage loss)
80% Storage depletion

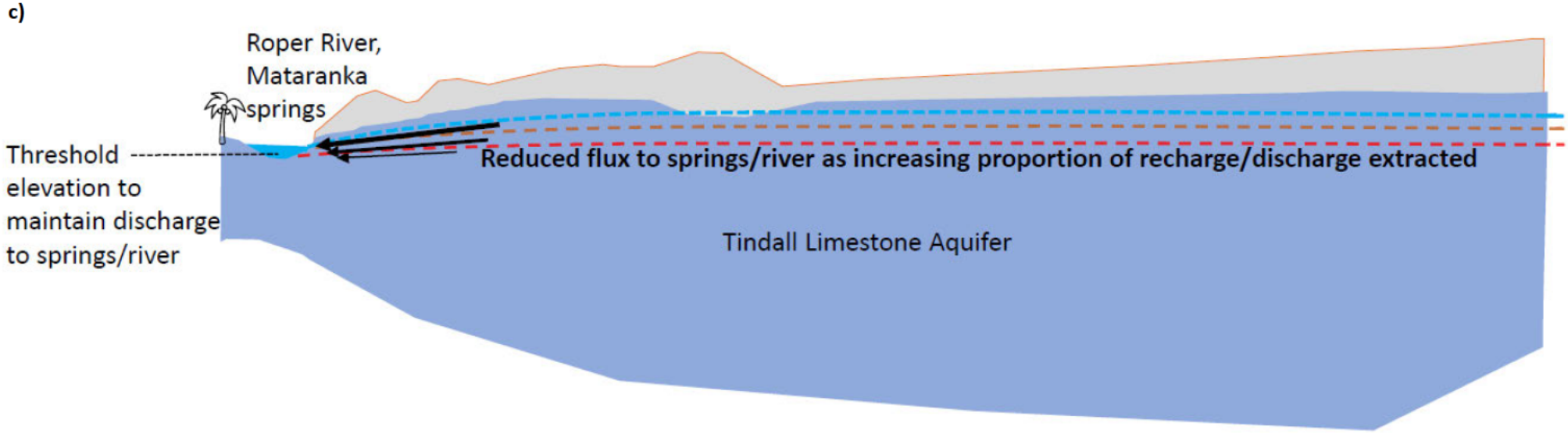


Figure 15: Conceptual diagrams showing how depletion of storage causes consequences for groundwater dependent ecosystems, surface water and inter-aquifer flows. Extraction of any significant proportion of storage will reduce rates of groundwater discharge to the surface and/or adjacent aquifers. Depending on the ratio of recharge to total storage, and extent to which discharge flows are captured by pumping at different locations and rates, these flows may be entirely lost. Example (a) conceptually represents the Tindall Limestone aquifer with 80% of estimated storage (28,200 to 56,400 GL) extracted over 100 years, with recharge of 330 GL/year (after Bruwer and Tickell, 2015). The red line represents the approximate water level, incorporating extraction offset by yearly recharge. Flow to the Roper River and springs is lost, due to change in groundwater flow directions and the capture of discharge. (B) Potential effect of depleting 80% of storage in the Georgina Basin. Due to minimal recharge, storage depletion would reverse hydraulic gradients. Throughflow into the Tindall Limestone (Daly Basin) would become a net loss of water to the Georgina Basin (Gum Ridge Formation), which is likely to reduce flows to GDEs in the Daly basin. (C) shows how extraction of any significant proportion of recharge and/or discharge from the Tindall Limestone would reduce flux rates to GDEs (e.g., the Roper River and Mataranka Springs), without necessarily reversing the flow direction or breaching water level thresholds required to sustain these sites. Locations of a) and c) correspond approximately to north Larrimah to Mataranka (red line on Fig. 11); b) approximately from the CLA west of Tennant Creek to Daly Waters (Black line, Fig. 11). Figures not to scale. More precise field data & modelling are required to predict the spatial and temporal consequences of groundwater extraction at different rates in different regions accurately.

A comparison of volumes of extraction that could be permissible under the Arid Zone rules to annual recharge rate (as per the data in Tables 2 and 3) indicates that in the Georgina basin, permissible extraction over a 100-year period would represent between approximately 60 to 400 times the volume of recharge expected over this timeframe. In the Daly Basin (where storage capacity is estimated to be lower and recharge rate higher), extraction volumes would approximately correspond with (or exceed) the estimated rate of recharge over 100 years, which is likely to substantially reduce flows to GDEs (Fig. 15).

Consideration of climate change impacts on recharge and aquifer storage

Much of the recharge in CLA emanates from annual rainfall. As with other regions, groundwater across the CLA will continue to respond to the impacts of climate change through changes in the characteristics of rainfall (e.g., intensity, seasonality). The negative trends in annual recharge between 2003 and 2016 in some critical areas of the CLA (Fig 4b) highlights this further, suggesting that slight changes in the intensity of annual rainfall and/or increased evapotranspiration rates could create a water budget deficit, affecting rainfall-based storage contributions to the aquifer. Recharge may be significantly less in some years compared to long term averages – the limited analysis of hydrographs conducted for the Georgina basin indicates that this is particularly true in this basin, where substantial recharge appears to have only occurred once in a few decades. Groundwater extraction at rates that exceed recharge even temporarily (due to its episodic nature) could coalesce with prolonged droughts, to deplete storage faster than expected, lowering the water table and ultimately damaging GDEs and their unique biodiversity. Damaging impacts of severe dry conditions on hydraulic properties (e.g., transmissivity of karst aquifers in France), which may not be readily reversible, have been documented elsewhere (Green et al. 2011).

Threats to environmental and cultural values sustained by groundwater if groundwater extraction rates representing a substantial fraction of storage and/or recharge are permitted

As outlined above, the use of Arid Zone contingent rules or other storage-based method to calculate sustainable yield for groundwater extraction from the CLA would pose a high risk of damaging sites dependent on groundwater discharge from the aquifer. Extracting up to 80% (as permitted under the current contingent rule) or 40%, as suggested by APPEA (2020) would pose a very high risk of damaging sites and values dependent on groundwater from the CLA e.g., through reversing hydraulic gradients away from GDEs, breaching key groundwater level thresholds for these, and/or compromising throughflows between different regions. Extraction of substantially lower proportions of storage would still pose significant risks to GDEs, through capture of flows to the surface and/or root zone (see section 2).

The extraction of a large fraction of recharge - e.g., 40% of the estimated average recharge, as proposed in the current draft Georgina-Wiso Water Allocation Plan, may similarly pose risks to multiple values sustained by CLA groundwater. Important considerations regarding the proposed adoption of an estimated sustainable yield of approximately 260 GL/year in this plan (as per the current draft) include:

1. Estimates of recharge rates within the Georgina and Wiso basins remain uncertain, with conflicting values derived from different methods (e.g., Table 1 of the Draft WAP Background report – Northern Territory Government, 2022b). The model-derived estimates of recharge used to calculate the 40% fraction of recharge are almost double the previous recharge estimate using the same model. From review of the reporting it appears that the major difference is a shortening of the period used to model recharge compared to the previous model run (Knapton, 2020). This means that the volume currently estimated to be 40% of average recharge, may not actually represent this fraction of the true recharge. Under the previous modelling (Knapton,

2020), the proposed ESY would represent more than 75% of long-term averaged recharge to the Georgina Basin. If the use of a fraction of recharge is the approach preferred for calculation of an ESY in this region, then using the current minimum estimated recharge rate (and taking a fraction of this) would be a more conservative approach, given the current lack of data. Sound justification for the use of 40% of the recharge should also be provided.

2. Recharge to the CLA is thought to be very infrequent in the region covered by the draft WAP (Georgina and Wiso basins). As discussed in Tickell and Bruwer (2017), it is likely there have only been a small number (three or four) of unusually wet climatic periods since monitoring began in the early 1900s, in which effective recharge to the Georgina Basin CLA has taken place. Extracting a substantial proportion of the long-term averaged recharge each year would therefore mean extraction would far exceed recharge in most years, excluding these episodic recharge events (in which recharge would far exceed extraction). If there are many years or decades between substantial recharge events - as occurred for nearly four decades between the 1970s and early 2010s, the level of yearly extraction proposed along with limited recharge would result in effective mining of aquifer storage between recharge events, causing substantial reductions in groundwater levels (drawdown) and fluxes during these periods. Better understanding of the importance of maintaining groundwater levels for protecting stygofauna communities (e.g. Rees et al., 2021), throughflows to other parts of the CLA (Evans et al., 2020), water quality (Tickell and Bruwer, 2017) and ensuring structural integrity of the aquifer are required before such extraction rates - and the groundwater level reductions they would cause - can be said to be sustainable, i.e., protective of environmental, cultural and economic values.

3. Groundwater discharge mechanisms from the Wiso and Georgina basins are poorly understood. It is questionable to believe that there is little or no groundwater discharge from these basins currently occurring – as appears to be assumed in the draft WAP (e.g., Table 1 of Northern Territory Government, 2022a). Outflow of groundwater is likely to be occurring at rates of similar order to the estimated long-term average recharge – in line with general steady-state conditions typically encountered in relatively un-developed aquifers (Alley et al, 1999). The outflow/discharge of groundwater is likely to be occurring either through evapotranspiration, flow to springs (such as those on the west of the Wiso basin that are currently poorly understood), groundwater throughflow to other regions (which has been considered but may be under-estimated), and/or inter-aquifer leakage. The large imbalance between estimated recharge and outflow/discharge currently reflected in the draft WAP may well reflect limited data currently available to quantify groundwater outflows rather than an actual large imbalance between inflows and outflows.

Ultimately, the extraction of the volumes of water proposed each year in the draft Georgina Wiso WAP would likely have flow-on effects for the rest of the CLA water balance and associated values. As discussed in section 3, 40% of the long-term average annual recharge is at the high end of typical fractions of recharge used to calculate estimated sustainable yields in other jurisdictions, such as the SDLs determined for Murray Darling Basin catchments (Walker et al., 2020). Without addressing the issues described above, the adoption of the proposed ESY/extraction rates in the draft WAP may seriously jeopardise environmental and cultural values. Of further considerable concern is the fact that cultural and environmental values supported by the CLA groundwater in this region (encompassing appropriate stakeholder engagement) appear not to have been effectively documented and considered in the setting of the ESY, and this is not proposed to be addressed until halfway

through the life of the plan. This runs counter to best practice water management approaches, which ensure that stakeholder management occurs early and frequently in the determination of water plan rules (e.g., Thomann et al., 2020 and further discussion in Section 3).

In the Daly Basin, the sites most at risk from excessive extraction of CLA groundwater would be the Roper River and Mataranka Springs (on the east), and to the west, Flora River and its associated springs. It is well established that these sites are strongly dependent on groundwater discharge from the Tindall Limestone aquifer. If extraction rates within the Daly Basin (e.g. Flora Tindall and Mataranka WAP areas) allow for a significant percentage of storage depletion, then these sites would be at high risk of harm. Even if significant extraction rates are permitted a long distance from the GDEs (e.g. groundwater extractions focused near Larrimah, or Daly Waters, above the Beetaloo sub-basin), the most likely *long-term* consequence of increasing groundwater extraction rates within the Daly basin is the capture of discharge that ultimately sustains these critically important GDEs (Ponce, 2007). Further, the depletion of storage in the Georgina and/or Wiso basins to the south would result in throughflow from these basins no longer sustaining the Tindall Limestone, and (as shown in Fig. 15b) a change to a net loss of groundwater throughflow, with groundwater from the Tindall Limestone instead flowing back towards the Gum Ridge Formation.

Ecohydrological and modelling studies have yet to (as far as we are aware) determine the threshold groundwater elevations required to sustain the Mataranka springs, Roper River and other springs and groundwater dependent streams and vegetation above the CLA, nor have they determined the extent of reduction in baseflow and/or associated environmental impacts that would likely be caused at different extraction rates in different areas. Some estimates using numerical modelling, examining potential impacts of extraction at different rates on baseflow to the Roper River have been documented; for example, Bruwer and Tickell (2015) modelled the effect of extracting 20% of estimated recharge of the Tindall Limestone via a wellfield near Larrimah, finding that this would result in a reduction in baseflow to the Roper River of approximately 20% in the long-term. The environmental consequences of such a reduction (i.e., extent to which the values described in section 1c would be harmed) are not known, although they have been explored in Jolly et al. (2004) to some extent. Reductions in flow to springs and/or baseflows in the Roper would cause corresponding declines in river flows downstream. Thus, as well as groundwater dependence of Mataranka Springs and Roper River from the CLA in its upstream sections, downstream sections of the Roper are vulnerable to saltwater intrusion if flows decline below certain thresholds. In the 1950s and 60s, substantial reductions in flow along the Roper caused the loss of the water supply for the Ngukurr Aboriginal community (Zaar, 2009).

It is currently unclear what the major groundwater discharge mechanisms for the Georgina and Wiso basins are; throughflow to the Daly Basin is clearly one component, and discharge to springs a probable additional component (Evans et al., 2020), but it is not clear where or how much discharge takes place, or what the ultimate fate of much of the CLA groundwater flowing through these basins is. This may encompass cross-flow to other aquifer units and/or diffuse evapotranspiration (including by GDEs that are not well documented). As such, the consequences of pumping at rates that deplete storage, and thus reduce groundwater discharge significantly, are not well understood. Stygofauna communities identified in the CLA by Rees et al., (2020) would be at high risk of losing their habitat if a significant proportion of storage was depleted in these basins, due to the low recharge rates - which would mean extensive drawdown would occur over wide areas, with limited recovery of water levels for a long period of time. Irreversible aquifer compaction, development of surface collapse structures and/or reductions in groundwater quality (e.g. increasing salinity due to enhanced leakage from low-quality water bodies) also cannot be ruled out.

3. Advise on how an "estimated sustainable yield" should be calculated for the purposes of water allocation plans in the Beetaloo Basin to safeguard against risks to dependencies (particularly Mataranka springs and Roper River).

In line with the discussion above, current groundwater management rules in the Northern Territory should be urgently updated, so that they ensure protection of the groundwater dependent values sustained by the CLA and any other groundwater resources. Updated groundwater management rules set out in the WAPs currently being developed should firstly outline clearly the key groundwater dependent values of each region, and/or the connectivity between extraction within the relevant plan area, and other regions of the CLA where the groundwater sustains key values. Secondly, the WAPs should document how adverse impacts to these values are to be monitored and prevented, informed by rigorous baseline studies and modelling - e.g., to determine minimum groundwater levels and flow rates (as well as quality) required to sustain river baseflow, springs, stygofauna, groundwater dependent vegetation, and access to groundwater and surface water for other purposes/users. This must include thorough scientific work to address knowledge gaps regarding the ecological, cultural and water use values sustained by CLA groundwater in the Georgina and Wiso Basins, where data and knowledge are to date relatively lacking. The following is a brief review of groundwater management approaches adopted elsewhere in Australia to provide context in support of the proposed updated management regime outlined below ('A path to sustainable groundwater management in the CLA'):

Approaches to sustainable groundwater management

Approaches to groundwater management in Australia and internationally vary considerably (Cook et al., 2023); however, many jurisdictions set regional and/or local caps on extraction volumes from a given aquifer, terming this a 'sustainable yield' or some variation (e.g., 'Permissible consumptive volume' in Victoria). Approximately half of the groundwater management areas declared in Australia adopt a limit on volumetric extraction rates of this kind (Barnett et al., 2020). In many of these districts, water trading is also permitted between users within the groundwater management area, provided total extraction rates stay below the overall cap for the aquifer. In some regions (such as the Lower Burdekin in Queensland), extraction rate limits can change depending on other variables – such as the salinity of groundwater, to mitigate the risk of saline intrusion (Thomann et al., 2020). Water trading may also be used as a mechanism to encourage water use away from areas where it may risk causing adverse consequences, into areas considered low-risk (e.g. Southern Rural Water, 2010).

The determination of extraction cap limits within different groundwater management areas relies on different approaches, depending on jurisdiction (Cook et al., 2023). Many states (such as NSW, Victoria and WA) have commissioned state-wide reviews into appropriate sustainable yields for different aquifer systems and have used these as the basis for setting or adjusting extraction rate limits. In some areas where groundwater extraction is already intensive, and there are significant values at stake (such as groundwater flows to surface water), numerical modelling is used to determine allocation rates, such as for the Namoi alluvial aquifer, one of the most intensively utilized groundwater resources in Australia (NSW Government, 2019). The region with the greatest number of groundwater management areas (and greatest cumulative extraction volumes) in Australia is the Murray Darling Basin. According to the methodology adopted by the Murray Darling Basin Authority in its 2012 Basin Plan, caps on rates of groundwater extraction - termed Sustainable Diversion Limits (SDLs) within sub-regions of the basin, are set based on an analysis of the rate of diffuse groundwater recharge, and analysis of the risks of extracting different fractions of this recharge on aquifer integrity, baseflow to streams, groundwater quality, and GDEs. In areas where these risks are deemed high, sustainable yields/SDLs are set at 5% of recharge or

less – in other ‘low risk’ areas, the fraction may be as high as 70%, but this is rare (Walker et al., 2020).

Alternative or complementary groundwater management rules (in addition to volumetric extraction rate caps) include the use of trigger levels, whereby the management objective is to maintain groundwater levels in an aquifer above a threshold required to protect certain values. This is usually designed to achieve either protection of environmental assets (such as groundwater discharge to rivers or springs) or prevent bore interference and loss of access to the resource. A combination of a cap on yearly extraction volumes within a district, plus trigger-based rules which result in a cut to the volumetric extraction cap if levels fall below a certain value, are used in some groundwater management areas to address concerns over both access to the resource, and flow of groundwater to the surface or other aquifers (e.g., Katunga WSPA in Victoria, see Goulburn Murray Water, 2017). There are also examples where conjunctive groundwater-surface water management rules are implemented – e.g., limits on groundwater pumping depending on the distance to a stream (i.e., buffer zones around the stream), and pumping limits that change seasonally to correspond with periods of higher/lower streamflow and thus limit stream depletion (Goulburn Murray Water, 2012). These approaches hold significant potential, when combined with a sustainable yield cap, to balance a desire for groundwater development to support agriculture or other industries, the needs to ensure ongoing access for domestic and stock users, and the health of groundwater dependent surface waters and GDEs.

The Northern Territory’s Arid Zone contingent allocation rule appears to be one of the only cases in Australia where a storage-based approach is applied to the determination of a ‘sustainable’ yield. This may reflect the knowledge that Alice Springs’ town water supply requires far greater rates of extraction than the natural recharge rate (DLRM, 2016), to supply a fundamental need for the township. If this is the rationale for the Arid Zone contingent rules remaining in place in the NT, then it would be straightforward to ratify the Alice Springs Water Control District as exempt from management rules that prevent over-extraction, and allow for continued pumping at greater than the recharge rate in this zone (ideally on a temporary basis while alternative sources are developed). Allowing extraction that depletes aquifer storage to supply adequate drinking water to a major town (a fundamental human need) is very different to allowing such extraction in new areas to supply water for private industry.

The use of the Arid Zone contingent rules or other method that uses a fraction of the total storage volume of the aquifer will not provide the necessary protection required to sustain the ecological and cultural values supported by groundwater in the CLA (as discussed in Section 2) and would lead to damage or (potentially) complete loss of GDEs and access to the resource for existing water users. In the case of the Georgina-Wiso Water Allocation Plan, the current proposal to allow yearly extraction of 40% of the (poorly constrained) long-term average recharge would effectively allow ongoing depletion of aquifer storage in this system, due to the highly episodic nature of recharge. The associated impacts of such depletion (which could be expected to continue for years or decades between significant recharge events) have not been addressed in the draft WAP.

Due to the relatively sparse population and infrastructure in the Georgina and Wiso basins, it is probable that groundwater extraction for irrigation, oil and gas development would be initially concentrated in particular geographic areas, e.g., where road infrastructure allows easy access. Hence, the extraction of groundwater under the ESY proposed in the draft plan would be unlikely to be evenly distributed throughout the WAP area. Modelling the extent of drawdown and the localized impacts of this (such as loss of stygofauna, subsidence and migration of saline groundwater) in scenarios where the ESY rates are concentrated in particular zones should form part of the analysis of the suitability of the ESY, considering this.

A path to sustainable groundwater management in the CLA

The most effective way to manage groundwater to protect the environmental and cultural values sustained by the CLA in the Daly, Georgina and Wiso basins would be a combination of both volume and trigger-level based rules, that encompass:

1. **Volumetric extraction rate limits** which in the long-term ensure:
   a) groundwater flows do not decline in such a way as to compromise the health of the groundwater dependent ecosystems sustained by these flows. This requires careful analysis of recharge and discharge flux rates, environmental dependencies on these flows, and the extent of 'capture' by pumping at different rates in the different CLA basins. The connectivity of the CLA flows to rivers (e.g. the Roper, Flora and Daly) and throughflow across sub-regions and basin boundaries (e.g. the dependence of flows within the Daly basin on inflow from the Georgina and Wiso basins), must be properly considered in this process. Sustainable yields set within a given management area must be shown to be sustainable cumulatively, in conjunction with those set in adjacent WAP areas.

   b) the renewability of groundwater resources, preventing ongoing storage depletion and/or detrimental capture of surface flows, e.g., by not exceeding any significant fraction of the recharge/discharge, in recognition of the high value of groundwater to the maintenance of the Roper River, Mataranka springs and other GDEs and communities.

2. **Clearly defined and well monitored water level triggers/thresholds**, which are determined to be the groundwater elevations required to sustain environmental and cultural values of key groundwater dependent sites and ecosystems. When threshold levels are approached or crossed, reductions in groundwater pumping would be triggered, in line with level-based management approaches adopted in other parts of Australia and internationally. Trigger levels must be set at an appropriate distance from the environmental assets seeking to be protected, to account for time-lags between changes in extraction rates, hydraulic gradients and flow rates in an aquifer. Buffer zones around high value GDEs should be enacted, in which groundwater extraction is restricted and/or not permitted, to minimize the risk of short-term damage that may result from rapid drawdown and/or capture of fluxes near the point of extraction.

A mechanism to adjust the volumetric rates and trigger levels to consider climatic conditions - e.g., periods of unusually low rainfall and high evapotranspiration, following which groundwater levels and fluxes are likely to deplete more rapidly in response to extraction, should also be included. This would align with the intent of the National Water Initiative (Walker et al., 2021).

The setting of appropriate trigger levels requires in-depth eco-hydrological studies to determine the threshold groundwater levels required to maintain flows to springs and rivers, the viability of stygofauna, and access to groundwater by vegetation. Following these studies, a series of trigger levels at various distances from each GDE should be set, with clearly defined monitoring locations. If these threshold levels are approached or crossed, groundwater extractions should (according to management rules) be reduced or ceased until they stabilise or recover above the threshold. This approach should be conducted in conjunction with numerical or analytical modelling, to ensure the trigger points can provide sufficient early warning (incorporating time-lags in response to changes in extraction rates), to protect the GDE (Currell, 2016; Noorduijn et al., 2019). This combination of flux and trigger-based management values would align with current best practice for sustainable groundwater management (Thomann et al., 2020).

Proper determination of the appropriate extraction rate limits and triggers to satisfy both 1) and 2) in each WAP (and cumulatively), will require further scientific work, including both field studies and modelling, to establish and monitor:

- Recharge rates throughout the CLA and its sub-basins and zones (particularly where these are not already well constrained), including recharge from streams, lakes and karst structures
- Discharge fluxes from the aquifer to the surface, and between different basins (i.e., throughflow, which remains poorly constrained, and vertical inter-aquifer leakage)
- The environmental dependencies on water levels and discharge fluxes from the CLA (i.e., ecohydrological studies)
- How extraction at different rates, and in different regions, changes both groundwater levels and discharge fluxes, including the timescales and spatial distribution of these responses
- Different GDEs' tolerance for changes in both groundwater levels at different locations, and groundwater discharge fluxes (flow rates)

The combination of strategies and rules described above is the only clear path to sustainable aquifer management in the Cambrian Limestone Aquifer and Beetaloo sub-region.

Setting a sustainable yield for the Tindall Limestone aquifer

Under the current water allocation planning framework rules, the Tindall Limestone aquifer (which is critical for maintenance of the Mataranka Springs, Roper and Flora rivers and other GDEs) falls in the Top End zone, and as such, a default position for setting a volumetric cap on extractions would be 20% of the Basin's estimated recharge (i.e., approximately 66 GL/year). Bruwer and Tickell, 2015 conducted modelling of groundwater extraction from Daly Waters to Mataranka under this scenario, involving an additional 40 GL/year of extraction surrounding Larrimah, plus the existing 26 GL/yr of licensed extractions in the CLA to the north (predominantly near Mataranka). This modelling indicated that in the long term, the additional pumping would result in an approximately 20% reduction in flows in the Roper River, following an equilibration period of approximately 300 years. The environmental and cultural significance of these flow reductions was not assessed, and it has not been determined whether 20% reduction in baseflows, particularly during particularly dry years, could have significant detrimental impacts on ecological and/or cultural values of the Roper River. Analysis by Jolly et al., (2004) indicated that in years of below average rainfall, such reductions may jeopardise GDEs and cause significant saltwater ingress up the Roper River.

A previous draft of the Mataranka Tindall WAP from 2012 proposed the use of 15% of recharge as an extraction cap, which (if applied over the whole Tindall Limestone aquifer) would equate to approximately 50 GL/year. Determining the effect on baseflows to the Roper River, Mataranka Springs and other GDEs, and assessing the associated risk from ecological, cultural and water resources viewpoints, would be important to determine if this is an appropriate extraction cap. Should the dependence of ecological and cultural values of these sites during dry periods be put at risk, lower fractions of recharge should be considered.

One way to help determine appropriate sustainable yields is through numerical modelling, noting that Knapton (2020) completed major FEFLOW-MIKE11 coupled groundwater/surface modelling of the CLA, designed to aid current and future assessment of groundwater abstraction scenarios. The impetus for the modelling was the recommendations of the Pepper Inquiry, including that there was a need for "development of a regional groundwater model to assess the effects of proposed water extraction of the onshore shale gas industry on the dynamics and yield of the regional aquifer system." A key aspect of the modelling was also to enable water planning to conduct predictive uncertainty analysis to help determine the level of confidence with which the impacts of extraction at given rates could be made.

The draft Georgina Wiso WAP appears to have involved further modelling, based on the work of Knapton (2020), to inform the recharge rate used to calculate the proposed ESY. The precise changes to the previous model and/or updates in modelling assumptions are not clear from the plan's documentation.

It should be noted that numerical modelling is only as robust as the field data used to develop its conceptual elements and parameters. Most of the key knowledge gaps discussed above and below in this report still require additional field studies, before modelling can be considered reliable to predict impacts within acceptable ranges of uncertainty. This is important due to current limitations acknowledged in the modelling – e.g., it is based on conventional porous media flow, whereas it is known that flow in the CLA is predominantly through secondary porosity, and water balance/budget estimates and inter-aquifer connectivity remain relatively poorly constrained through most of the region (Knapton, 2020).

Sustainable management regimes for other management zones in the CLA

Key considerations in the setting of extraction caps in the southern CLA basins – i.e., Georgina Basin and Wiso Basin, are:

a) Current uncertainty in the recharge rates for these basins (the rates are not well constrained and there is evidence recharge may occur by both diffuse and preferential mechanisms – see Deslandes et al., 2019; de Caritat et al., 2019).
b) Lack of understanding of the major groundwater discharge mechanism(s) in these basins (e.g. spring discharge, diffuse ET losses, inter-aquifer leakage). These discharges are likely to be significantly changed by a large increase in groundwater extraction rates - as the capture of discharge is often the dominant long-term consequence of groundwater extraction. The environmental, social, cultural and economic consequences of increases in extraction can't be determined until the pre-existing baseline, and changes to this are properly understood.
c) Uncertainty over the extent of throughflow from the two basins into the Daly Basin (Tindall Limestone) and likely flow-on effects to GDEs in the Tindall Limestone if these throughflow volumes decline and/or reverse over time.
d) The potential for irreversible loss of storage and/or reductions in aquifer transmissivity, causing subsidence and aquifer compaction, if groundwater levels substantially decline.
e) The extent of damage to stygofauna communities (e.g., Oberprier et al., 2021) that may occur under different levels of drawdown in these basins.
f) The likelihood of migration of saline groundwater into areas of fresher groundwater under the influence of intensive groundwater extraction in particular areas.

Mechanisms to ensure the following are also critical to ensure rigor and trust in groundwater management processes:

- The scientific basis for the setting of sustainable yields, trigger levels and any other groundwater management rules must be clear and transparent, and any supporting datasets and modelling made publicly available.
- Ample opportunities for input to the design of the management rules from the public and key stakeholder groups, e.g., Traditional Owners and conservation groups who can speak to the value of the ecosystems and waters sustained by the aquifer(s) and what is at stake if these are lost.
- Participation of independent scientific and water policy experts in the process of reviewing and developing science-based management rules to protect values identified as being in need of protection.

4. Identify key gaps, misinterpretations and inconsistencies in the existing data, science, interpretation, analysis, modelling and conclusions Identify the critical science requirements for robust water allocation.

As discussed above, the setting of new/updated groundwater management rules that can ensure protection of the values sustained by the CLA requires a significant amount of scientific data and analysis, to address current knowledge gaps. In response to the Pepper Inquiry's recommendations, a program of scientific work – the Strategic Regional Environment and Baseline Assessment (SREBA), has been underway since 2018, attempting to address knowledge gaps raised in the inquiry and those highlighted in this report (Table 5):

Topic	Anthony Lagoon Formation	Gum Ridge Formation	Basalt	Neoproterozoic sandstones
Water level network	MODERATE	GOOD	POOR	POOR
Water quality network	MODERATE	GOOD	POOR	POOR
Aquifer connectivity	POOR	POOR	POOR	POOR
Aquifer extent and thickness	MODERATE	GOOD	MODERATE	POOR
Aquifer parameters	MODERATE	MODERATE	MODERATE	POOR
Recharge and discharge processes	POOR	GOOD	POOR	POOR

Table 5: Hydrogeological knowledge gaps identified in the SREBA review, as of 2021 (Northern Territory Government, 2021).

Key gaps requiring additional data and knowledge, which (according to the above) are currently being addressed through ongoing studies include:

- More detailed quantification of groundwater recharge and its mechanisms/processes in the three CLA sub-basins
- Better understanding of inter-aquifer connectivity and likely fluxes between different layers and units within and across the three CLA Basins.
- Further data characterising aquifer and aquitard hydraulic properties
- A greatly improved monitoring network for both water quality and quantity, encompassing nested sites allowing for analysis of inter-aquifer connectivity.

Scientific work is also required to address further issues identified in this review, in order to implement a robust groundwater management regime. It is unclear to what extent the SREBA or other programs are going to address these:

- Eco-hydrological studies to determine threshold groundwater levels and flow gradients required to sustain discharge flows to the Roper River, Mataranka Springs, Flora River springs and other GDEs – such as vegetation sustained by permanent access to shallow groundwater. Such studies are required both to inform details of updated groundwater management rules, and to establish appropriate monitoring programs that can document changes to GDEs and allow for informed actions to protect these.
- More data and information about the springs of the Flora River and those on the western margin of the Wiso Basin (Top Springs), e.g., documenting rates of discharge, source aquifer(s) and vulnerability to depletion due to up-gradient groundwater extraction.
- A more in-depth analysis of the major current mechanism(s) of groundwater discharge from the Georgina and Wiso basins (encompassing the above, as well as diffuse inter-aquifer leakage, ET by vegetation communities and un-documented springs and stream baseflow), to determine what the likely long-term impact of

increased groundwater extraction is within these relatively under-characterised aquifer systems.

- Determining hydrological and water quality requirements of stygofauna, and analysis of the extent to which these subterranean ecosystems may be impacted by groundwater extraction at different rates in different regions
- The likely time scales of the responses of aquifers to extractions at different rates and locations, and how the response evolves through time (e.g. proportions of storage depletion vs stream/spring depletion caused by pumping, and how this changes through time)
- The importance of episodic recharge, particularly in the southern CLA basins, and the likely recurrence interval for major recharge events, which provide the majority of water to the aquifers over the long-term.
- The likely impact of climate change on groundwater recharge rates and mechanisms, groundwater discharge (e.g., via evapotranspiration) and flow-on effects to GDEs.

At present, existing knowledge gaps prevent a comprehensive analysis of the likely impacts of groundwater extraction from the CLA at different rates and in different areas on the key environmental and cultural values the aquifer sustains, or the adoption of appropriate caps on groundwater extraction rates and trigger levels to protect GDEs and river baseflows. Finalising the CLA / Beetaloo WAPs, and making future groundwater licensing decisions in a manner that is scientifically robust, will require these gaps to be (urgently) addressed.

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Appendix A: List of questions/topics to address in this report (Environment Centre NT)

1. **Using publicly available scientific reports (which have been collated by the Environment Centre NT and will be provided to you) develop a conceptual understanding of the Cambrian Limestone aquifer, including:**

   a. The hydrogeological structure of the Cambrian Limestone Aquifer (including the configuration, geometry and hydraulic properties);

   b. The water balance components and their dynamics for key groundwater systems, including inputs (eg recharge from rainfall events or leakage from rivers, groundwater inflows from other aquifers), through-flow (eg definition of groundwater flow paths, watertable and groundwater level contours) and outputs (eg spring discharge, baseflow to rivers, evapotranspirative use by vegetation, outflow to other aquifers, groundwater pumping); and

   c. The dependencies on the key groundwater systems from the hydrological perspective (eg groundwater discharge maintaining river flows), environmental perspective (ie ecosystems reliant on groundwater such as vegetation accessing shallow groundwater, aquatic ecosystems in springs and groundwater-fed rivers) and cultural perspective.

2. **Advise on the risks to dependencies (particularly the Mataranka springs complex and the Roper River) of utilising:**

   a. the Arid Zone contingent allocation rules in the NT Water Allocation Planning Framework as the basis for establishing an "estimated sustainable yield" in the Beetaloo Basin (with specific reference to the proposed Mataranka Tindall Water Allocation Plan and the Georgina Basin Water Allocation Plan);

   b. an "estimated sustainable yield" based on a significant proportion of storage of the Cambrian Limestone Aquifer or its constitutive aquifers (with specific reference to the asserted estimated sustainable yield of 40% of the storage of the Gum Ridge Formation identified in the APPEA fact sheet).

3. **Advise on how an "estimated sustainable yield" should be calculated for the purposes of water allocation plans in the Beetaloo Basin** to safeguard against risks to dependencies (particularly the Mataranka springs complex and the Roper River).

4. **Identify key gaps, misinterpretations and inconsistencies in the existing data, science, interpretation, analysis, modelling and conclusions**. Identify and prioritise the key sources of uncertainty relating to the hydrogeological architecture, water balance, groundwater dependencies and risks from existing and potential resource development, and the science needs to reduce these uncertainties. Identify the critical science requirements for robust water allocation.

SREBA Expert Review – Groundwater

[redacted]

Introduction & Summary findings

The Beetaloo Strategic Regional Environmental and Baseline Assessment (SREBA) is a series of studies and datasets commissioned by the NT Government, in response to the findings and recommendations of the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (Pepper Inquiry). This document contains a review of the SREBA studies relating to groundwater, commissioned by the Environment Centre, NT. The scope of the review encompasses analysis of the extent to which the SREBA studies and datasets released in 2023 have addressed knowledge gaps regarding groundwater, that were identified as needing to be addressed, via recommendations of the Inquiry (outlined in Chapter 7 of the final report, and the SREBA Framework), prior to the commencement of an onshore gas industry in the region.

This review represents the independent expert opinions of the authors. While it is not related to any legal proceedings, it has been prepared in accordance with the Northern Territory Expert Witness Code of Conduct (2015) section 2 which states that: "An expert witness is not an advocate for a party and has a paramount duty, overriding any duty to the party to the proceedings or other person retaining the expert witness, to assist the Court impartially on matters relevant to the area of expertise of the witness."

This review identified the following areas where SREBA studies have largely addressed key objectives/knowledge gaps identified in the Pepper Inquiry:

- Monitoring data throughout most of the Cambrian Limestone Aquifer (CLA) system, encompassing the Tindall, Gum Ridge and Montijenni Limestone units, provides suitable baseline characterisation of groundwater levels over a range of climatic states. It should be noted that monitoring bore coverage (and thus baseline data) remains limited in certain key areas though. The SREBA area is of considerable size, warranting an extensive bore network to collect such data.

- Connectivity between the lower and upper CLA hydrogeological units - e.g., Anthony Lagoon and Gum Ridge Formations is relatively well-understood through analysis of groundwater level, hydrochemistry data and hydraulic testing – again noting that the density of nested monitoring bores is limited in some areas.

- Major groundwater flow-paths in the CLA, and discharge areas for these - e.g., Mataranka Springs, Roper River and Flora River have been further characterised (although these were known prior to the SREBA). Source aquifer(s) and flow-paths to the springs associated with these flow paths are less well-understood.

- Long-term average diffuse groundwater recharge rates for the CLA are relatively well-constrained, through analysis of multiple independent recharge estimation

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[2] Australian Rivers Institute, Griffith University

techniques; although coverage of recharge data and the degree of confidence in recharge rate estimates is better in certain areas than others.

This review identified the following areas where SREBA studies have not addressed key objectives/knowledge gasps identified in the Pepper Inquiry:

- There is a lack of groundwater monitoring bores - particularly nested sites, to characterise the groundwater level behaviour and flow gradients in the aquifer units below the CLA - e.g., Neoproterozoic sandstones, Kalkarindji Suite Volcanics, and Mesoproterozoic Beetaloo sub-basin formations (the latter of which are potential targets for shale gas development).

- There are certain areas where CLA groundwater levels and flow paths remain relatively poorly documented, such as at the edges of the Wiso and Georgina Basins, and above the Daly Waters high.

- There is limited understanding of the flow paths and water sources to key groundwater discharge features in the SREBA area, e.g., Top Springs and Hot Springs Valley, and the rates and mechanisms of groundwater discharge to these and other discharge features – e.g., Flora River springs.

- There remain substantial knowledge gaps regarding the geological architecture of the SREBA area, from the deep Beetaloo Basin rocks through to the shallow Cambrian and Cretaceous aquifers. Understanding of inter-aquifer (and inter-basin) connectivity, particularly between rocks that may be targeted for shale gas development and the overlying shallow aquifers is localised to a handful of bore sites monitoring different depths in the geological sequence. Many additional nested monitoring bore sites and other scientific studies adopting multiple lines of evidence (e.g., geophysics, geology, water and gas isotopes, and water level gradients) are required to establish the level of inter-aquifer connectivity across different areas of the SREBA. Current understanding of connectivity between a) Neoproterozoic and overlying Cambrian aquifers, and b) Beetaloo sub-basin rocks and shallower aquifers, remains very limited. This results in ongoing uncertainty regarding likely impacts of deep shale gas extraction on shallow aquifers.

- Preliminary data (mostly from environmental tracer sampling) indicate that there are areas where there is likely to be substantial connectivity between deep aquifer units and the shallow CLA (and/or springs), where groundwater discharge from deep units occurs. Such areas - where connectivity between the Beetaloo basin rocks and overlying Cambrian aquifer(s) may be considerable (e.g., Daly Waters High, and OT Downs sub-basin), do not appear to have been extensively drilled with monitoring bores or characterised with geophysics and hydraulic testing, to establish the level of vertical connectivity. The extent of these areas, and the potential impacts of increased water (or hydrocarbon) extraction from different depths in these regions (e.g., on inter-aquifer leakage and spring discharge rates) have also not been established.

- Recharge mechanisms and dynamics (e.g., variability of recharge with respect to key climatic variables and events), remain poorly understood. Localised recharge rates, and the relative importance of diffuse vs. preferential/focussed recharge, remain largely unknown in the SREBA area. While some additional analysis of recharge via preferential flow (e.g. sinkhole recharge) has been included in the reporting, SREBA studies have not generated a significant amount of new data to inform a more comprehensive quantification of recharge associated with preferential flow.

- The role of major climatic events on recharge (e.g., through rare, episodic periods of extended high rainfall), particularly in the arid parts of the SREBA, are also poorly understood. Such events are important in the consideration of water balances, and appropriate long-term sustainable extraction rates. The potential influence of climate change – e.g., increasing temperatures and evapotranspiration rates on recharge, which is also critical to water balance analyses going forward, does not appear to have been analysed.

- Reliance on numerical modelling to estimate recharge rates – a primary technique relied upon in updated regional water resources assessments in the SREBA area - must consider the high possibility of model non-uniqueness (due to uncertainty of multiple different model input parameters). This means that model calibration may not effectively constrain rates of recharge within robust and precise ranges.

- Additional analysis of remote sensing data can help to constrain recharge and its dependence on climatic variables, as well as understanding the importance of groundwater in sustaining surface water and vegetation through different climatic periods. Preliminary data analysed in this study and in the SREBA studies, indicate that both recharge rates and the permanence of surface water (connected to groundwater) vary considerably with yearly climate, undergoing periods when recharge rates are low, and vegetation becomes strongly dependent on groundwater. There remain considerable unknowns with respect to climate-groundwater-surface water interactions and resilience of these systems. These interactions must be understood to develop robust estimates of sustainable yields from the aquifer system.

- Estimation of sustainable groundwater extraction rates for the CLA would require considerable further data and analysis. This should encompass a comprehensive understanding of groundwater discharge rates and mechanisms (which sustain surface water, vegetation, and other GDEs) and potential changes to these under future climate and development scenarios. Current sustainable yield estimation appears to have been largely conducted using water balance estimates derived from groundwater numerical modelling; however, the full methodology and assumptions are not available to be reviewed in detail, precluding a full analysis of the appropriateness, and level of uncertainty associated with these.

- Data gaps relating to the hydrogeological parameters, water balance and inter-aquifer connectivity for the aquifer units below the CLA (e.g. Neoproterozoic sandstones) mean that sustainable extraction rates from these units cannot be determined, and require substantial additional information.

- There remains a lack of groundwater quality data for certain aquifers and hydrostratigraphic units – particularly those below the Cambrian Limestone Aquifer. Very few analyses have been conducted of groundwater quality/hydrochemistry from the Bukalara Sandstone, Antrim Plateau Volcanics, or deeper units within the Beetaloo sub-basin (shale gas exploration targets).

- There has been a lack of detailed characterisation of the major hydrogeochemical processes that control groundwater quality in different aquifers / units within the SREBA area (as opposed to basic characterisation of hydrochemical parameters, which is relatively extensive for the CLA).

- There is a lack of vertical profiling of groundwater quality/geochemistry with depth, e.g., from the CLA down into the underlying Proterozoic units, encompassing horizontal transects that capture variability in these vertical profiles (an explicit knowledge gap highlighted in the SREBA Framework objectives). This prevents a clear understanding of how water quality and geochemistry vary with respect to geological structure and layering, the key processes that control water quality, and future risks associated with water and/or hydrocarbon extraction (such as inter-aquifer mixing, water-rock interactions and solute migration).

- Limited data exist for characterising different types and sources of methane occurring throughout the aquifer system – e.g., extensive datasets for methane concentrations and isotopic composition in different aquifers. Methane is likely to be an important potential contaminant associated with shale gas activity, meaning this is an important knowledge gap. Coverage of data for groundwater microbiological analyses and trace/minor water quality components, that are also important potential indicators of water quality impacts associated with unconventional gas development, are also limited.

- Characterisation of key isotopic end-member compositions of different waters within the SREBA aquifer system, to enable future analysis of potential causes of any changes in groundwater quality (e.g., due to inter-aquifer mixing induced by greater rates of groundwater extraction, fugitive gas migration in response to gas development, or leakages/surface spills of fracking fluids) is generally lacking.

Extent to which data presented in SREBA address objectives/knowledge gaps identified in the Fracking Inquiry

Here we review the major objectives of the SREBA framework relating to groundwater, and analyse the extent to which the SREBA studies and datasets have addressed these. The review examines each of the objectives outlined in section 3 of the SREBA Framework (2020). For relevant background on the major aquifers within and overlying the Beetaloo sub-basin (the target for unconventional gas extraction), readers are referred to the SREBA regional report and references therein (DEPWS, 2022a).

Objective 1: Establish a baseline for groundwater (and surface water[3]) hydrology over a period that is representative of the climatic cycles of the area and of the geological and geomorphological variation across the region

Groundwater monitoring data have been compiled and are presented in various SREBA reports, including Amery and Tickell (2022), ELA (2022) and the SREBA Regional Report (DEPWS, 2022a). This review examined whether these data, and their analysis, provide comprehensive spatial and temporal coverage of groundwater levels, groundwater flow patterns, recharge and discharge (considered to be the major components of 'groundwater hydrology'), from the major aquifer units within the SREBA area.

Table 1 of the 2021 SREBA Water Quality and Quantity studies (Project 1) reviewed and summarised gaps in the information considered to be "essential to establish a pre-development baseline assessment for each of the main Cambrian and Neoproterozoic aquifers" (Northern Territory Government, 2021). This report identified that groundwater monitoring coverage was variable throughout the different regions and aquifers of the SREBA, with significant gaps in data for the Anthony Lagoon Formation, Antrim Plateau Basalt (Kalkarindji Suite) and Neoproterozoic Sandstones. The 2021 review table (reproduced below) also noted that there was a 'poor' understanding of inter-aquifer connectivity across all of these units and the Gum Ridge Formation, and 'moderate' to 'poor' understanding of aquifer hydrogeological parameters in these units. Below, we thus analyse whether subsequent SREBA data collection and monitoring infrastructure have since addressed these gaps.

Topic	Anthony Lagoon Formation	Gum Ridge Formation	Basalt	Neoproterozoic sandstones
Water level network	MODERATE	GOOD	POOR	POOR
Water quality network	MODERATE	GOOD	POOR	POOR
Aquifer connectivity	POOR	POOR	POOR	POOR
Aquifer extent and thickness	MODERATE	GOOD	MODERATE	POOR
Aquifer parameters	MODERATE	MODERATE	MODERATE	POOR
Recharge and discharge processes	POOR	GOOD	POOR	POOR

Table 1: State of knowledge (as of 2021) for baseline characterisation of groundwater and aquifer characteristics (Northern Territory Government, 2021).

[3]Note that a detailed analysis of surface water is not included within the scope of the current review; the primary focus is groundwater, in line with the authors' expertise.

Groundwater level data

Amery and Tickell (2022) present analysis of groundwater level data from 165 locations across the Cambrian Limestone Aquifer (the main shallow water supply aquifer above the Beetaloo sub-Basin), which they use to create new maps of groundwater potentiometric surface (elevation) and depth to water. Further hydrogeological data, including groundwater level monitoring, are presented in Tickell (2022), which focusses on analysing connectivity between the Anthony Lagoon and Gum Ridge formations (the two major aquifers in the CLA within the Georgina Basin).

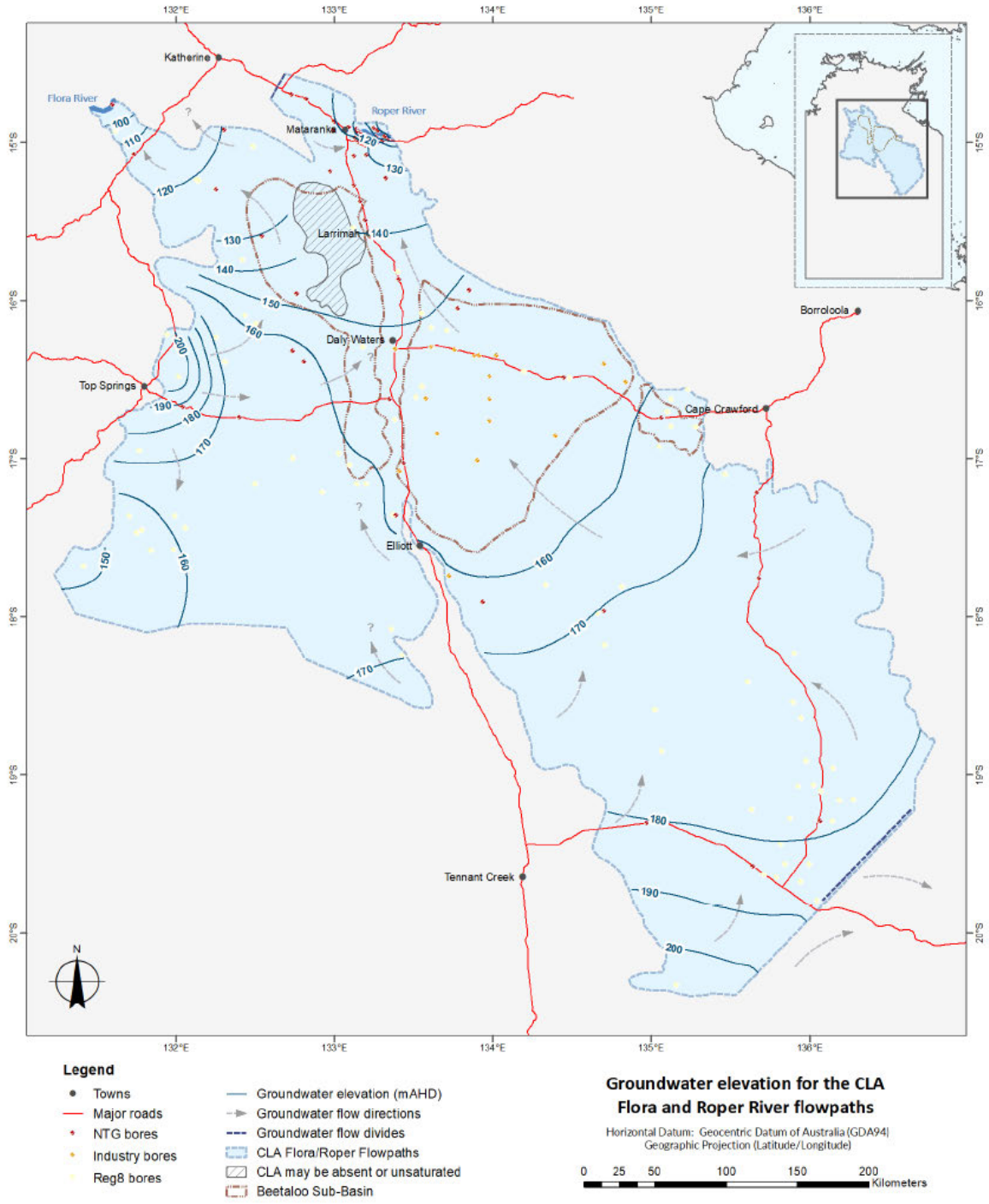

Figure 1 – New groundwater elevation map for CLA (Amery and Tickell, 2022) indicating density of groundwater level data points.

The new maps presented in Amery and Tickell (2022) provide reasonably good coverage of groundwater level measurements within the Cambrian Limestone Aquifer (CLA); however, they include regions with higher and lower density of data points (Figure 1). For example, water level data in the southern Wiso basin (near Elliot), southern Georgina basin (near Tennant Creek), and near the western edge of the SREBA area (e.g., near Top Springs) are very limited – leading to uncertainty as to the detailed groundwater flow paths in these areas (Amery and Tickell, 2022).

New bores in aquifers with previously limited water level data

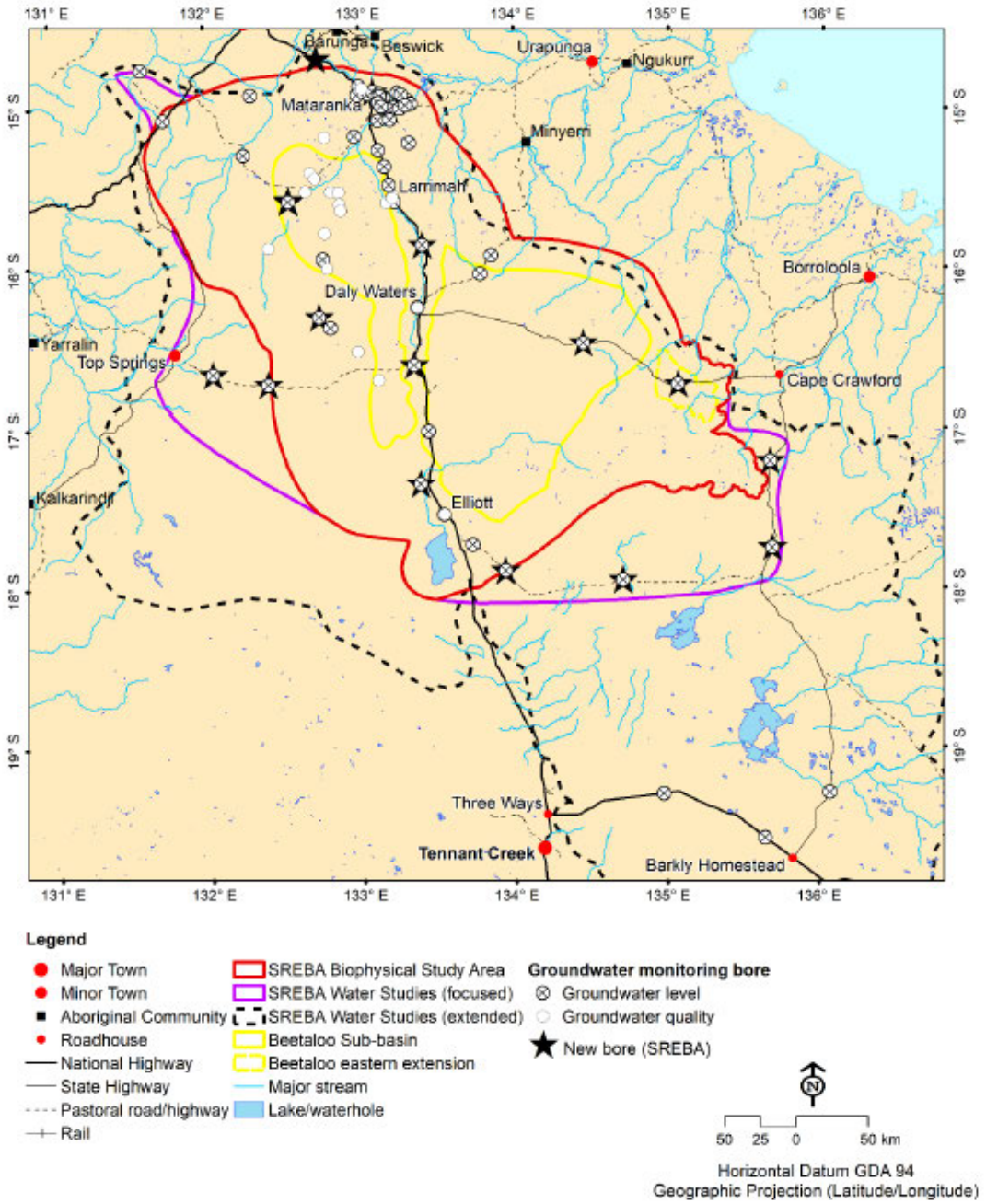

Figure 2 – New monitoring bores drilled specifically for SREBA water studies (ELA, 2022).

In order to obtain groundwater level data for geological units where existing baseline data were previously lacking (see Table 1), new groundwater monitoring bores in these units are required, and level data must be collected for a sufficient period of time to characterise temporal variability (i.e., change over time in response to climate and

other factors). The drilling of some new bores specifically for groundwater level and quality monitoring (and a small number of pumping tests) is outlined in ELA (2022), which notes that 23 new bores were drilled for the SREBA water studies. Sixteen of these bores are in CLA units, while two new bores targeted the Kalkarindji Suite/Antrim Plateau Basalt, and three in the Neoproterozoic Bukalara Sandstone (all at one locality). Above the CLA, two new bores were also constructed in the shallow Cretaceous sandstone. New bore locations are shown in Figure 2.

Assessment of the extent to which the new drilling and monitoring data have addressed the knowledge gaps outlined in in Table 1 for the major hydrogeological units is briefly summarised below:

Anthony Lagoon Formation: Groundwater monitoring coverage and baseline data for the Anthony Lagoon Formation was determined to be 'moderate' in the 2021 SREBA Project review (Table 1). Amery (2022) reports construction of three new monitoring bores in the unit, while Amery and Tickell (2022) indicate that six bores used to create the new groundwater surface maps are dedicated monitoring bores from this formation. This compares to more than 30 dedicated monitoring bores in each of the Gum Ridge Formation, Tindall Limestone and Montijenni Limestone. There are also a considerable number of bores – mostly constructed by industry for monitoring groundwater for gas exploration activities – where water level data have been utilised in the mapping, listed as 'ALF/GRF'. This is interpreted as screening both the Anthony Lagoon and Gum Ridge formations (although this has not been confirmed). Whether these bores are appropriate for baseline monitoring of water level trends over time (or whether this is feasible) depends on bore construction, the degree of connection between the two units in these areas, and the willingness of industry to provide data and/or access to the infrastructure. It is difficult to say whether there has been a significant improvement in monitoring bore and baseline water level data coverage for the Anthony Lagoon Formation until this is confirmed.

Hydrographs presented in Tickell, (2022) indicate that there are five nested pairs of bores which together monitor water levels in the Anthony Lagoon Formation and underlying Gum Ridge Formation. These nested bore pairs are located along a west-east transect within the Georgina Basin. These sites provide baseline data timeseries that are a reliable indication of groundwater levels in each unit, and to some degree, the level of connectivity between them – although as discussed below, the time period in which data have been collected is short in all but one of the pairs. Nested sites cover a relatively limited spatial area within a very large aquifer system. Further nested bores across the upper and lower CLA units - as well as those targeting the deeper aquifers – see below) are a critical requirement for fully understanding groundwater flow gradients, aquifer responses to climate, and inter-aquifer connectivity.

Antrim Plateau Volcanics (Kalkarindji Suite): Two new bores have been drilled within this lower Cambrian unit (below the CLA), both located in Elsey National Park in the Daly Basin (to the north of where Beetaloo basin rocks underlie the Cambrian and Neoproterozoic units). Monitoring bore coverage in this unit elsewhere throughout the SREBA remains limited. It is noted in the SREBA regional study that "where it (i.e., the volcanics unit) is absent, there is potential for direct connection between the deeper

Neoproterozoic or Mesoproterozoic aquifers…and the CLA." (DEWPS, 2022). Geophysical data – e.g., airborne magnetic surveys, also suggest areas where the volcanic sheet contains significant gaps, likely due to erosional processes after its deposition (Foss and Dhu, 2016). The volcanics unit is largely conceptualised as being an aquitard, although it is noted that in some places, water bores do access groundwater from the formation. Lamontagne et al., (2021) noted that groundwater discharge from this unit may be responsible for the observed isotope signatures in spring water from the Mataranka Springs complex, which indicate a deep source of water in addition to discharge from the Tindall Limestone. Monitoring bores within this unit are therefore an important requirement to understand inter-aquifer connectivity and groundwater discharge contributions - e.g., through water level monitoring and sampling for environmental tracer compositions.

Neoproterozoic Sandstones: There are a very limited number of bores in the Neoproterozoic sandstone aquifer units – e.g., Bukalara Sandstone, to address the identified gap in monitoring coverage and hydrogeological data for these rocks (Table 1). Tickell, (2022) discusses two bores in the Bukalara Sandstone which have monitored groundwater levels and quality below the Cambrian Limestone Aquifer, and which are paired with shallower CLA bores, enabling some analysis of connectivity. Short (2021) describes a drilling and pumping test program conducted during the SREBA for the Sturt Plateau. Three bores (all within close proximity) were drilled in the Bukalara Sandstone, beneath Wiso basin sediments. One was for pumping/production and two were for monitoring drawdown responses during a pumping test. This is one of the Bukalara monitoring sites mentioned in Tickell 2022; the other is at the bore Carpentaria 1 in the Georgina Basin. It is not clear whether there are any additional bores suitable for monitoring baseline groundwater levels in the Neoproterozoic rocks elsewhere in the SREBA area, despite it being noted that the Bukalara Sandstone is widespread and likely continuous throughout it. In some areas, this aquifer directly underlies the CLA, and may thus connect groundwater from deep Beetaloo sub-basin units and shallow aquifers (ELA, 2022). An additional 'Unnamed Sandstone' unit also lies between the Bukalara Sandstone (and Cox Formation, an aquitard which together with the Bukalara Sandstone forms the Kiana Group) and the overlying Cambrian rocks (DEPWS, 2022a and Tickell, 2022). Understanding groundwater level behaviour in this unit is also important to assess potential connectivity between deep and shallow aquifers. It is unclear whether any groundwater level monitoring bores were installed into this unit for the SREBA; it appears to remain another important gap in groundwater monitoring infrastructure / data coverage.

Temporal coverage of monitoring bores

A key aspect of the Pepper Inquiry recommendation(s) regarding groundwater hydrology/baseline data, is the need to characterise groundwater level and flow behaviour "over a period that is representative of the climatic cycles of the area". The temporal coverage of groundwater level monitoring data is therefore a critical consideration in assessing the adequacy of the SREBA groundwater baseline studies. Bores must have sufficient temporal coverage to be representative of both seasonal (within a year) and multi-year climatic behaviour (e.g., through drought and flood

periods). The data used to produce the new potentiometric surface and depth to water maps in the CLA (Amery and Tickell, 2022) were mostly collected from late 2018 into 2022. Data from Bureau of Meteorology (BOM) rainfall stations within the SREBA area over this period can be summarised as follows:

Daly Waters: Late 2018 to the end of 2021 includes one year with well below long-term average rainfall (2019), one year with well above average rainfall (2020) and one year that is close to the long-term mean (2021). Each of these years had pronounced dry and wet seasons.

Katherine: The period includes two years with rainfall below the long-term mean (2019 and 2020) and one year (2021) slightly above the long-term mean of 967.2mm.

Elliot: The period includes two below average rainfall years (including the lowest on record – 2019) and one year above the long-term mean (2020).

For these localities, which broadly cover the major climatic zones across the SREBA area, BOM rainfall data include a range of climatic conditions, broadly representative of wet and dry climatic states (although the northern area lacks a significantly above average rainfall year). Where groundwater level data have been continuously collected throughout this period, in a range of bores, this would serve as a reasonable baseline. It should be noted that there are times when rainfall during the wet season can be extremely high, e.g., associated with major cyclone systems (such as 1974) and that groundwater level behaviour during such periods is not well represented in the more recent baseline monitoring. Such periods are likely of great importance for groundwater recharge in the arid parts of the SREBA area; currently an understanding of associated recharge rates and processes is limited by lack of groundwater data from such periods (see Currell and Ndehedehe, 2022).

Hydrographs from CLA aquifer units within the SREBA area are presented in Appendix B of Amery and Tickell (2022). Many of these cover the baseline period noted above (late 2018 to early 2022), and some extend back considerably further in time (>15 years). However, there are other hydrographs that only commenced monitoring in 2020, meaning there are limited data representative of dry climatic conditions – the last below average rainfall year being 2019. The coverage of groundwater monitoring with time-series data representative of the region's variable climate is high for some areas – e.g., Mataranka and along the Barkly, Buchanan, and Carpentaria highways; however, coverage is limited in other, more remote areas of the SREBA. Most hydrographs contain water level data recorded using continuous loggers (which captures both short and long-term groundwater level responses); however, this only commenced recently (e.g., mid-2020) in many bores. In other bores, there are only a small number of manual water level readings, which give limited indication of responses to climate (e.g., RN038810, RN038810 at Larrimah, RN018206, RN018927 on the Barkly Highway, RN009304 at Elliot):

Of the nested upper/lower CLA paired monitoring bore sites mentioned above, which record water level timeseries in the Gum Ridge and Anthony Lagoon Formations (using data loggers), four have data collected from mid-2020 through to mid-2021 (a limited

snapshot with respect to climate variability), while one pair has data extending from late 2014 to 2022, which covers a wide range of seasons and climatic states.

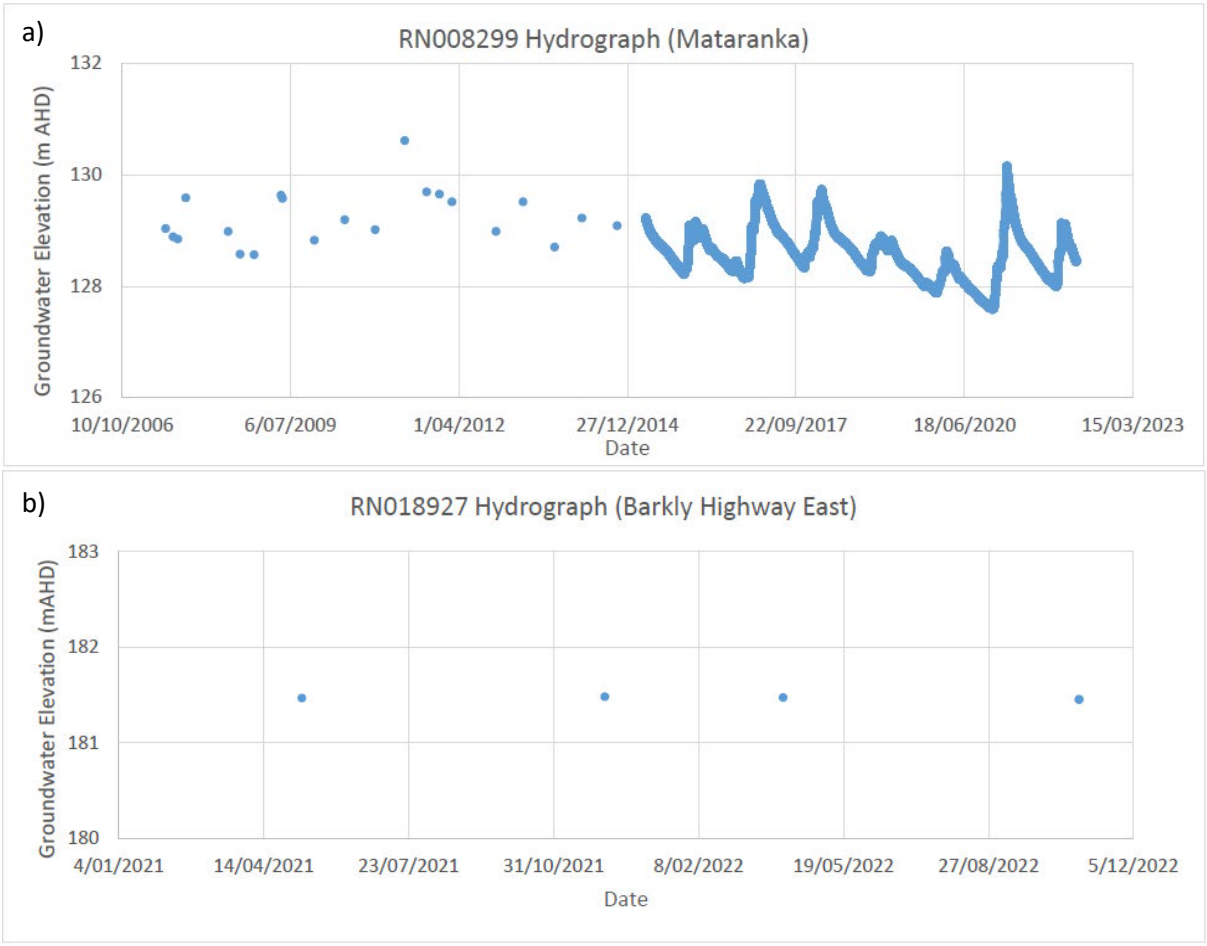

Figure 3 – Examples of monitoring bore hydrographs compiled by Amery and Tickell, 2022; a) Continuous time-series monitored with data logger (since 2015); b) small number of manual measurements, giving little indication of variability over time.

As mentioned above, there are few monitoring bores collecting data for more data-poor aquifers in the SREBA area (identified during the 2021 SREBA Project review - Table 1), i.e., the Antrim Plateau Volcanics and Neoproterozoic sandstone aquifers. Baseline data coverage in these units would therefore not meet the first objective of the SREBA water studies (SREBA Framework, 2020). A further issue is that there do not appear to be monitoring data collected from within the Mesoproterozoic Roper Group sediments – which are the rocks targeted by the gas industry - aside from some previously published data in Fulton and Knapton, (2015). This is important, as assessment of connectivity between target units for hydraulic fracturing and the overlying aquifers, requires analysis of vertical hydraulic gradients between these formations.

Table 3 summarises the status of baseline groundwater level data for the various regions and aquifers of the SREBA area:

Unit /Aquifer name	Monitoring bore spatial coverage	Temporal coverage (period monitored)	Comments

Tindall Limestone (CLA)	Generally good (although coverage appears to be relatively sparse between Daly Waters and Larrimah)	Good; some bores monitored > 10 years	Water level variation and flow paths are relatively well-characterised; this is an extensively utilised aquifer in the region surrounding Mataranka and Katherine. Coverage further south (e.g. near Larrimah) less extensive.
Gum Ridge Formation (CLA)	Good (though lacking near edges of Georgina Basin)	Most new monitoring bores recording data from late 2018 onwards; some longer records also available (>10 years data)	Flow patterns and baseline data at the western Georgina basin boundary (Daly Waters) and southern basin (north of Tennant Creek) poorly understood, due to lack of monitoring bores. Coverage is better through central areas of the basin, including above Beetaloo sub-basin.
Anthony Lagoon Formation (CLA)	Moderate	New bores mostly installed in 2020-21; time-series data limited	Additional bores within the ALF/GRF have been installed, mostly by industry. Number of dedicated monitoring bores (as opposed to those screening both CLA units) is unclear. Temporal coverage in most bores relatively limited (compared to other CLA units).
Montijenni Limestone (CLA)	Good (although limited in western Wiso Basin)	Appears to be good in NT government monitoring bores; although number of these bores limited in some areas, e.g., edges of Wiso basin	Connectivity with groundwater flowpath(s) in the Georgina Basin (across eastern Wiso Basin boundary) not well understood.
Kalkarindji suite basalt (Antrim Plateau Volcanics):	Poor	Very limited	Monitoring bores are generally lacking; two additional bores constructed for SREBA.

Below CLA / above Beetaloo sub-basin.			
Un-named Sandstone unit: Below CLA / above Beetaloo basin	Poor	Very limited	Monitoring bores (completely?) lacking
Bukalara Sandstone (Kiana Group) Below Kalkarindji suite / above Beetaloo basin	Poor	Very limited	Monitoring bores generally lacking. Tickell (2022) notes two localities with monitoring bores in the unit and overlying CLA which enable assessment of connectivity. Short (2021) describes drilling a site with three bores for pumping test analysis.
Roper Group (Beetaloo Basin, target for shale gas)	Poor	Very limited	Monitoring bores lacking – unclear if there are plans to address this gap. While there are no water supply aquifers in these rocks, it is important to understand water levels and quality to enable future impact assessment in overlying aquifers.

Table 3: Summary of groundwater monitoring bore coverage for different units within the SREBA.

Groundwater flow paths and discharge to surface water

Three major flow paths within the CLA have been defined through groundwater investigations over the past ~20 years; Roper, Flora and King-Roper. These have been mapped in more detail through the data collected and compiled for the SREBA (Amery and Tickell, 2022). The major groundwater discharge areas for these flow paths are known – Roper River, Flora River, and Mataranka Springs; however, other discharge areas are not as well-characterised (see below).

Discharge of groundwater to the Roper River and Flora River has been quantified through past studies (e.g., Karp, 1997 & 2008); however, there are uncertainties regarding the source(s) and timescale(s) of flows to the surface via springs (see Lamontagne et al., 2021 and further discussion below), and the SREBA studies do not appear to have significantly addressed these uncertainties, such as the extent of flow contribution from deep units below the CLA to Mataranka and Flora River springs. Tracer studies to identify origins of water and timescales of flow to the Flora River springs are lacking in part due to limitations encountered in a CDU study on this topic (commissioned for the SREBA; Irvine and Duvert, 2022).

Further areas of groundwater discharge within the SREBA have been identified, notably Top Springs (western Wiso Basin) and Hot Springs Valley (eastern Georgina Basin – see Figure 4-21 of the SREBA Regional Report, DEPWS, 2022a). The flow-paths, source aquifer(s) and timescales of flow to these areas remain poorly understood, and they have not been fully integrated into an understanding of groundwater flow paths and inter-aquifer connectivity. Regarding Top Springs, Tickell, (2022) noted that:

> "Several small springs discharge from the Lower CLA on the western margin of the Wiso Basin. These include Lonely Spring and Palm Spring. The source of several other springs; Old Top Spring, Illawarra Spring, Killarney Spring and Top Spring located in the same general area is not yet established however they are likely fed from a limestone and chert unit that is interbedded in the Kalkarindji Suite basalt…It is also possible that the Lower CLA is the source (or the partial source) for those springs."

> "In the Top Springs area a groundwater mound is present, indicating basin-wards flow to the east. The mound is relatively steep which reflects thinning of the aquifer along the western margin. There is some indication that the eastward flow turns to the north east in the vicinity of Daly Waters and possibly crosses into the Roper River flowpath. Some minor westwards flow must occur around Top Springs because Lonely Spring and possibly a few other small springs discharge from the Montejinni Limestone."

> "On the far south-western side flow is from east to west, toward the basin margin. To date no springs have been recorded in that area but it is worthy of closer investigation."

These observations highlight ongoing uncertainty regarding source aquifer(s), flow paths and discharge rates for these springs. A further uncertainty critical to assessment of the SREBA area's water balance and hydrogeological processes, is the mechanism(s) by which regional-scale groundwater flows leave the CLA. The SREBA analysis (DEPWSa, 2022; Tickell, 2022) concludes that much of the discharge to the Flora and Roper rivers probably originates from recharge relatively close to the rivers, rather than from regional flows integrating recharge over large spatial scales. If this is the case, it remains unclear where the rest of the groundwater recharged into the CLA ultimately discharges (e.g., through cross-aquifer flow, diffuse ET by vegetation, or other un-characterised discharge features). Discharge of a more regional and/or deeper flow component appears to be indicated by preliminary tracer data from springs (Lamontagne et al., 2021; Irvine and Duvert, 2022), but this is not well understood.

Another important area of considerable groundwater discharge within the SREBA area (above the Beetaloo sub-basin) is Hot Springs Valley in the Georgina Basin, which was visited during a late stage of the SREBA water studies. Groundwater discharges from these springs at considerable rates (e.g,, Tickell, 2022 estimated flows of approximately 30 to 40 L/s for two springs) and the source of water is likely to be one or more deep aquifers, consistent with high temperatures (DEPWS, 2022a). However,

the origins of the spring water, timescales of flow, variability in flows and/or chemistry over time, and connectivity with regional/local groundwater flow paths, are all uncertain. The current lack of groundwater data from units below the CLA – such as the Kalkarindji Suite, Bukalara Sandstone, and other Proterozoic aquifers (See Table 1 and 2), and a lack of nested monitoring bores targeting deep and shallow aquifers together, means that these questions cannot be addressed at present. This is a critical knowledge gap in the context of potential shale gas development, as a deep source of groundwater discharge may be particularly susceptible to impacts from hydraulic fracturing (e.g., targeting the deep Proterozoic rocks of the Beetaloo sub-Basin).

Groundwater throughflow

The SREBA groundwater studies conclude that regional groundwater through-flow between the Georgina and Wiso Basins into the Daly Basin (along the Roper and Flora flow paths) is a relatively minor component of the overall water balance, in comparison to localised/nearby recharge. Estimates of throughflow have varied among different studies – e.g. Tickell and Bruwer, 2015; Knapton, 2020 and the SREBA water resource assessments. The estimates of throughflow should be seen in the context of a lack of full accounting for discharge sources, rates and areas (see above). There is also remaining uncertainty regarding cross-flow between the Flora and Roper flow paths in the vicinity of the junction of the three CLA sub-basins (near Daly Waters). This has implications for the water budget, including the degree of throughflow previously estimated in the water resource assessments for the different regions:

> "The pattern of groundwater flow is known on a broad scale but in some areas there is significant uncertainty due to wide gaps in the monitoring network. Particular areas that would be useful to investigate include the current north-south flow boundary between the Flora and Roper flow paths. There are indications that in the vicinity of Daly Waters there is flow from the Wiso Basin to the Georgina Basin. If correct, then the boundary between the two flow paths may need to be adjusted which would affect the water balances of the respective Water Allocation Plan areas." (Tickell, 2022).

In summary, while the SREBA studies have helped to characterise baseline groundwater levels and flow paths within large areas within the CLA, there remain considerable gaps in the data and knowledge relating to the first objective of the SREBA water studies (SREBA Framework, 2020). These include:

- A lack of monitoring bores, including nested sites, to characterise the groundwater level behaviour and flow gradients in the aquifer units below the CLA - e.g., Neoproterozoic sandstones, Kalkarindji Suite Volcanics, and Mesoproterozoic formations (potential targets for shale gas development).

- Areas where CLA groundwater levels and flow paths remain relatively poorly known -such as at the edges of the Wiso and Georgina Basins, and above the Daly Waters high.

- Limited understanding of the flow paths and water sources to key groundwater discharge features in the SREBA area (e.g., Top Springs and Hot Springs Valley)

and the rates and mechanisms of groundwater discharge to these and other discharge features – e.g., Flora River springs.

Objective 2: "Characterise the hydrostratigraphy of the region sufficient to identify and characterise the aquifer systems and any interconnectivity that could be affected by the extraction of water for any onshore shale gas development."

Connectivity between different aquifers, and between shallow groundwater and the surface environment, is a vital component of assessing the impacts and risks associated with increased extraction of groundwater and/or hydrocarbons from sedimentary basins (Jackson et al., 2013a; Jackson et al., 2013b; Scientific Inquiry into Hydraulic Fracturing in the NT, 2018). This section explores the extent to which the SREBA studies have generated understanding of the level of connectivity within and between the hydrogeological units in the SREBA area, inline with the Pepper Inquiry's recommendations.

Connectivity within the CLA

Tickell (2022) examined the issue of Intra- and Inter-aquifer connectivity for the major aquifer units, including the upper and lower CLA (major water supply aquifer for the region), and units below – Antrim Plateau Volcanics (Kalkarindji Suite), Neoproterozoic sedimentary rocks, and Mesoproterozoic Beetaloo sub-basin rocks. The analysis is based on geology, geophysics, hydrochemistry and water level data, much of which pre-dates the SREBA studies - e.g., work conducted for the Bioregional Assessment (GBA) or GISERA studies, but which has been further supplemented by some additional datasets and analysis commissioned for the SREBA.

The Tickell (2022) report and ELA (2022) conclude that while there is considerable evidence of separation between the upper and lower CLA in the northern part of the SREBA (the Daly Basin), elsewhere – such as in the Georgina Basin, the CLA behaves as a large, hydraulically inter-connected aquifer system, mostly semi-confined below Cretaceous cover. One of the final recommendations in Tickell (2022) is that despite the evidence of connectivity between the upper and lower CLA aquifers, the two sub-units should 'continue to be treated as not being hydraulically connected and separate resources.' This is largely related to risk management; in the absence of comprehensive local-scale understanding of connectivity throughout the aquifer system, new production bores that ignore potential separation between the two units may act to create pathways for greater connectivity than currently exists.

For the purposes of assessing potential long-term impacts of increased extraction of water from the SREBA area, evidence of strong hydraulic connection between the Upper and Lower CLA units in key areas (such as the Georgina Basin) must be carefully considered. This is critical to ensuring pathways for propagation of drawdown from deeper to shallower levels (or vice-versa) - which may affect groundwater discharge to the surface - are incorporated into risk assessments for increased water extraction from the CLA. It remains unclear the extent to which evidence of inter-aquifer connectivity between the two CLA units described in Tickell (2022) has been

reflected in numerical modelling of the groundwater system – such modelling appears not been substantially revised or updated since the reporting by Knapton (2020).

Pumping tests in the various Cambrian Limestone Aquifer units have been conducted in different areas of the SREBA, mostly through hydrogeological investigation programs conducted prior to SREBA studies. Data from more than 150 such tests have been compiled in DEPWS (2022b) and Amery (2022). These studies identify the range of transmissivity and storativity values for the aquifers, which set the upper and lower boundaries for appropriate parameters to model CLA groundwater. The coverage of these tests (like the baseline groundwater level data) is higher in certain regions and lower in others e.g., the Wiso Basin (Figure 4).

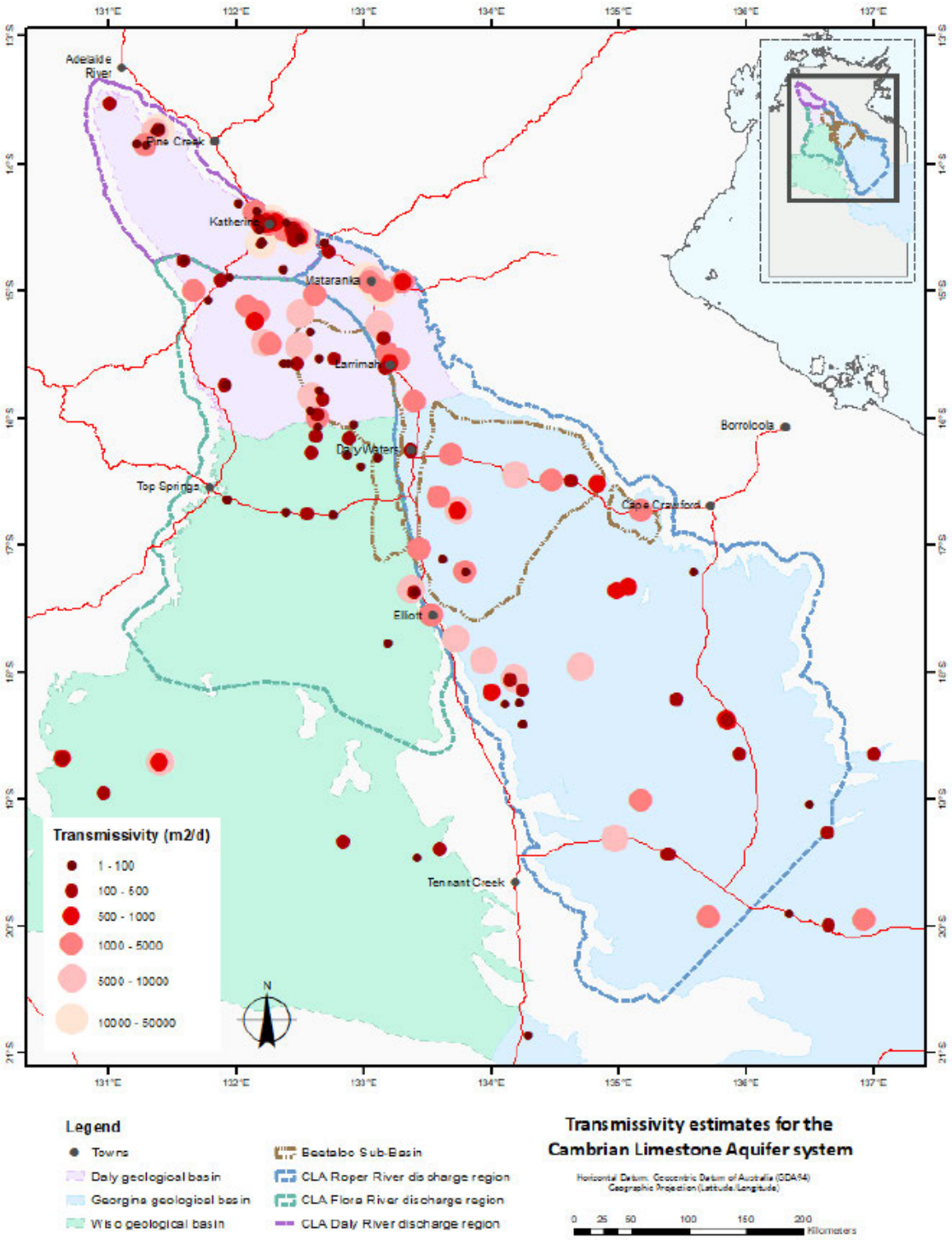

Figure 4 – Map showing coverage of bores from which aquifer test data (transmissivity) are available (Amery, 2022).

Shallow-Deep aquifer connectivity

Available data to inform the question of connectivity between the shallow CLA aquifers and deeper hydrogeological units of the SREBA area (e.g. lower Cambrian volcanic rocks, Neoproterozoic sandstones and Mesoproterozoic Beetaloo Basin units) are limited. Field data to understand inter-aquifer connectivity across the geological sequence remains localised to some areas where there has been deep drilling and characterisation of stratigraphy, a handful of bore pairs monitoring the CLA and underlying Neoproterozoic sandstone (including one pumping test to assess connectivity), and some limited environmental tracer and geophysics data from springs and certain bores, mostly collected during GBA or GISERA studies (e.g. Lamontagne et al., 2021; Frery et al., 2022). The understanding of deep-shallow aquifer connectivity does not appear to have significantly advanced beyond the analysis completed for the GBA (Evans et al., 2020), who noted that there are five potential pathways of inter-aquifer connectivity, but that "The degree of inter-aquifer connectivity is not well characterised." The GBA study published by Frery et al (2022) contained some additional analysis of connectivity associated with fault zones based on geophysics and tracer data which is valuable (see below), but the authors also highlighted that their work provided only preliminary evidence of deep-shallow connectivity, and that significant additional data are needed to understand connectivity comprehensively. This is critical to successful achievement of the SREBA Framework objective, including robust assessments of risks of groundwater leakage and contaminant migration associated with unconventional gas activities.

As noted in Tickell (2022), an understanding of connectivity between the deep and shallow units of the SREBA area requires construction and testing (e.g., using hydrochemical tracer data and pumping test analysis), of nested groundwater monitoring bores tapping the various units at different depths:

> "Knowledge about connectivity between the CLA and deeper aquifers is based on subsurface geological relationships determined by deep drilling, geophysical surveys and detection of ^{3}He in groundwater. Surfaces of key layers have been generated by Frogtech Geoscience (2018b & 2018a) and more recently by GBA (2019). These were used by Evans et al. (2020) to identify areas where the CLA is in contact with deeper aquifers. Information on vertical pressure gradients between the CLA and deeper formations in the Roper and Kiana Groups was compiled by Fulton and Knapton, (2015). Although data was only available from four petroleum wells there was an upward pressure gradient in each well, indicating the potential for upward movement of groundwater. To date, there are only two sites (Carpentaria 1 and Larrizona shown on Figure 20) where bores have been drilled in these areas to monitor groundwater levels and water chemistry in both the CLA and the underlying aquifer."

It should be stressed that the mapping of areas of potential deep-shallow aquifer connectivity (e.g. Figure 4 of Tickell, 2022) is based on a small number of deep bores, and there remains considerable uncertainty as to the extent, thickness and hydraulic properties of the deep aquifer units and intervening aquitards below the CLA, down to the Beetaloo basin rocks, and presence / absence of geological structures. A program of geological, geophysical and geochemical investigations (e.g., encompassing deep drilling and rock/sediment analysis, seismic and electromagnetic surveys, isotopic and hydrochemical vertical profiling and vertical head gradient analysis) is required to resolve this.

Key aspects of inter-aquifer connectivity relative to impact assessment

The lower Cambrian Antrim Plateau Volcanics / Kalkarindji Suite are largely conceptualised in the SREBA reporting (and GBA studies) as a regional-scale aquitard. The unit sits between the Beetaloo basin rocks and shallower CLA aquifer(s) and is considered likely to limit the potential for connectivity between these systems (DEPWS, 2022a). However, it is also noted in some of the SREBA material that the basalts are locally utilised for water supply, and they are not laterally continuous across the region (e.g., Figure 2 of Tickell, 2022; Foss and Dhu, 2016). The potential for significant groundwater discharge from the unit on the margin of the Wiso Basin was also noted (DEPWS, 2022). Further investigation of the extent and thickness of the basalts, their lithological properties, and how this might affect connectivity with units above and below is thus an important aspect of meeting Objective 2. Such analysis could be conducted by means of further logging of bores in data-poor areas and pumping tests and/or tracer studies targeting the basalts and units above and below. The hydrogeological behaviour of this unit is critically important to assessing inter-aquifer connectivity and associated risk from water and/or gas extraction, due to its position between the Beetaloo basin and younger Cambrian aquifers.

The other major units between the deep Beetaloo basin rocks and the CLA include the Bukalara Sandstone and Cox Formation (Kiana Group) and an un-named Neoproterozoic sandstone that has recently been identified during deep bore drilling in the area. The extent, thickness and lithology of these units is not well understood, other than having been mapped to some extent below the Daly and northern Georgina basins (see Figure 4 of Tickell, 2022). Tickell (2022) notes that there are areas where the Neoproterozoic sandstones and CLA aquifers are in direct connection, providing a potential pathway for deep-shallow groundwater connectivity:

> "Only two formations: the unnamed sandstone (Altmann et al 2020) and the Bukalara Sandstone can be considered to be mappable aquifers. The former has mostly been identified beneath the Kalkarindji Suite. One exception is at the well Tanumbirini 1 where it is in direct contact with the CLA. Bukalara Sandstone occurs in three windows directly beneath the CLA. The first is centred on Elliott 1. A smaller area is south-east of Tanumbirini 1 and the third occurrence is in the eastern-most outlier of the Beetaloo Sub-basin area, intersected in the water monitoring bores for Carpentaria 1 and 2."

Two sites include bores constructed specifically to examine connectivity between the Bukalara Sandstone and overlying CLA for the SREBA (Short, 2021; Tickell, 2022). These provide an indication of the thickness and lithological properties of the units, as well as deep-shallow connectivity at these two localities (a very limited number given the size of the SREBA area and significance of the aquifer connectivity issue):

> "Two of the sites with paired bores have been constructed for monitoring the Lower CLA and the underlying Bukalara Sandstone and equivalents. The first is at Larrizona Station (Western Creek Road) where the Lower CLA is separated from the unnamed sandstone and Bukalara Sandstone by over 120 m of basalt (Short, 2021). The other is at the Carpentaria 1 site where the Lower CLA directly overlies the Bukalara Sandstone."

The investigation work of Short (2021) shows that connectivity is limited at the first of these sites, while Tickell (2022) notes that the other site where bores occur in both units, shows strong indications of connectivity:

> "At the Carpentaria 1 location, groundwaters in both aquifers are magnesium bicarbonate types (Figure 27) and have comparable TDS values. The Lower CLA has a TDS of 686 mg/L and the Bukalara Sandstone is 576 mg/L. That difference is due to higher calcium and bicarbonate concentrations in the CLA. These observations indicate that the two formations have good hydraulic connection. Similar water levels measured in both formations support that conclusion."

Connectivity between groundwater from deep, Proterozoic rocks and the shallow aquifer system in the eastern part of the SREBA (Tanumbirini station) is consistent with a deep source of groundwater sustaining the spring flows within Hot Springs Valley. Gaining a better understanding of the extent of this zone of connectivity, the hydraulic properties of the units, and the likely rates of leakage between the aquifers in response to groundwater extraction is critical to meeting the SREBA Objectives, but this is unresolved at the current time.

The SREBA regional report (DEPWS, 2022a) also notes that there is an area – the Daly Waters High – where both the lower Cambrian basalts, and Neoproterozoic rocks are absent, meaning the Beetaloo basin rocks (targets for shale gas development) may be directly in contact with the CLA. It also does not appear that inter-basin connectivity in this region has been assessed in any detail. This would require the installation of nested monitoring bores targeting the Beetaloo basin rocks, and overlying CLA unit(s), analysis of water level trends, hydraulic testing, and environmental tracer sampling.

Hydraulic testing

As discussed above, there have been a considerable number of pumping tests conducted within CLA bores (albeit with data coverage greater in some parts of the SREBA area than others – see Figure 4). However, pumping tests which target deeper aquifers below the CLA, to inform analysis of inter-aquifer connectivity between deep and shallow aquifers, are very limited. One pumping test was specifically commissioned for the SREBA (Short, 2021). This indicated limited connectivity

between the CLA and Neoproterozoic sandstone (comprising the Bukalara and Unnamed sandstone described above) at the locality, during a four-day constant rate test. Testing for a longer period of time (e.g. >7 days) and with additional monitoring bores in the intervening Antrim Plateau Volcanics, and similar pumping tests at other localities, would be needed to further constrain whether significant leakage is likely to occur in response to pumping from the aquifer in the long-term and on a regional scale.

The testing described in Short (2021) and the second site at Carpentaria-1 are local scale studies which highlight that both the stratigraphy (e.g., thickness and extent of the Neoproterozoic sandstone units) and their hydraulic properties – e.g., connectivity between these units and the CLA above – are variable in different parts of the SREBA area, and this has only recently begun to be characterised. Understanding whether such connectivity is more extensive in other areas – e.g., where the intervening basalts are thin or absent, or where geological structures may enhance connectivity (as demonstrated in Frery et al., 2022), requires additional drilling and pumping tests, supplemented with other lines of evidence (e.g. geophysics and geochemical data).

Geophysics and Environmental Tracer data

The analysis of seismic, remote sensing, gravity, airborne electromagnetic and gamma log data (i.e., geophysics) together with geological logs, is an important part of characterising geological structures that may impact on inter-aquifer connectivity at local and regional scales. Environmental tracers - such as isotopes of helium, strontium and other radioisotopes in groundwater, also provide important evidence that can identify areas of deep-shallow aquifer connection. Analysis of high-resolution topography and geomorphology is also an important aspect of such studies – e.g., Frery et al., (2022) noted that surface drainage patterns above the OT Downs fault zone are influenced by the underlying geological structure(s).

Faulting was identified in the GBA studies (Evans et al., 2020) as a key potential pathway for connectivity between deep and shallow aquifers in the region, and investigations using geophysics and tracers were conducted by Frery et al., (2022). The coverage of seismic and other geophysical data to map out the extent and depth of fault zones, along with environmental tracer data from springs and bores, to identify pathways and extent of deep fluid flow to shallow depths, are still very limited. Based on the combination of geophysics and tracer data available currently, Tickell (2022) concluded:

> "The datasets described above were all used to define five areas where there is higher potential for connectivity along faults. These include the OT Downs Fault Zone, the Mataranka Springs Complex (north Birdum Creek Fault area), the central part of the western Beetaloo Sub-basin, the Elliott area and the central part of the eastern sub-basin. The only known examples of water moving along a fault from a considerable depth are hot springs associate with the OT Downs Fault Zone." (i.e., Hot Springs Valley).

Further,

> "Two hot springs on Tanumbirini Station were visited by Zaar (2009) along Beauty Creek and Lagoon Creek, northwest flowing tributaries of the upper Cox River. Both streams are likely to follow major faults that are part of the OT Downs Fault Zone. The spring on Beauty Creek (Water Resources Division site number G9055086) had a temperature greater than 60˚C and an estimated discharge of 30 L/s. The spring on Lagoon Creek (G9055076) had an estimated discharge of 20 L/s but the temperature was not measured. A second visit took place in September 2022 (Zaar and Tickell, 2022) and G9055086 and another spring on Gorge Creek (not G9055076) were visited. Estimated discharges and selected water quality parameters of the three springs are listed in (Table 5) This series of springs was identified during the GBA program (Evans et al. 2020) as an area of interest for the Beetaloo Sub-basin because the outcropping formations in the area and the likely groundwater source for these springs are the deep Mesoproterozoic formations that are part of the gas resource sequence."

Environmental tracer data (particularly helium) from Mataranka Springs (Lamontagne et al., 2021) and Hot Springs Valley (Frery et al., 2022) indicate a deep water source contributing to spring flow in both of these important groundwater discharge areas:

> "High concentrations of radiogenic 4He (> 10^{-7} cm^3 STP g^{-1}) at Rainbow Spring, Bitter Spring and in nearby groundwater also indicated an input of deeper, older groundwater. The presence of older groundwater within the CLA demonstrates the need for an appropriate baseline characterisation of the vertical exchange of groundwater in Beetaloo Sub-basin ahead of unconventional gas resource development." Lamontagne et al., (2021).

> "The noble gas helium, produced by natural decay of uranium and thorium in the aquifer and indicative of the input of old groundwater, was detected in several bores from the CLA and two springs, suggesting upward flow of old groundwater from deeper aquifers. The amount of this inflow cannot be quantified without knowing the helium concentration in those formations. No indication of mantle helium has been found in the Beetaloo Sub-basin. Additional research is required to understand the nature of the vertical connectivity demonstrated by helium". (Frery et al., 2022)

The analysis of tracer data still thus appears to be in the early stages of defining the source(s) of fluids at different depths in areas of potential inter-aquifer (and basin) connectivity. Some further data to inform analysis of the depth/source of water flowing to the Hot Springs Valley springs is noted as being in the process of being collected:

> "During the September 2022 site visit, samples for environmental tracers (helium, carbon-14, chlorine-36, tritium, strontium isotopes and stable water isotopes) were also collected from the main Beauty Creek Hot Spring vent to help identify potential source aquifers and discharge mechanisms. At the time of reporting, results of these tracers had not been provided by CSIRO to inform the development of this section. However, a member of the SREBA greenhouse gas baseline studies was present during the field visit, and they

recorded detectable and correlated concentrations of methane and ethane in the air surrounding the Beauty Creek Hot Spring vent when bubbles were noted to be emanating from the spring vent. This provides further evidence of a deep source, possibly associated with Beetaloo Sub-basin gas exploration targets." (Tickell, 2022).

A key issue to consider is whether extraction of groundwater and/or hydrocarbons may cause enhanced movement of groundwater along structure features/zones that facilitate enhanced permeability between deep and shallow geological units. While the above studies provide preliminary evidence of deep groundwater and/or gas flow reaching shallow aquifers and the surface environment, a full assessment of the extent of connectivity and likely behaviour of the springs and shallow aquifers in response to extraction of water and/or gas (as per the SREBA Framework objectives), will require substantial additional data and analysis (Frery et al., 2022).

Overall, the number of deep bores available to fully constrain the thickness, extent and lithological properties of the formations below the CLA and above the Beetaloo basin is small, and areas where connectivity has been further assessed through hydraulic testing, geophysics and environmental tracer data limited. Deep bores should be constructed through the full thickness the aquifer system, with logging of changes in multiple geophysical and water quality parameters with depth, followed by construction of a nested piezometer site tapping the aquifers at multiple depths. The analysis of tracers, geophysics and pumping tests, covering a range of localities, will be necessary to fully address the SREBA water studies objectives.

In summary, there remain critical data and knowledge gaps regarding the extent of inter-aquifer connectivity for key units that may be subject to water and/or gas extraction in the future:

- Additional nested monitoring bore sites are required to enable hydraulic and geochemical testing, to establish the level of inter-aquifer connectivity across the range of geological profiles within the SREBA region – in particular, between the Neoproterozoic and Mesoproterozoic units, and the overlying Cambrian aquifers.

- Regions where connectivity between the Beetaloo basin rocks and overlying Cambrian aquifer(s) may be considerable – such as the Daly Waters High and OT Downs sub-basin (near Hot Springs Valley) do not appear to have been extensively drilled or characterised (e.g. with tracer sampling, multiple geophysical techniques and hydraulic testing) to understand lithological profiles, groundwater level gradients and other potential indicators of vertical connectivity.

- Preliminary data (mostly from hydrochemical/environmental tracer sampling) indicate areas of substantial connectivity between deep aquifer units and the shallow CLA and/or springs, where groundwater discharge from deep units occurs. The extent of these areas, and the potential impacts of increased water (or hydrocarbon) extraction from different depths (e.g., on inter-aquifer leakage and spring discharge rates) have not been established.

Objective 3: "Quantify recharge rates (and where possible, recharge zones) and establish the sustainable yield for potentially affected aquifer systems."

Estimation of recharge rates for the aquifers of the SREBA region has been compiled from various previous studies, as outlined in Chapter 4 of the Regional Report (DEPWS, 2022a). This report details the four main recharge processes across the CLA, as well as mapping recharge potential at regional scale (shown in Fig. 4-20). Analysis of recharge rates and recharge areas for the major aquifers relies upon studies conducted through CSIRO and Geoscience Australia (the GBA program), along with numerical modelling conducted by the Water Resources Division of the Northern Territory Government (Knapton, 2020). The SREBA studies conducted limited additional field data collection to quantify recharge rates.

Recharge to groundwater occurs by a combination of diffuse recharge (spread across the landscape) and focussed recharge (associated with specific landscape features). Ranges of diffuse recharge rates across much of the SREBA area have been relatively well-constrained through chloride mass balance analysis, reported by Crosbie and Rachakonda (2021).

However, the range of overall recharge rate estimates derived from different sources and techniques (e.g., chloride mass balance and various modelling studies) is still wide. For example, low-end CLA recharge estimates for the CLA in the Georgina Basin are on the order of 100 GL/year, while the DR2 model and constrained chloride mass balance estimates are over 500 and 1000 GL/year, respectively (DEPWS, 2022c). This indicates considerable residual uncertainty in the estimated values.

Environmental tracer and other data indicate that recharge is likely to be highly preferential in many areas, as well as being strongly episodic - associated with short term periods of high rainfall, particularly in the more arid southern parts of the SREBA. These recharge mechanisms are not well quantified using chloride mass balance. The SREBA and GBA studies identified that recharge through sinkholes - large openings in limestone at or near the surface - is an important component of groundwater recharge to the CLA. Some new mapping of sinkholes has been conducted, to better constrain where these features may be contributing preferential recharge (Tickell, 2022; DEPWS, 2022a). Nonetheless, according to Tickell (2022), localised preferential recharge contributions remain poorly quantified, especially in southern CLA (i.e., above the Beetaloo sub-basin):

> "Various modelling techniques have determined recharge amounts on a regional scale, however contributions from individual recharge mechanisms on a more local scale have not been quantified." (Tickell, 2022).

Tickell 2022 and the other SREBA reports argue that the DR2 model is the most reliable estimator of recharge rates, and this is the approach taken to water balance estimation in the regional water resource reports produced under the SREBAr:

> "Of the data sources above, the DR2 Model is considered to be the most accurate in regard to the quantitative estimates of recharge rates across the region. This is because the model is tailor-made and based on the most up-to-

> date conceptualisation of the entire connected water resource (i.e., CLA and Roper and Daly Rivers), as well as calibrated to observed groundwater levels and river discharges. It is less powerful for predicting recharge locations and requires a prior understanding of the differences in recharge areas to be built into it. Recharge areas are described in Knapton (2020) but these areas are refined based on how well the model performs."

There are significant challenges with relying on numerical modelling as a tool in groundwater recharge estimation, in the absence of extensive field data to ground-truth recharge estimates and other model parameters (Sanford, 2002; Knowling and Werner, 2016).

Model-based recharge estimation, conducted by varying rates and locations (along with other unknown input parameters) and assessing calibration of the model's outputs against field observation data (e.g., groundwater levels and fluxes), suffers from the issue of non-uniqueness. This means that if multiple model parameters – such as recharge rates, hydraulic conductivity and storage coefficients - are all unknown or uncertain (e.g., due to a lack of sufficient field data), then the matching between modelled and observed data during calibration can be achieved through an infinite number of model parameter combinations, many of which may be far from representing the true aquifer characteristics and water balance inputs (Anderson et al., 2015; Knowling and Werner, 2016). The issue of non-uniqueness in model calibration becomes more and more pronounced as model complexity increases. A water balancing approach, using the DR2 numerical model, is adopted in the water resource reviews of the main sub-areas of the SREBA (DEPWS, 2022c; DEPWS, 2022d). In the Georgina Basin review, there is a large difference between mean and median recharge rate estimates derived from the modelling – consistent with highly episodic recharge – which is poorly documented or understood through field observations.

More generally, there is considerable variability in estimates of water balance terms (including recharge, discharge, and throughflow) derived from various iterations of modelling and field-based studies (see Currell and Ndehedehe, 2022). It appears that parameters such as the adopted storage coefficient(s) in the modelling, have a major effect on estimation of water balance terms:

> "The water balance includes the volume of water in storage, combined with the inputs (recharge, inflow) and outputs (outflow and ET from groundwater). The volume of groundwater storage presented in the water balance (667,480 GL) was determined for the CLA and overlying Cretaceous sediments. The model assumes a drainable porosity (or specific yield) of 0.04 (4%), which results in a storage volume that is significantly lower than the storage estimates presented by Tickell and Bruwer (2017) of 1,766,000 to 3,532,000 GL which mistakenly used specific yield estimates of 0.2 - 0.4 (20 - 40%)." (DEPWS, 2022a)

Verification of aquifer parameter values throughout the SREBA area (using field data) remains limited, particularly in data-poor regions (discussed above and highlighted in

Table 1). This creates a risk that model calibration alone results in highly uncertain estimates of recharge and other water balance terms. The significant differences in estimated recharge rates derived from multiple techniques (including the model) for the CLA - see also Currell and Ndehedehe, (2022) - indicates that there are considerable margins of uncertainty in these parameters, which cannot be resolved through model calibration alone.

Satellite-based estimates of recharge

There are further lines of evidence, which can contribute to an understanding of recharge rates, mechanisms and relationship to climatic variables that have not been incorporated into the SREBA studies, e.g., analysis of satellite-based gravity and related remote sensing data.

Data from the Gravity Recovery and Climate Experiment (GRACE), which was launched in 2002 have helped to improve our understanding of the impacts of climate change and human water extraction on groundwater hydrology globally. Be it local or global, the use of GRACE in assessing groundwater status and water budget is well known (e.g., Rodell et al., 2018) and recently, its feasibility in recharge estimation, and identifying areas where groundwater drawdown exceeds recharge, has been established (Rockstrom et al, 2023; Stewart-Koster et al., 2023). The use of GRACE data to estimate annual recharge for the extended SREBA water study area, following the methodology outlined in Stewart-Koster et al., (2023), confirms that there is strong variability between years (Figure 5). Extreme wet and dry years result in considerable differences between high and low recharge values, consistent with a highly episodic recharge regime. The northern section of the SREBA area receives the highest annual recharge, coinciding with the strong annual rainfall. While mean annual recharge in years with above-average rainfall may exceed 300 mm, recharge is restricted in years with below average rainfall (e.g., 2013, 2016), ranging from 50-70 mm/yr (Fig. 5).

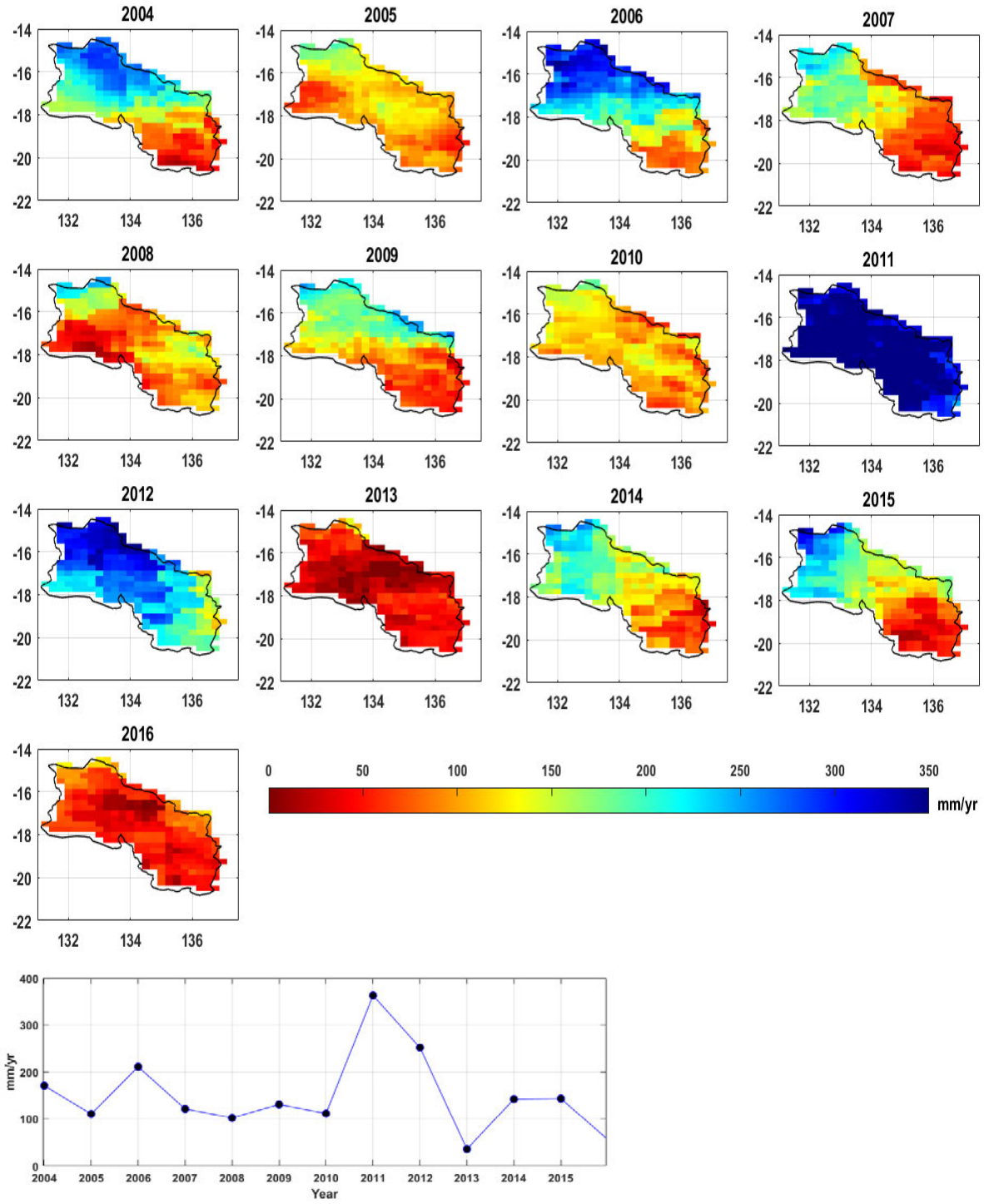

Figure 5 - Changes in spatial distribution of annual recharge between 2004 and 2016 over the CLA (bottom panel shows aerial averaged temporal variation), estimated from satellite gravity data (Ndehedehe, this study).

Trends in annual recharge assessed for the 2004-2016 period using GRACE show gradual declines around the Beetaloo sub-basin and Beetaloo eastern extension (Figure 5), illustrating impacts of climate variability on recharge. The approach recognises the complex interactions associated with groundwater recharge, especially how extremes in climate can restrict recharge a surface water availability. Pixel-based recharge values were estimated using annually aggregated groundwater values

processed from the GRACE data, and trends subsequently estimated for the 2004-2016 period (Figures 5 & 6).

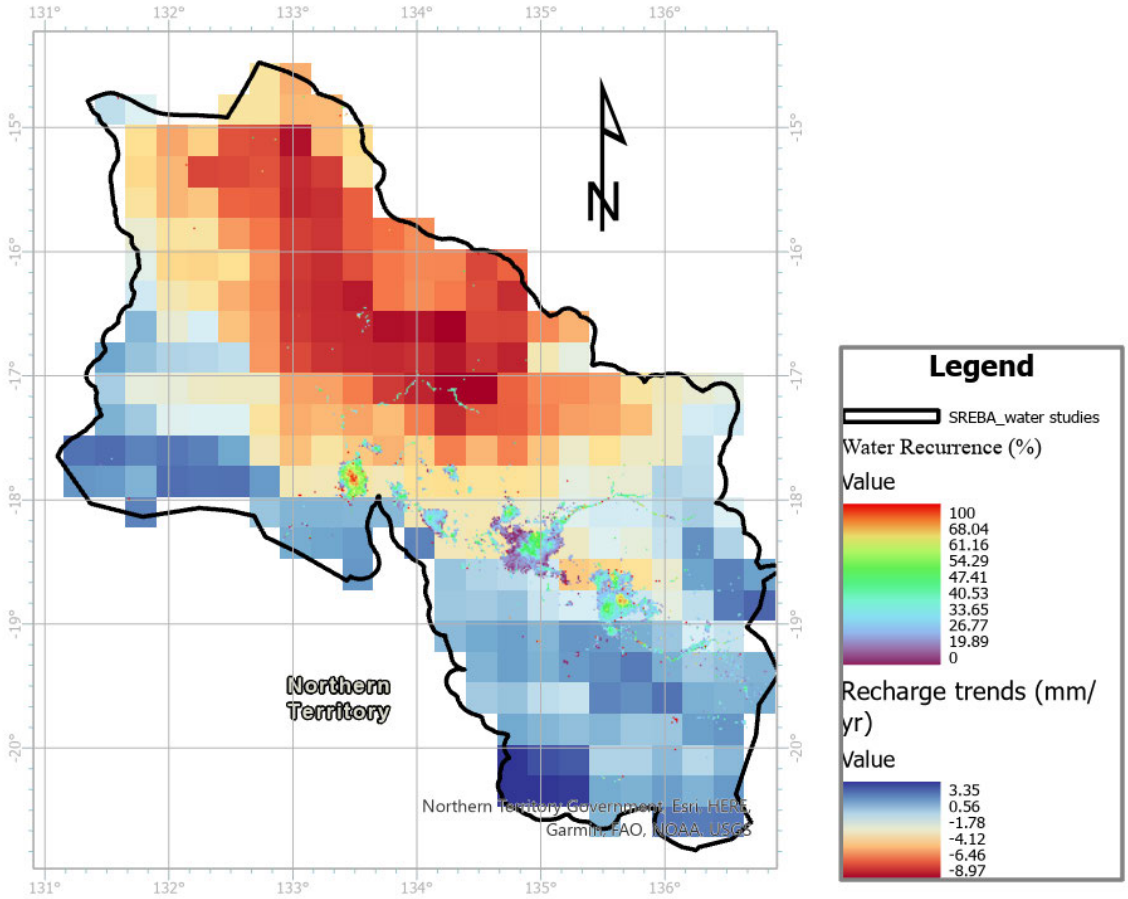

Figure 6 - Trends in annual recharge rate (2004 and 2016) estimated from satellite gravity data, and water recurrence based on historical Landsat data (Ndehedehe, this study). The background raster map is recharge rate trend, while the overlay/inset is water recurrence.

Due to the high connectivity between the CLA aquifers throughout the SREBA area (see previous section of this review) there may be a considerable risk of alteration of natural patterns and variability of groundwater recharge, as well as groundwater discharge, if significant increases in water extraction occur (Currell and Ndehedehe, 2022). As discussed in Alley et al., (1999) and other studies examining methodologies for determining a Sustainable Yield, extraction of groundwater does not just change volumes of water in storage. It also results in changes to rates and locations of discharge of groundwater to the surface (typically reducing these in the long-term) as well as recharge rates, and patterns of ground-surface water interaction. For example, excess available surface water (shown as water that has a relatively low recurrence – Fig 6) may be drawn into the affected aquifer(s) as a new recharge source, to replace water being extracted. Understanding these changes and their environmental, social, and economic implications, is critical for effective sustainable yield determination.

Globally, there is considerable interconnection between groundwater and surface water systems, as much streamflow benefits from groundwater baseflow (Berghuijs et al., 2023). In the event of large-scale increases in groundwater extraction in the SREBA

area, impacts on groundwater-surface water interactions that further limit groundwater flows to streams and springs would be likely to occur. This is discussed in detail in Currell and Ndehedehe (2022), which examined the issue of appropriate sustainable yield determination for the CLA. Importantly, the recharge and discharge rates and mechanisms for the other aquifer units below the CLA within the SREBA area – such as the Neoproterozoic Sandstones, remain poorly understood, along with their interconnections with the CLA and surface environment (see previous section). This adds to uncertainty regarding appropriate sustainable yield determination in the SREBA aquifer system.

Excess water or 'Available Water'

The SREBA studies provide some new insights into groundwater discharge processes, using remotely sensed data. 'Excess water' or net precipitation was investigated at identified springs, by quantifying the difference between actual evapotranspiration and precipitation during the 2000-2022 period (Gautam et al., 2022). While actual evapotranspiration represents outgoing fluxes or water loss from a catchment, 'excess water' can serve as an indicator of water availability and help assess potential future changes to water budgets. The significant change in water balance in the spring systems reported by Gautam et al., (2022) confirms the vulnerability of the CLA to drought impacts. Prolonged below-normal precipitation increases evaporative demand, resulting in some vegetation communities (which are not groundwater-dependent) being reliant on groundwater. This can happen when excess water declines due to increases in actual evapotranspiration under limited rainfall. Since 2011, there is a significant decline in cumulative 'excess water' for two of the spring systems (Flora and Mataranka) reported in Gautam et al., (2022). This was attributed to evaporative losses from surface water at Flora River and increased water uptake by vegetation at Mataranka. Further,

> "..there is also sporadic evidence of groundwater use at the two southern sites [Top Springs and Hot Springs Valley], such as during the 2018–2020 period when P-AET (excess water) shifted to negative values".

There remain knowledge gaps regarding water availability and/or changes to 'excess water' within other parts of the SREBA, including the dynamics of interactions between ground and surface water bodies shown on Figure 6 above (which is based on satellite gravity data-trends in recharge over time and Landsat data on permanence of surface water bodies), in addition to the spring complexes mentioned above. The importance of knowledge around surface-groundwater hydrological fluxes, among other aspects of the water balance, is acknowledged in Gautam et al., (2022):

> "Further research and modelling into closing the water balance would provide a more in-depth view of the water condition and help understand the role of groundwater in sustaining riparian ecosystems across the region".

Sustainable Yields

The question of what constitutes a Sustainable Yield in different aquifers and regions within the SREBA is a critical aspect of addressing the Pepper Inquiry

recommendations / SREBA Framework objectives. This topic is discussed extensively in our previous report focussing on the Cambrian Limestone Aquifer (Currell and Ndehedehe, 2022). To briefly summarise key findings:

- Determining sustainable yields should focus on determining where reductions in groundwater discharge will occur in response to groundwater extraction at different rates (and any additional recharge drawn into the aquifer from the surface), and how important these waters are from environmental, economic, and socio-cultural perspectives (Alley et al., 1999). Direct impacts of storage depletion - e.g., drawdown to the point that GDEs, including terrestrial vegetation, can no longer access groundwater – should also be considered (alongside changes to discharge and recharge).

- In the arid, southern regions of the CLA, where recharge is highly episodic, the calculation of an estimated sustainable yield based on long-term average recharge rates is problematic, as there may be extended periods (i.e., decades) in which recharge is well below the mean. In turn, extraction at a sustainable yield that is derived based on an annual long-term average recharge, would result in significant reductions in groundwater levels and fluxes, potentially for many years (or decades) consecutively. The recurrence interval for major recharge events in episodically-driven systems (such as the southern, arid zones of the SREBA area) may be very long – the last major episodic event appears to have occurred associated with extreme rainfall in 1974, and this remains poorly quantified / understood due to lack of monitoring at the time.

Moreover, there appears to be limited understanding of the water balance and connections between ground and surface water associated with other aquifer units (apart from the CLA) e.g., Lower Cambrian Volcanics and Neoproterozoic sandstone aquifers. As discussed in other sections of this report, the groundwater hydrology, aquifer parameters and connectivity between these aquifers and their overlying / underlying hydrogeological units (including the CLA) are poorly understood. This means that a comprehensive analysis of sustainable yields for these aquifers, and the potential impacts on other aquifers (through connectivity) is not yet possible.

A summary of key findings regarding this SREBA Framework objective is:

- Long-term average diffuse groundwater recharge rates for the CLA are relatively well-constrained in the SREBA area. However, multiple recharge estimation techniques provide quite different overall rate estimates (indicating ongoing uncertainty) and the coverage of data and degree of confidence in the estimates is better in certain areas than others (e.g., data are limited in the Wiso basin). While some additional analysis of recharge through other mechanisms (e.g. sinkhole recharge) has been included in the SREBA reporting, it does not appear that the SREBA studies have generated a significant amount of new data to inform a more comprehensive quantification of recharge rates and their variability / uncertainty.

- There is a lack of available data to inform an understanding of the importance, rates and mechanism(s) of rare, episodic groundwater recharge events within the

semi-arid/arid parts of the SREBA, to help inform assessments of the long-term regional water balance. Localised recharge rates and mechanisms (e.g., their relative importance of diffuse vs. preferential/focussed recharge) remain generally poorly understood. This must be carefully considered and addressed to develop robust estimates of sustainable extraction rates.

- Reliance on numerical modelling to estimate recharge rates – which is a primary technique in updated regional water resources assessments - must consider the high possibility of model non-uniqueness (due to the uncertainty of multiple different model input parameters). This means that model calibration may not effectively constrain the rates of recharge within robust and precise ranges.

- Additional analysis of remote sensing data can help to constrain recharge and its dependence on climatic variables, as well as understanding the importance of groundwater in sustaining surface water and vegetation through different climatic periods. Preliminary data analysed in this study and SREBA studies, indicate that both recharge rates and the permanence of surface water (connected to groundwater) vary considerably with yearly climate, undergoing periods when recharge rates are low, and vegetation becomes strongly dependent on groundwater. There remain considerable unknowns with respect to climate-groundwater-surface water interactions, however. These interactions must be understood (together with recharge), to develop robust sustainable yield estimates.

- Estimation of sustainable groundwater extraction rates requires considerable further data and analysis. This should encompass a comprehensive understanding of groundwater discharge rates and mechanisms (which sustain surface water, vegetation and GDEs) and potential changes to these under various extraction scenarios. Current sustainable yield estimation appears to have been largely conducted using water balance estimates derived from groundwater numerical modelling; however, the full methodology and assumptions are not available to be reviewed in detail (since reporting on the DR2 model by Knapton, 2020).

- Data gaps relating to the hydrogeological parameters, water balance and inter-aquifer connectivity for the aquifer units below the CLA (e.g. Neoproterozoic sandstones) mean that sustainable extraction rates from these units, and potential impacts of extraction from these on other aquifers (including the CLA) cannot be determined.

Objective 4: "Develop suitably calibrated groundwater-surface water flow models to quantify the connectivity between groundwater and surface water systems to predict the likely impacts of hydrological perturbation as the result of any potential onshore shale gas development and production."

Water resource assessments, based on coupled numerical ground-surface water modelling, have been published for the major regions/sub basins of the SREBA area - Wiso Basin, Georgina Basin and Flora water management area. The modelling used to underpin these water resource assessments is documented (to a degree) in Knapton (2020) – i.e., the DR2 model. According to the Georgina Basin water resource assessment report, this model has not been revised/updated significantly since 2020:

> "The most recent upgrade of the model occurred in 2020, and included updated aquifer geometry and conceptualisation, and an additional 10 years of field monitoring and climate data."

As such, any more recent drilling data, hydraulic testing of aquifers, and hydrograph information (for transient calibration) that was collected since 2020 (e.g., as part of the SREBA studies) would not be included in the modelling.

Currell and Ndehedehe (2022) examined the modelling documented in Knapton (2020) in the context of assessing whether there was sufficient basis to enable quantification of sustainable extraction rates from the CLA aquifer system. Currell and Ndehedehe (2022) noted some important knowledge gaps in this regard. They also recommended against the use of fractions of estimated aquifer storage volume or estimated average recharge rates in the calculation of sustainable yields as these remain uncertain, and do not capture all aspects of the impacts of extraction. Determination of sustainable yields additionally requires comprehensive analysis of the full aquifer system's regional and sub-regional water balances (including robust estimates of inter aquifer leakage rates), rates and locations of groundwater discharge to surface water and other groundwater dependent ecosystems, and the likely relative components of storage depletion vs. capture of groundwater discharge under different water extraction scenarios. These conclusions remain unchanged in light of the SREBA water studies.

A further detailed review of the suitability of the DR2 model for addressing this SREBA Objective is not included in this review, as:

a) There is not (to our knowledge) further detailed documentation of upgrades to the DR2 model's parameterisation or calibration beyond what is outlined in Knapton (2020), or comprehensive documentation of the modelling of new water extraction scenarios simulated by the model;

b) The authors are not expert numerical groundwater modellers, and a review of the modelling (if the relevant material were available) would best be conducted by a dedicated groundwater modelling professional or organisation with such expertise. The modelling review should have access to full details regarding modelling assumptions, parameterisation, calibration, and uncertainty analysis.

Objective 5: "Establish a baseline for water quality, including measuring vertical profiles of water quality parameters through potentially affected aquifers and surface waters, noting that this will need to be done at a number of locations across a region to inform the lateral variations in quality. In semi-arid and arid regions, particular attention should be paid to the water quality of perennial to near-perennial water bodies that are likely to provide dry season refugia for aquatic biota and drinking water sources for wildlife[4]"

Groundwater quality data compiled and collected during the SREBA water studies are summarised in Shand et al., (2022) and ELA (2022). There is a substantial amount of groundwater hydrochemical data available from bores in the SREBA area (see Figure 7). However, similar to groundwater level baseline data, some aquifer units have much greater availability/coverage of water quality data than others.

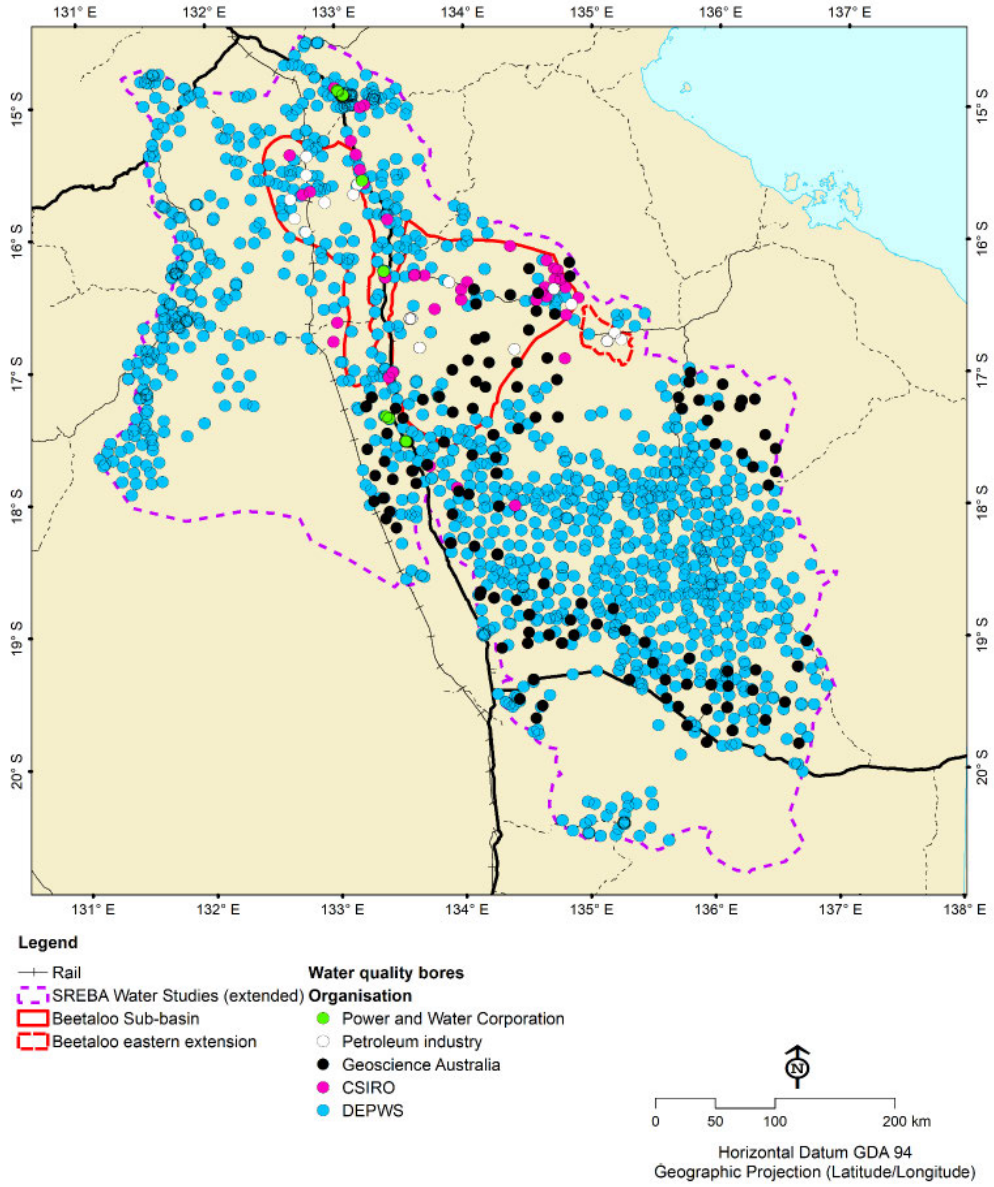

Figure 7 – Locations of bores where at least one groundwater quality measurement is available (ELA, 2022).

[4] Note: The analysis here is confined to the topic of groundwater quality baseline data, as the reviewers do not have extensive expertise in surface water quality requirements for aquatic biota.

What should a groundwater quality baseline in areas of unconventional gas exploration include?

There is an extensive global literature on the issue of potential impacts of shale and other unconventional gas development on groundwater quality, and requirements for comprehensive baseline data in such regions (Vidic et al., 2013; Jackson et al., 2013a; Vengosh et al., 2014; Humez et al., 2016; US EPA, 2016). Analysis of relevant studies from other contexts (particularly the US, where a shale gas industry is established) was considered in the Pepper Inquiry and formed part of the basis for the recommendation(s) with respect to baseline groundwater quality. Briefly, a comprehensive baseline dataset should include:

- Sufficient coverage of water quality samples throughout the aquifers of interest (including different depths) and sufficient time-series data to allow for a statistically robust analysis of the range and variability of groundwater quality characteristics for these aquifers. This is required to assess any future changes due to gas extraction and associated activities and clearly identify the significance of changes in water quality parameters;

- Extensive data for water quality characteristics / contaminants that are likely to be associated with shale gas. Dissolved methane concentrations are critical in the context of fugitive/stray gas risk (Jackson et al., 2013b), and the isotopic composition of methane and other hydrocarbon gases should be documented so that sources of any potential fugitive gas identified in water supply bores can be fingerprinted (Jackson et al., 2013b; Humez et al., 2016). Other common trace elements that are associated with shale gas brines and present in fracking flowback waters also need detailed baseline characterisation in shallow aquifers and surface waters, in particular elements like barium, strontium and radium, which are often enriched in shale brines (Warner et al 2013). Microbial communities in the aquifer system may also be substantially impacted by oil and gas development, and may serve as important indicators of processes causing water quality changes, including stray gas contamination (e.g. Van Stempvoort et al., 2005). Such indicators should be included in baseline water quality datasets along with hydrochemical and isotopic parameters.

- Field groundwater physico-chemical parameters – redox potential (Eh/ORP), pH, DO and EC are a very important aspect of baseline groundwater quality, as unconventional gas development impacts (such as fugitive gas migration or inter-aquifer leakage) may trigger changes in these variables, such as through catalysing redox reactions in the aquifer(s) in response to changes in dissolved oxygen and redox potential. These indicators can be important early warning indicators of an impact on groundwater quality.

- These data and their analysis should also allow for baseline understanding of the key processes that impact groundwater quality – e.g., soil zone reactions and evapotranspiration during groundwater recharge, water-rock interaction within the different aquifer units, inter-aquifer mixing (either natural or induced),

redox and other geo-microbiological processes impacting on contaminant concentrations. Thus, data must not simply be collected and reported as concentration levels and ranges as an end in itself, but must also be continuously analysed and interpreted with respect to hydrogeochemical processes. Such understanding is required so that any future change in the dominant processes affecting groundwater quality can be effectively determined (Jackson et al., 2013a & b).

The extent to which the current data and analysis of these addresses these objectives are examined further below.

Extent of coverage of baseline groundwater quality data in the SREBA area

ELA (2022) summarised the findings of the review of groundwater quality baseline data commissioned for the SREBA by the National Centre for Groundwater Research and Training (Shand et al, 2022), noting that the available data were 'useful for providing a broad-scale overview of water quality trends across the primary HSU of concern (i.e., the CLA).'

However, regarding the Neoproterozoic sandstone aquifer(s), Antrim Plateau Volcanics and the deeper Beetaloo basin hydrostratigraphic units, the baseline water quality data are much more limited (Shand et al., 2022). There are 4744 total groundwater quality records available from within the SREBA area - the majority from the CLA (> 2800). Water quality baseline coverage is limited in other deeper aquifer units below the CLA (below 150 m depth) with Neoproterozoic and Mesoproterozoic rocks having approximately 250 samples – among which only five are from the Bukalara Sandstone - and the Antrim Plateau Volcanics approximately 140 samples (see Table 2 of Shand et al 2022). Shand et al. (2022) noted:

> "There are very few samples from the formations underlying the CLA i.e. the Bukalara Sandstone (5 samples or 0.1% of the data) and the Cox Formation no samples."

The gap in available water quality/hydrochemical data for the units below the CLA is a significant issue, as the future identification of the cause(s) for changes in water quality parameters in aquifers that are utilised more extensively (e.g., the CLA) requires suitable characterisation of end-member concentrations of water quality components in other potentially connected hydrostratigraphic units. These units may influence groundwater quality through (for example) inter-aquifer leakage caused by water or gas extraction (Ayotte et al., 2011).

As noted in Tickell (2022) and Shand et al., (2022), there has been (as yet) limited analysis of the available hydrochemical data to understand the major processes and controls on water quality within the different aquifers (noting that Shand et al 2022 document some initial steps and recommendations in this regard).

> "To date, no regional study has been carried out on variations in groundwater quality. Various parameters have been mapped but little interpretation of the data has been made. The water quality dataset is extensive and offers an opportunity to obtain more information about processes such as recharge and

rock-water interaction. Studies of the level as those done by de Caritat et al. (2019) and Brodie et al. (2021) are considered applicable to the CLA. A certain amount of additional sampling would be necessary to fill in data gaps." (Tickell, 2022).

Additional bores drilled for the SREBA to inform water quality analysis

ELA (2022) contains details of the new groundwater bore drilling and quality sampling conducted for the SREBA. In total, 23 new bores were drilled (See Figure 2), among which 20 were sampled (in two events) specifically for groundwater quality baseline data. Coverage of monitoring bores, encompassing these new sites, across the SREBA area is relatively dense in regions of existing groundwater extraction and historic government monitoring programs (e.g., near Mataranka); but remains sparse in other areas, such as between and Larrimah, Daly Waters and Elliot, and the central Wiso and Georgina Basins (Figure 2). These are areas that overlie the Beetaloo sub-basin rocks and thus may be targets for unconventional gas and groundwater extraction.

The rest of the baseline groundwater quality data reviewed in ELA (2022) and Shand et al., (2022) were collected associated with other projects - e.g., conducted by CSIRO/GISERA and Geoscience Australia, or previous/ongoing NTG monitoring programs. As with the water level monitoring data, there is a strong bias in most studies towards sampling within the CLA – the primary water supply aquifer – with smaller numbers of samples collected from deeper units.

Vertical (and lateral) profiling of groundwater quality and geochemistry

A key aspect of Objective 5 of the SREBA Water Studies (see above) is the characterisation of hydrochemistry and water quality along vertical profiles – i.e., at nested monitoring bores tapping the different aquifer units at different depths. As discussed under the review of Objectives 1 and 2 above, nested groundwater monitoring sites within the SREBA area are rare (e.g., confined to 5 sites with paired bores tapping the upper/lower CLA, and two sites where the CLA and Bukalara Sandstone are both monitored). Hence the objective of vertical groundwater quality profiling remains largely un-addressed.

Ensuring this data/knowledge gap is resolved – along with better understanding of vertical inter-aquifer connectivity between Proterozoic and Cambrian units (see above) is vital to the protection of shallow groundwater resources in areas of potential gas development. End member concentrations and isotopic compositions of key potential contaminants associated with shale gas development (such as methane, boron, and lithium) are required both from water supply aquifers, and units targeted for gas development. This is needed both to detect future impacts, and accurately determine their cause and mechanism (Jackson et al., 2013a; Warner et al., 2014).

Baseline data for key hydrochemical parameters in the context of potential gas development

Shand et al (2022) examined the available data for different water quality/ hydrochemical parameters within the available baseline datasets, within the major

hydrostratigraphic units. A brief summary of the findings (with particular focus on constituents highly relevant in areas of unconventional gas) is given below:

Pysico-chemical parameters

Shand et al., note that data coverage for EC, pH, redox and dissolved oxygen is poor – with fewer than 10% of water quality analyses reporting these parameters. This is important as these parameters are needed if any geochemical modelling is to be carried out, and they can be highly sensitive indicators of potential groundwater impacts associated with hydrocarbon extraction (Van Stempvoort et al., 2005).

Major ions and nutrients

Most of the water quality analyses contained in the baseline datasets include data for major ions, minor ions and nutrients (although generally only nitrate data are available, with limited ammonia and nitrite).

Microbiological components of groundwater

A relatively small subset of bores within the SREBA groundwater quality database (reviewed by Shand et al (2022)) have data on the makeup and prevalence of bacterial communities in the groundwater:

> "Different bacterial analyses (Plate Counts and Coliforms/Streptococci) are available for between 0.7 and 13% of the data. The data were often 'ND', which we assume is not detected.

Van Stempvoort et al., (2005) identified Sulfate Reducing Bacteria (SRB) as a key monitoring parameter in identifying contamination associated with oil and gas activity in Alberta, Canada. It is unclear whether analysis of these bacterial communities has been conducted in the aquifers within the SREBA area.

Organic compounds and gases

A total of 46 organic components are present in the dataset. The main custodians for the data are CSIRO, Geoscience Australia and gas companies. They are typically in the range of 4-8% of analysed samples. Methane concentrations in groundwater have been reported for bores in certain regions of the SREBA area (discussed below in conjunction with methane isotopes).

Minor/Trace elements & radionuclides

Trace element analysis was identified in 0.2 to 18% of samples, while approximately 4% of samples had analysis for gross alpha and beta activity (mainly CSIRO and onshore gas company data). It is assumed that among the trace elements analysed, there would be reasonable coverage of parameters that are important in the context of unconventional gas – e.g. barium, strontium, boron, radium, although a detailed examination of the datasets for these parameters has not been conducted here.

Methane concentrations and isotopes

Methane concentrations in groundwater have been recorded in 216 instances (Table 4 of Shand et al, 2022); among which all but 15 samples are in the CLA. Methane data

from deeper units appear to be highly limited. This is an important knowledge gap given the need to understand the risk of fugitive gas migration in regions of potential unconventional gas activity (Jackson et al., 2013a & b).

It does not appear that any extensive sampling of groundwater for environmental isotopes, to support baseline groundwater quality assessments, was carried out through the SREBA water studies (noting that some isotope data were collected for assessment of flow paths and timescales of flow to the Flora River, by Irvine and Duvert, 2022). This is an important aspect of baseline groundwater quality programs in areas of potential unconventional gas development (e.g., Jackson et al., 2013a & 2013b), as it is required to distinguish different potential sources of methane in groundwater – e.g., thermogenic gas associated with shale gas deposits, vs. gas produced in shallow aquifer via microbial degradation of organic matter.

Data were collected on methane concentrations and isotopic compositions in bores within the SREBA area for a GISERA project (Wilkes et al., 2019) and for the Northern Australia Hydrogeochemical Survey (NAHS) (Schroder et al 2021), which partly overlapped with the SREBA boundary. In combination, these two studies analysed approximately 100 samples for methane concentrations in groundwater (spread across the Beetaloo sub-basin, Tennant Creek, McArthur River and Nicholson South). This review identified 7 samples where isotopes of methane were successfully analysed among the 100 samples (which are a sub-set of the 216 samples identified in Shand et al., 2022).

This is very limited coverage considering the size of the SREBA area and the number of aquifer units potentially containing methane - which could migrate between aquifers as a result of shale gas development. For comparison, the Victorian government's Water Science Studies in the Gippsland and Otway basins, conducted during the Parliamentary inquiry into Unconventional gas (Victorian Government, 2015a & b; Currell et al 2017) sampled a total of 60 bores for methane concentrations (along with major ions, nutrients and a range of hydrocarbons), among which 38 bores were analysed for methane isotopes, including multiple aquifers and depths. Unconventional gas development was at that time only considered a potential scenario (which did not ultimately progress), and the industry and its approvals were at a much less advanced stage than currently in the NT. Characterisation of methane concentrations and isotopic compositions in the SREBA area thus remains a significant knowledge gap.

Summary

A considerable quantity of groundwater quality baseline data have been compiled through the SREBA, including major ion, trace element, and to some extent hydrocarbon and microbial characteristics. A set of additional bores drilled for the SREBA provides some level of increased coverage of water quality data; the data coverage is considerably higher within the CLA compared to other geological units within the sequence from the Beetaloo sub-basin to the surface.

Key knowledge and data gaps in the groundwater quality baseline for the SREBA area to address Objective 5 include:

- A general lack of groundwater quality data for aquifers and hydrostratigraphic units below the Cambrian Limestone Aquifer – e.g., very few analyses from the Bukalara Sandstone, units within the Beetaloo sub-basin and Antrim Plateau Volcanics;

- A lack of detailed characterisation of the major hydrogeochemical processes that control groundwater quality in different aquifers / units within the SREBA area.

- A lack of vertical profiles of groundwater quality/geochemistry with depth, e.g. from the CLA down to the Proterozoic units (and encompassing horizontal transects that capture variability in these vertical profiles associated with geological and other controls), as per SREBA Framework Objective 5

- Limited environmental isotope/tracer data, microbiological analyses and trace/minor water quality components that are important potential indicators of water quality impacts associated with unconventional gas development;

- Characterisation of key isotopic end-member compositions of different waters within the SREBA aquifer system, to enable future analysis of potential causes of any changes in groundwater quality (e.g. due to inter-aquifer mixing induced by greater rates of groundwater extraction, fugitive gas migration in response to gas development, or leakages/surface spills of fracking fluids).

Conclusion

The SREBA water studies were commissioned in response to recommendations of the Scientific Inquiry into Hydraulic Fracturing in the NT and have since collected and compiled a substantial amount of groundwater-related data, towards addressing the SREBA Framework objectives and Pepper Inquiry recommendations. This review has found that, while some of the SREBA water objectives have been largely addressed (or there has been substantial progress towards them), there are still major knowledge and data gaps on topics that are central SREBA Framework objectives. These knowledge and data gaps are summarised at the end of each section of this report and in the Executive Summary.

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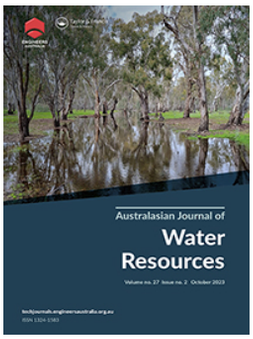

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Risks in the current groundwater regulation approach in the Beetaloo region, Northern Territory, Australia

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ABSTRACT

Plans are underway to greatly increase rates of groundwater extraction from the Northern Territory's Cambrian Limestone Aquifer (CLA), particularly above the Beetaloo sub-basin, to allow expansion of shale gas and agricultural industries. We analyse current groundwater regulations in the NT, and the state of knowledge regarding key aspects of the region's hydrogeology and values sustained by groundwater. We find that the current rules governing the administration of groundwater licencing in areas without a Water Allocation Plan (WAP) – the Top End and Arid Zone rules – are poorly suited to protect ecological, Indigenous socio-cultural and other water use values. These rules (as currently applied) allow the depletion of substantial groundwater storage in areas that fall within the 'arid zone' (as defined in NT policy). Such depletion risks the reduction or loss of groundwater flows to ecosystems and stygofauna habitat and reduced throughflow of groundwater between different regions, within the highly connected CLA system. This may disrupt water flows that sustain local livelihoods and those that are integral to Indigenous peoples' beliefs and cultural practices. The new WAP that applies over much of the Beetaloo sub-basin (Georgina-Wiso WAP) is also deficient in key areas. It has failed to comply with national water policy, in that no substantive steps have been taken to understand Indigenous cultural and ecological values sustained by groundwater prior to setting an Estimated Sustainable Yield. A more precautionary, inclusive approach to determining groundwater regulations would involve a) setting of conservative water extraction limits combined with trigger levels for ecosystem protection and b) co-management in partnership with Aboriginal peoples, with both consultation and decision-making processes that recognise their inherent rights and interests in water. This will be critical to avoiding long-term environmental and socio-cultural harm from over-extraction of groundwater.

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1. Introduction

Recent water licencing decisions in Australia's Northern Territory have triggered public controversy, debate, and legal review (e.g. Jonscher 2022; O'Donnell et al. 2022; Water Resources Review Panel 2021). The heightened attention has particularly focussed on groundwater, to which irrigation and oil and gas interests are currently seeking greatly increased access to underpin major expansion plans (Fitzgerald 2022; Scientific Inquiry into Hydraulic Fracturing in the Northern Territory 2018).

Much of the pressure to develop groundwater is within the area underlain by the Beetaloo sub-basin, a thick sequence of sedimentary rocks which host significant oil and gas deposits (Evans et al. 2020). Overlying the Beetaloo and intervening geological sequence is the Cambrian Limestone Aquifer (CLA), a large inter-connected karst system, which hosts substantial quantities of high-quality groundwater (Currell and Ndehedehe 2022; Knapton 2020). Development of shale gas has received support from the federal and Northern Territory governments; however, viability of the industry is contingent upon access to water for sand washing and hydraulic fracturing. Simultaneously, as part of a long-standing commitment to developing the north, governments are encouraging agri-business interests (e.g. irrigated cotton and horticulture) to establish large-scale operations. These plans, which would involve major increases in rates of groundwater extraction from the CLA, have met with opposition from many quarters, particularly Indigenous organisations and conservation groups, who are concerned about over-extraction and pollution (Fitzgerald 2022).

Groundwater flows underpin ecological, cultural, and economic values throughout the NT (Barber and Jackson 2011; Currell and Ndehedehe 2022; Pusey et al. 2020). They sustain the episodic rivers that Jackson et al. (2008) identified as sites of considerable cultural significance to both Indigenous traditional owners and the settler population. Most water supplies, e.g. stock water for pastoral stations and small

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community supplies, are sourced from CLA groundwater bores, and many tourist enterprises depend on springs and dry season flows sourced from the aquifer. It is thus imperative that groundwater is managed sustainably and equitably, in ways that aspire to ensure these values are maintained, and all stakeholders are afforded meaningful participation. The rights and interests of Indigenous peoples warrant particular attention because as with surface water, groundwater is governed by rich and complex Indigenous institutions of ownership and management (Jackson et al. In Press; Langton 2002).

The Northern Territory has been described as a 'hydrological frontier' (Langton 2002), within which water licencing and allocation rules and processes lag behind national standards, such as the National Water Initiative (NWI), and which – according to O'Donnell et al., (2022), perpetuate a system of colonial extraction that disproportionately disadvantages Indigenous traditional owners. As development pressures on groundwater increase in the NT, progress on water allocation plans (WAPs) has been slow, and to date most groundwater licences have been granted in areas without WAPs, using 'contingent' allocation rules (see Section 3).

Despite detailed recommendations from the 2017 Scientific Inquiry into Hydraulic Fracturing chaired by The Hon Justice Rachel Pepper (hereafter referred to as the Pepper Inquiry), including the need for more robust water planning processes and resolution of major scientific knowledge gaps prior to the establishment of a shale gas industry, progress towards these objectives has been limited. The NT government's Strategic Regional Environment and Baseline Assessment framework (SREBA) was designed to address the knowledge gaps identified in the Pepper Inquiry (Northern Territory Government 2020). The SREBA was completed and released in May 2023 (DEPWS 2022); however, significant gaps identified by the Pepper Inquiry – such as understanding inter-aquifer connectivity and social impacts on Indigenous peoples, remain un-addressed (Currell and Ndehedehe 2023; Ritchie 2023).

Considerable uncertainty remains regarding key aspects of the CLA (and wider NT) groundwater resources, such as the timing, mechanisms and rates of groundwater recharge and discharge, the dependence of these flows on climatic and other variables, the level of connectivity between different aquifer units and (sub-)basins, and the tolerance of ecosystems – both above ground and subterranean – to changes in groundwater flows, levels, and quality (Currell and Ndehedehe 2022, 2023; Evans et al. 2020; Northern Territory Government, 2021).

The process by which water allocation plans have been developed has also been criticised for lacking transparency, providing limited opportunities for public participation, for facilitating piecemeal assessments of environmental risks and failing to mitigate risks to Indigenous communities (Fitzgerald 2022; Ritchie 2023). The scientific rationale for allocating large volumes of groundwater from the CLA to industry has been disputed and subjected to legal challenge (e.g. Water Resources Review Panel 2021). In combination, these governance issues create a significant risk of harm to the groundwaters of the NT, the values and uses they sustain, and the rights and interests of Indigenous peoples.

The main objectives of this paper are to analyse current groundwater regulations in the NT, the state of knowledge regarding the region's hydrogeology and values sustained by groundwater, and risks to these values should rates of extraction increase under current management arrangements. We begin with a summary of contextual information about the study area (Section 2). We define this as the CLA, particularly within the Beetaloo Strategic Regional Environmental and Baseline Assessment (SREBA) area (Figure 1), the focus area for addressing water knowledge gaps identified in the Pepper Inquiry. We then review the water licencing and allocation regime in the Northern Territory and analyse risks to groundwater-supported values inherent in this regime (Section 3). Our focus is particularly on rules that apply to licencing decisions outside of water allocation plan areas – which includes significant parts of the SREBA area – as well as the recently announced (November 2023) Georgina Wiso Water Allocation Plan (Northern Territory Government 2023c), which overlaps with the southern SREBA area. We then summarise key values at stake which may be at risk of harm if increased groundwater extraction is permitted under the current management regime (Section 4). Finally, we provide recommendations to help chart a path towards effective, equitable, and sustainable co-management of groundwater (Section 5).

2. Study/focus area

2.1. Geographic setting including social context

The Cambrian Limestone Aquifer (CLA) underlies approximately 28,000 km^2 of the Northern Territory (Figure 1). The subtropical climate of alternating wet and dry seasons means that surface water availability is highly seasonal and, in many places, limited. Average yearly precipitation increases from approximately 350 mm in the south (near Tennant Creek) to ~1200 mm at the aquifer's northernmost extent (between Darwin and Katherine). Potential evapotranspiration follows an opposing trend, decreasing from ~3600 mm in the south to ~2400 mm in the north. Most rivers flow freely, without major water

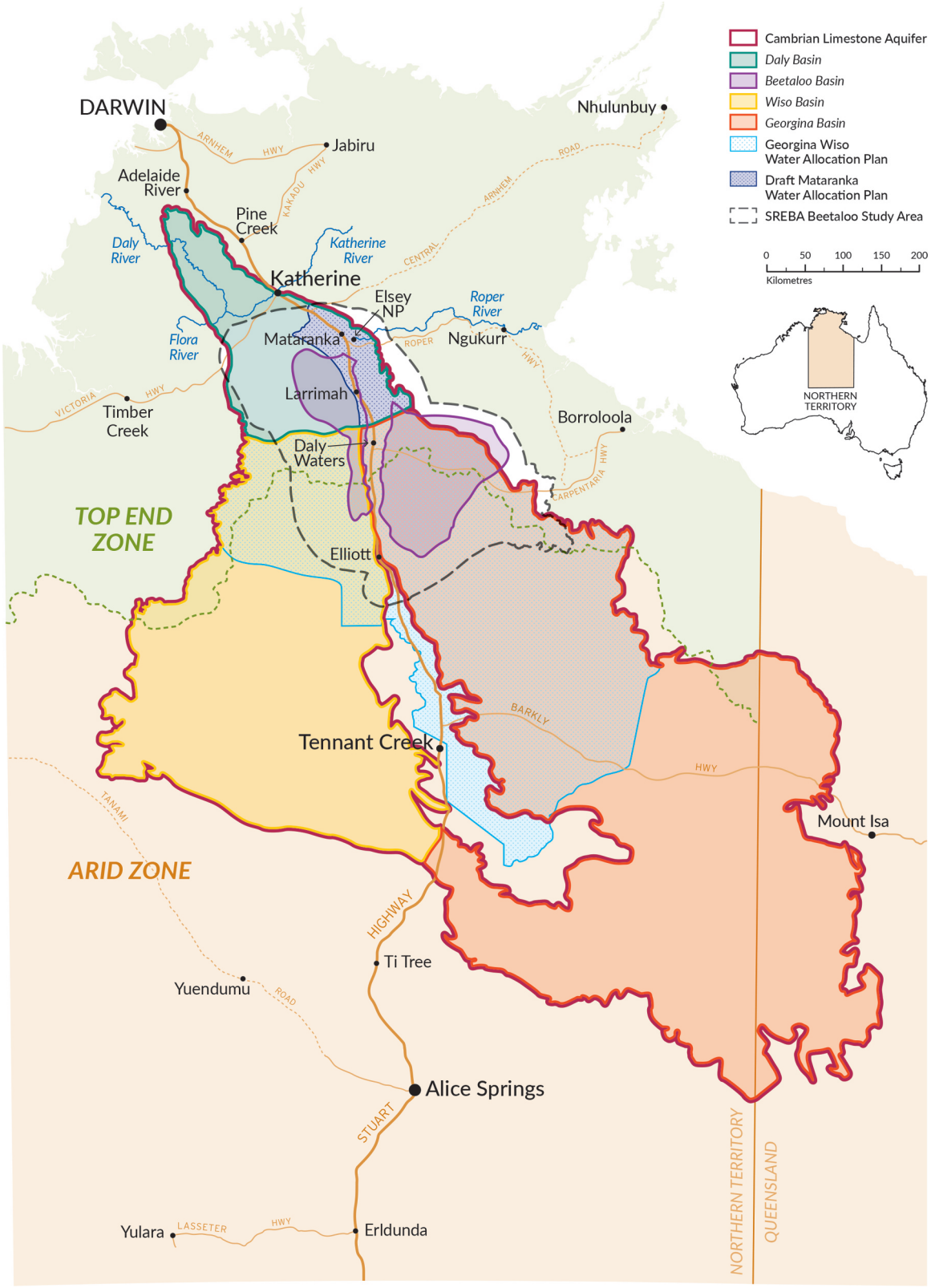

Figure 1. Location of the study area showing extent of the Cambrian Limestone aquifer (CLA) and underlying Beetaloo basin, the boundary between Top End and Arid zones as defined in the NT water allocation framework, and relevant water allocation plan areas. SREBA = Strategic Regional environmental and Baseline Assessment area, as defined in Northern Territory Government (2020).

storage or harvesting infrastructure. CLA groundwater, extracted from bores, supports community water supplies and the pastoral industry, as well as limited irrigated agriculture (Northern Territory Government 2017). The region is characterised by low population density with only two large towns, Katherine and Tennant Creek, which are also largely reliant on groundwater.

Numerous Indigenous language groups hold non-exclusive native title rights to substantial tracts of land

throughout this region. Approximately 10% of the SREBA area is held as Aboriginal freehold title under Commonwealth land rights legislation (DEPWS 2022). The members of these Traditional Owner groups are closely connected to their lands and waters via customary tenure, pre-historical, historical, and/or contemporary residence, the continued use of aquatic resources, cosmological beliefs and a body of environmental knowledge accumulated over hundreds of generations. There is evidence that Indigenous peoples have acted as purposeful environmental managers, e.g. manipulating the flows of water sourced from the CLA along the Roper River for centuries (Barber and Jackson 2014, 2015). This points to the need to better understand Indigenous water management practices and to draw on Indigenous knowledges to collaboratively govern water.

2.2. Hydrogeology of the CLA

The CLA comprises inter-layered limestone and mudstone, ranging in thickness from approximately 20 m to over 400 m, within three basins – Daly, Wiso, and Georgina (Figure 1). Most groundwater flow occurs within secondary porosity (fractures and karst features) in limestone. There is significant cross-basin connectivity between groundwater flows in equivalent limestone units in the three basins, indicated by hydrochemistry, water levels and stygofauna surveys (Knapton 2020; Oberprieler et al. 2021). The CLA is overlain by Cretaceous rocks; where these are absent, recharge to the aquifer and/or discharge to surface water as springs and baseflow to rivers occur (Evans et al. 2020; Knapton 2020). Underneath (i.e. deeper than) the CLA, sits the Beetaloo sub-basin, a ~5 km-thick sequence of Proterozoic sedimentary rocks that host saline water, oil and gas. The Beetaloo underlies the northern Georgina and Wiso basins, and southern Daly Basin (Figure 1). Connectivity between groundwater in the CLA aquifers and Beetaloo basin (as well as intervening sedimentary and volcanic rocks) remains generally poorly understood, notwithstanding some geophysical and geochemical investigations undertaken since the Pepper Inquiry (Frery et al. 2022; Tickell 2022). A deep component of groundwater flow (from below the CLA) to springs at Mataranka has recently been identified, based on isotope studies, in addition to substantial flows from the CLA (Lamontagne et al. 2021).

Groundwater salinity is variable, generally ranging between 500 and 2500 mg/L total dissolved solids (TDS), albeit with some zones that are significantly more saline (Tickell and Bruwer 2017). This groundwater is generally suitable for stock watering, irrigation, and in some cases, potable supply. Aquifer hydraulic parameters – e.g. transmissivity and storativity, have been estimated based on pumping tests, with the greatest density of these having been completed in the Daly Basin (Bruwer and Tickell 2015; T 2022; Tickell and Bruwer 2017). Transmissivity (T) varies considerably depending on local geology but in some regions greatly exceeds 500 m^3/day/m; considered prospective for the development of water supplies.

Estimation of groundwater recharge across the CLA has been attempted using multiple approaches (Table 1), all of which have acknowledged limitations, mostly due to the large geographic area and gaps in data coverage – both spatial and temporal. Groundwater discharge mechanisms and rates – e.g. baseflow to streams, springs, and inter-aquifer/inter-basin leakage – are poorly quantified over most of the CLA (Evans et al. 2020). The exception is the Roper River and Mataranka Springs, where groundwater from the Tindall Limestone (the major CLA aquifer in the Daly Basin) sustains permanent pools, wetlands, and river sections, making up a significant proportion of the flows in the Roper River, and tributaries in the upstream catchment (Bruwer and Tickell 2015; Karp 2008; Lamontagne et al. 2021). Table 2 summarises key data and knowledge gaps regarding the hydrogeology of the CLA, based on recent reviews (Currell and Ndehedehe 2022, 2023).

3. The NT Government's approach to groundwater licencing and management

Water licencing is administered under the Northern Territory Water Act (1992). The Act provides for the creation of WAPs but this is not mandatory (see 22B(1)). If there is a plan in place, then '[w]ater resource management in a water control district is to be in accordance with any water allocation plan declared in respect of the district' (see 22B(4)). WAPs must also allocate water within the Estimated Sustainable Yield (ESY) to beneficial uses (s.22B(5)), noting that there is no definition of ESY contained in the Act.

The delineation of plan area boundaries only partially aligns with hydro(geo)logical boundaries (Figure 1). While the recently declared Georgina-Wiso WAP covers a large portion of the CLA, there remain significant areas of the aquifer system outside declared plan areas. In 2022, only approximately 30% of water licences in the NT applied to areas with a WAP (O'Donnell et al. 2022). The NT Government is working on a WAP for the Mataranka region – where most groundwater extraction from the CLA has been focussed to date (see Figure 1); this area covers only a sub-region of the wider Daly basin. Planning for the Flora River WAP (also within the Daly basin) is yet to commence.

Table 1. Estimates of groundwater recharge rate to the CLA.

Basin/Unit(s)	Point-based recharge rate estimates (mm/year)	Volumetric recharge rate (CLA)	Method(s) used	Reference
Daly Basin (Tindall Limestone).	8.7 to 28.5 mm/yr (diffuse recharge in areas of shallow/exposed CLA)	Approx. 330 GL/yr (range from 286 to 722 GL/yr).	Water table fluctuations, Chloride mass balance, water balance, model	Bruwer and Tickell (2015)
		177 GL/yr	Coupled ground-surface water modelling	Knapton (2020).
	49 to 156 mm/yr (5^{th} to 95^{th} percentiles)		Chloride mass balance, probabilistic, constrained using baseflow separation & remote sensing data	Crosbie and Rachakonda (2021)
Georgina Basin (Gum Ridge/ Anthony Lagoon Formation)	0.9 to 12.2 mm/yr (diffuse recharge in areas of shallow/exposed CLA)	20 to 179 GL/yr (Gum Ridge Fm) 51 GL/yr (Anthony Lagoon Fm)	Chloride mass balance	Tickell and Bruwer (2017)
	5 to 18 mm/yr (diffuse recharge, 5^{th} to 95^{th} percentile)		Chloride mass balance, probabilistic, constrained using baseflow separation & remote sensing data	Crosbie and Rachakonda (2021)
		315 GL/yr (Georgina);	Coupled ground-surface water modelling	Knapton (2020)
		585 GL/yr	Coupled ground-surface water modelling	Northern Territory Government, 2023a.
Wiso Basin (Montejinni Limestone)		46 GL/yr	Coupled ground-surface water modelling	Northern Territory Government, 2023a.
	9 to 31 mm/yr (5^{th} to 95^{th} percentile)		Chloride mass balance, constrained using baseflow separation and remote sensing data	Crosbie and Rachakonda (2021)
Beetaloo region (including northern Georgina and Wiso basins, and southern Daly basin)	1 to 25 mm/yr (diffuse, increasing from south to north); 140 to 190 mm/yr (preferential recharge through sinkholes)		Tritium, Chloride mass balance (recharge rate); CFCs, SF6 and noble gases (qualitative insights)	Deslandes et al., (2019)

Table 2. Current status of knowledge regarding groundwater resources of the CLA.

Question/issue	Daly Basin	Georgina Basin	Wiso Basin	Beetaloo sub-Basin	Reference(s)
Groundwater monitoring network	Moderate to good	Moderate to good	Poor to moderate	Poor	Northern Territory Government, 2021; Amery and Tickell (2022); Currell and Ndehedehe (2023)
Inter-aquifer connectivity	Moderate	Poor – moderate	Poor	Poor	Lamontagne et al., (2021); Frery et al., (2022); Northern Territory Government 2021; Tickell (2022); Currell and Ndehedehe (2023).
Aquifer extent and thickness	Good	Moderate – good	Moderate	Poor – moderate	Evans et al., (2020); Northern Territory Government, 2021; DEPWS (2022)
Aquifer hydraulic parameters	Moderate – good	Moderate	Moderate	Poor	Northern Territory Government, 2021; Tickell and Bruwer (2017); Knapton (2020); T (2022)
Groundwater recharge and discharge processes, locations and rates	Moderate – good	Moderate – poor	Poor	Poor	Northern Territory Government, 2021; Currell and Ndehedehe (2022); Table 1 (this paper).
Dependence of ecosystems on groundwater	Moderate	Poor-moderate	Poor-moderate	Poor	Karp (2008); Knapton (2009); Lamontagne et al., (2021); Oberprieler et al., (2021); Gautam et al., (2022).
Tolerance of GDEs to changes in water level & quality	Poor	Poor	Poor	Poor	Currell and Ndehedehe (2022); Currell and Ndehedehe (2023)
Indigenous cultural values associated with groundwater	Moderate – good	Poor	Poor	Poor	Barber and Jackson (2012); (2014); (2015); Cooper and Jackson (2008); Northern Territory Government (2023a)

In the absence of a WAP, the policy governing groundwater licencing is the 2000 Northern Territory Water Allocation Planning Framework, which defines two separate zones – Top End and Arid Zone (Figure 1). Within these zones, different rules determine the amount of groundwater that can be extracted.

In the 'Top End' Zone:

- '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 'Arid Zone':

- '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'. (Northern Territory Government 2000).

Limited information is available to explain the rationale for this approach, although testimony to the Australian Senate in 2003 by a former NT Water Controller provides some indication:

> . . . we seek to retain at least 80 per cent of river flows and 80 per cent of the ground water resource for environmental use. Thereby, in a planning sense and in our licensing procedures, we are looking to license up no more than. . .20 per cent of the ground water recharge. In a ground water balance sense . . . that means that we are retaining at least 80 per cent of the discharge to the environment from ground water systems.

Regarding the Arid Zone rules, the NT Water Controller said:

> The behaviour of our aquifers is different in the south than in the north. Our recharge mechanisms are fundamentally different and are much lower, but we have much larger storage. Our policy for aquifers in the southern two-thirds is to permit mining of the resource over at least 100 years, but our mining at this stage is limited to 80 per cent of the aquifer storage at the start of extraction.[1]

A more recent licencing decision (described below) and various media statements made by the Northern Territory Government since[2] indicate that it believes the Arid Zone rules can be applied more widely, including north of the previously determined boundary – i.e. within the Top End zone (Fitzgerald 2022; Bardon 2022). There are, however, multiple problematic aspects to the Arid Zone rule, which we summarise briefly below.

3.1. Location of the zones with respect to groundwater systems of the NT

The Top-End/Arid Zone boundary line (Figure 1) corresponds to the division between northward and southward draining surface water catchments (Short and Bond 2021). It also broadly corresponds with climatic variables, such as the 600 mm average yearly rainfall isopach – although 600 mm/year is higher than accepted definitions of 'arid' (Tchakerian and Pease 2015). However, the line does not correspond with a meaningful hydrogeological boundary (e.g. a groundwater divide or geological basin boundary). Importantly, the CLA in both zones is interconnected, meaning throughflows from the south (within the Arid Zone) contribute groundwater to the north, in the Top End zone (Knapton 2020; Tickell and Bruwer 2017). This was recognised during a legal challenge in 2020 to a large groundwater extraction licence (10,000 ML p.a.) issued to the NT Land Corporation near Larrimah. The aquifer to which the licence applied fell within the Top End Zone; however, the NT Water Controller applied the Arid Zone rule when granting the 'speculative' licence (see O'Donnell et al. 2022; Water Resources Review Panel 2021). The expert panel analysing the matter concluded that:

> The application of a significantly different allocation criteria of 20% of storage available for consumptive use (Top End Zone) to 80% of storage available for consumptive use (Arid Zone) to different portions of an aquifer system with high geologic and hydraulic connectivity is not consistent with proper groundwater management. It is not logical to have significantly different allocation criteria in neighbouring management areas for a hydraulically and geologically continuous aquifer, especially if it is important to maintain throughflow and natural discharge to the Roper River. (Water Resources Review Panel 2021)

This issue is critically important when considering the drafting of water allocation plans (WAPs). The recently declared Georgina-Wiso WAP area sits adjacent to the boundary of the yet-to-be declared Mataranka plan (see Figure 1). Within these regions, different maximum extraction rates are anticipated to apply. Given strong evidence of inter-connectivity throughout the CLA, it is imperative that these plans are coordinated to ensure extraction rates in one plan area do not adversely affect groundwater flows or levels in adjacent areas and that total extractions across the CLA are cumulatively sustainable.

3.2. Out-of-step with sustainable groundwater management best practice

The Pepper inquiry reviewed the NT Water Allocation Planning Framework and found that the use of the Arid Zone contingent rules (for onshore gas or any other extractive use) would: 'essentially permit "mining" of the groundwater resources and would be ecologically unsustainable' (Scientific Inquiry into Hydraulic Fracturing in the Northern Territory 2018). While the first part of the Arid Zone rule requiring 'no deleterious change in groundwater discharges to dependent ecosystems' would appear to be

a safeguard against 'mining' of groundwater, in practice, knowledge of the water requirements of GDEs in the NT is at an early stage of development, and as such it is the second criteria – permitting no more than 80% depletion of storage over a century – that primarily applies to decisions, and which is emphasised in government statements invoking the rule (e.g. Fitzgerald 2022).

The key management tool within the Water Allocation Planning Framework and draft WAPs is the Estimated Sustainable Yield (ESY) – that is, the volumetric rate of extraction permitted in each area. The concept of Sustainable Yield in managing groundwater has developed over more than 100 years in line with increasing understanding of interconnections between groundwater and other parts of the water cycle, and awareness of the ecological and sociocultural values groundwater sustains (Alley, Reilly, and Franke 1999; Bierkens and Wada 2019; Ponce 2007). Early thinking on the topic began with the 'Safe Yield', which hypothesised that if extraction rates did not exceed annual recharge, an aquifer would be protected against long-term storage depletion (Lee 1915; Todd 1959).

It was subsequently shown that this does not account for the critical role played by groundwater discharge in maintaining surface flows to streams, springs, and connected ecosystems (Theis 1940). These flows, as well as recharge itself, may be changed significantly by groundwater pumping, irrespective of whether extraction matches the rate of recharge (Alley, Reilly, and Franke 1999; Figure 2). Extracting the annual recharge flowing into an aquifer deprives the downstream environment of these flows and may induce additional recharge of water that is otherwise important to the surface environment. Collectively, these are termed 'Capture' (Theis 1940) which, depending on the context, may cause serious unacceptable environmental, social, cultural and/or economic impacts. Further, there is a growing understanding that major climatic events such as prolonged droughts can result in long-term and potentially irreversible changes in catchment behaviour (Peterson et al. 2021) and that climate change may shift rates of recharge and discharge continually into the future (changing what may previously be considered a sustainable yield). Tree-ring studies in the Daly River catchment (for example) indicate that the past few decades have been the wettest in approximately 600 years (Higgins et al. 2022); such conditions may not be stable or representative of rainfall patterns in the coming years and centuries.

The Arid Zone rule's two main components (no deleterious effect on GDEs and depletion of aquifer storage by up to 80% over 100 years) may appear to be distinct criteria; however, they are strongly interdependent. In systems receiving limited recharge, we argue that they are contradictory (Currell and Ndehedehe 2022). In settings where recharge is small relative to overall aquifer volume, extracting 80% of storage will inevitably result in the loss of groundwater flows to connected aquifer regions, surface water systems and GDEs. GDE health depends upon maintenance of aquifer water levels above thresholds which allow groundwater discharge to springs and baseflow to rivers, evapotranspiration by vegetation, and stygofauna habitat. Crucially, it also depends upon maintenance of flux rates to surface discharge points along

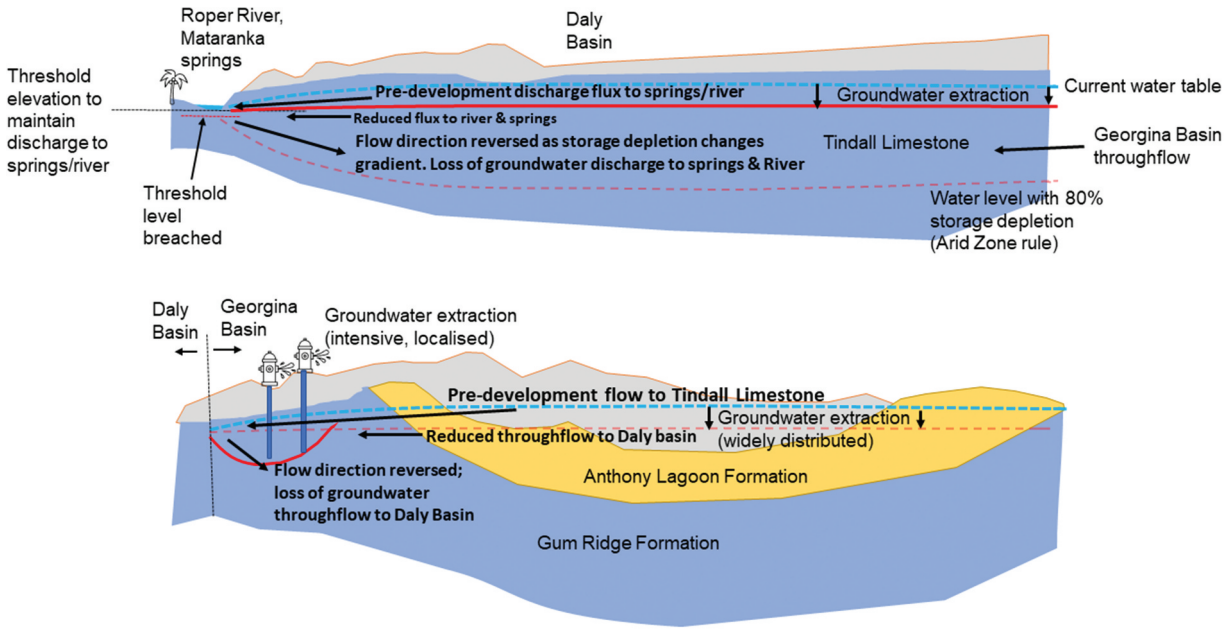

Figure 2. Conceptual representation of the risk/impact of increasing rates of extraction from Cambrian Limestone aquifer subregions (modified from Currell and Ndehedehe 2022). Note that water level surfaces are approximate representations, for visualisation purposes only.

the groundwater flow path. This is strongly related to the maintenance of aquifer water levels (i.e. storage depletion) though often in a non-linear way (Zipper et al. 2022).

As such, establishing the mechanisms, rates and importance of groundwater flows to the surface (e.g. river baseflow and spring flows), encompassing throughflows along regional flowpaths, and acceptable levels of impact to these is central to estimating the sustainable yield. Aside from discharge to the Roper River from the CLA (which has been quantified within reasonable levels of confidence), there has been limited quantification of discharge flows to the surface and establishment of associated threshold aquifer water levels required to sustain these, elsewhere in the CLA (see Table 2).

Permitting the 'mining' of a substantial fraction of storage under the Arid Zone rules or allocating an Estimated Sustainable Yield without clear understanding of groundwater discharge rates and processes, risks harm to GDEs, through one or a combination of:

a) Groundwater levels at points of discharge (e.g., spring or riverbank) may reduce below a threshold elevation, which causes groundwater flows to the surface to cease
b) Groundwater flow gradients change in direction and/or magnitude, such that groundwater flux from the aquifer reduces or no longer flows in the direction of the GDE
c) Throughflow between different CLA basins – e.g., from the Georgina or Wiso Basin in the south into the Daly Basin in the north, may be reduced by changes to groundwater flow gradients, with potential flow-on effects on GDEs distant from the point of extraction. (including the iconic Mataranka springs and upper Roper and Flora rivers)

For two of the CLA basins (Daly and Georgina), these impacts are represented conceptually in Figure 2:

3.3. No accounting for socio-cultural and conservation values and exclusion of local voices

Here, we turn our critique to the recently declared Georgina-Wiso WAP (Northern Territory Government 2023c). The Plan was drafted and declared without oversight from a stakeholder advisory committee, departing from standard practice in the NT, and expectations of the NWI. The WAP allocates a large volume (210 GL/year) to consumptive uses, which (if fully utilised) would be a 14-fold increase on current extraction rates. This has been done without considering the water requirements of places of importance to Indigenous people and of high conservation value. For these and other inadequacies, the Northern Land Council called on the NT government to withdraw the plan (Northern Land Council 2023); however, this appeal was ultimately ignored.

Some 13% of the land area regulated by the Plan are recognised as eligible Aboriginal land to which the Aboriginal Reserve (20,251 ML/p.a.) applies under the NT's Strategic Aboriginal Water Reserve Policy (Northern Territory Government 2023c). The purpose of the Strategic Aboriginal Reserve is to secure access to water to Aboriginal landowners for economic benefit (O'Donnell et al. 2022). However, there is no evidence in the WAP and associated documents (Northern Territory Government 2023c,b,c) that in determining the ESY, consideration was given to the cultural and social aspects of the environment. Further studies are proposed in the Implementation Actions statement; however, key Indigenous cultural sites relying on water and their requirements will not be identified until sometime between 2026 and 2028 (and other social and cultural values not until 2028). The monitoring of Indigenous cultural values is scheduled to commence in 2027–2028 (Northern Territory Government 2023b).

No effort was made to ascertain the water requirements of any places or activities of cultural significance or specify what management actions would protect such places or uses. The Council of Australian Government's Guidelines on Water Planning (2017) state that:

> Quantifying the volume, flow and timing of water required to realise cultural outcomes is fundamental if Indigenous peoples' needs for water are to be met through water planning and management processes. While there may be some alignment between cultural and environmental water needs, it is important to note that this is not always the case and there may be a need to differentiate cultural and environmental water requirements. (p 15)

The establishment of an Aboriginal Reference Group is proposed in the Plan as a means of obtaining information on cultural values and uses, however if such a group is created it may occur after licences are granted. The failure to provide a mechanism through which Indigenous voices, values, knowledge, experience, and priorities are to be considered and incorporated in the water planning and decision-making process is inconsistent with clause 52(i) of the National Water Initiative (NWI), which states that planning processes should ensure 'inclusion of indigenous representation in water planning wherever possible'.

No reason has been given by the government for why it was not possible to ensure meaningful engagement in this case, however the independent officer charged with overseeing the implementation of the recommendations of the NT's fracking inquiry attributed the omission to 'the imperative to meet the 31 December 2022 target' in the

government's Pepper Inquiry Implementation Plan (Ritchie 2023). In advice to the NT Chief Minister in May 2023, Dr David Ritchie cautioned the government:

> The fact that regional Water Advisory Committees have not yet been appointed for the areas where the onshore gas industry plans to expand their operations has reinforced the perception held by many Aboriginal people in affected communities that the traditional significance of groundwater has been ignored by government and industry. In the five years since the [Pepper] Inquiry's Final Report, the inadequacy of meaningful engagement with Aboriginal people in remote communities about their traditional concerns has continued to draw both condemnation and calls for remedial action by governments. (Ritchie 2023)

Furthermore, sub-section (vi) of Clause 25 of the NWI states that parties should 'identify and acknowledge surface and groundwater systems of high conservation value and manage these systems to protect and enhance those values'. The Plan includes a 20 ML/year allocation for environmental purposes (less than 0.01% of the volume allocated for consumptive use), yet the background report (Northern Territory Government 2023a) indicates that groundwater-dependent ecosystem mapping and ground-truthing are yet to be completed. The Plan contends that groundwater discharge to the surface by evapotranspiration does not occur (or is negligible) in the Georgina and Wiso basins, due to generally deep water tables. However, monitoring bore coverage remains sparse, and regions where groundwater is accessed by vegetation may simply remain poorly documented. There are (for example) springs in the western the Wiso Basin, whose vegetation appears likely to be sustained by CLA discharge, but whose water requirements and source aquifer have not been determined (Tickell 2022). Equating deep water tables to a lack of environmental dependence on groundwater also further downplays the importance of regional flows within highly connected aquifer systems like the CLA. Any water extracted along a regionally connected flow path ultimately captures flows to the regional discharge point(s) – which may be outside the plan area (for example, the Roper and Flora Rivers, see Figs 1 & 2). Protecting the ecological value of stygofauna, which inhabit deep aquifer environments, and whose habitat would be lost if water levels decline substantially, has also not been considered as a significant objective of the plan.

4. Values at risk

CLA groundwater is vital to sustaining multiple values – Indigenous and non-Indigenous socio-cultural, ecological, and economic (see Jackson 2006; Jackson et al. 2008; Pusey 2008). Studies of these values have focussed mostly on the northern portion of the CLA (the Daly basin), where intensive water and catchment planning has been underway since the early 2000s. This work is briefly summarised below; readers are referred to the references cited for further detail. Far less is known about the groundwater-related values in Georgina and Wiso basins, which are currently the most prospective areas for shale gas and, potentially, the expansion of large-scale irrigation development.

4.1. Indigenous socio-cultural values

In this region as with the rest of inland Australia, the availability of water shaped the movement of Indigenous peoples, and complex cultural landscapes were constructed around spiritually powerful water bodies created by ancestral beings. Water sources of the CLA, particularly springs, contain higher concentrations of culturally significant landscape features, including places with personal, family or clan group associations (Jackson and Barber 2016). Underground waters are also significant and frequently feature in Indigenous ritual knowledge (Cooper and Jackson 2008). For example, the groundwater-fed baseflows of the Katherine and Flora Rivers provide permanent water sources that sustain ecologically rich ecosystems and are correspondingly rich in the occurrence of Indigenous cultural sites and patterns of occupation and use (Cooper and Jackson 2008).

There are several published studies of the social arrangements and cultural practices relating to water, including the Indigenous knowledge of groundwater and surface water sources, held by cultural groups in the vicinity of the Daly River and Katherine (see Jackson 2006; Jackson and Altman 2009; Cooper and Jackson 2008; Barber and Jackson, 2011; 2014; 2015) and Merlan (1982). Cooper and Jackson (2008) argue that the extent of Indigenous hydrological knowledge is evidenced by the richness of terms and concepts contained within local languages. Every aspect of water as a phenomenon and a physical resource, as well as the hydro-morphological features it creates, is represented, and expressed in the languages of local Indigenous cultures. For example, the Jawoyn language has a term for water which is carbonated or high in lime, *maminga*, and is regarded as 'light water'.

Barber and Jackson (2011, 23–24) interviewed traditional owners of the Roper region. The views documented help explain the central and fundamental importance of water:

> 'Water is life, gives life to the land. It feeds the environment, keeps country cool and healthy. We don't like to damage country. It's good for fishing, swimming, camping. We use it for teaching too- cultural stories, bedtime stories, camping beside the river. Its our heritage. We need it to visit, enjoy life'. M.H.

> 'There is a spring close to Beswick community. That water never dies, it will always be there. It gives us water to drink, and for the animals too'. J.M.

Key sites within the upper Roper catchment to which Aboriginal peoples attach cultural and/or spiritual significance include Red Lily Wetlands, Barlyurra (a complex of water sites upstream of Red Lily Lagoon), waterholes and permanent springs along the Roper River and large riparian trees, which depend on groundwater. Oral accounts from the east of the CLA towards Borroloola are consistent with other accounts of the integral role of groundwater in connecting Aboriginal peoples with their ancestors and other entities across vast distances (Ah Chee 2002; Marshall 2017):

> 'The story of the Walalu, Stranger Rainbow Serpent is very important and very sacred … The Walalu is sometimes called Yankarra, which is Yanyuwa [language] for "the Stranger", he is called this because he came from such a long way away and, once he moves through Garrwa and Yanyuwa country he keeps moving all the way into Marra country, he moves through Alawa and Mangarrayi country, and finishes his journey at the Mataranka hot springs which is far to the west'. (Barber and Jackson 2011)

This knowledge of the inter-connectivity of groundwater over long distances is consistent with hydrogeological and hydrobiological lines of evidence (e.g. Oberprieler et al. 2021), which indicate extensive connectivity between the three basins hosting the CLA. It is thus of critical importance to consider impacts of groundwater usage in one region on others, as well as ensuring the custodians across regions share in making decisions affecting water flows.

Another example comes from the Katherine region where local Aboriginal people know that water is maintained in the Katherine River during the dry season because of the inflow of groundwater from springs. They attribute this inflow to the presence and actions of Rainbow Serpents:

> 'The spring him fill up with water from the ground, so now him dry [dry season] … that river still runnin' from that spring. Him bin that spring all the time. Important because that Rainbow Serpent they sit down there longa spring every time … When him dry you know that the spring gotta have him water because that Rainbol there'. (Cooper and Jackson 2008, 27)

According to Cooper and Jackson (2008), Wardaman knowledge also recognises the role of Rainbow Serpents in creating and maintaining groundwater and springs and provides an explanation of hydrogeological processes observed in western scientific studies. This includes an understanding of the connectivity and direction of flow through limestone strata, e.g. between underground water contained in the Tindall Aquifer and that which emerges at Mataranka and the Flora River (Bruwer and Tickell 2015).

Cultural practices relating to water have been detailed in these studies and court reports, including talking to country, 'watering' strangers and others in 'baptism' rituals, restrictions on behaviour and activities such as fishing, protecting others from harm and management and protection of sites. These practices are a consequence of belief in the continuing spiritual presence in the landscape of creation beings as well as more recent remembered and unremembered ancestors, or 'old people', returned to their countries as spirits (Cooper and Jackson 2008). A determining say in water governance and management is based on the responsibility of traditional owners and custodians to act appropriately within the network of relationships that constitutes Country.

We contend that it is highly likely that similar narratives, beliefs and values are associated with the water flows within and passing through the Georgina and Wiso basins, but the lack of effort to engage with traditional owners and understand these values – as part of water planning process, or western-science focussed research initiatives such as the SREBA, leaves no basis to understand and appropriately manage to protect such values and avoid or mitigate significant risk of harm to them. The Independent Officer overseeing implementation of the recommendations of the Pepper Inquiry concurs with this evaluation, concluding that even after the SREBA reports were released, risks to Aboriginal people and their culture, due to lack of meaningful engagement, remain at an 'unacceptable level' (Ritchie 2023, 13).

4.2. Other cultural, economic, and ecological values

Limited research has been conducted on the cultural groundwater values of the non-Indigenous community. Mataranka springs, encompassing iconic sites such as Bitter and Rainbow springs and Elsey National Park, are major tourism sites, with visitors contributing to the estimated $1.0 billion of direct and $1.2 indirect gross tourism value for the NT (Tourism 2020). There are also approximately 40 GL/year of current groundwater entitlements from the CLA in the Mataranka area – most for irrigated agriculture (Northern Territory Government 2017). Stock and domestic water use are estimated to be considerably lower, however these water supplies are critical for the pastoral industry which generates over $1 billion per year. Loss of access would make many stations unviable.

CLA groundwater also supports surface and subsurface ecosystems that are both obligate (requiring permanent groundwater) and facultative, as defined in Doody et al., (2019). The importance of groundwater

in sustaining Mataranka Thermal Pools, Red Lily Lagoon, Flying Fox Creek, Mainoru River and Wilton River, and associated vegetation communities is relatively well documented (Knapton 2009). These vegetation communities are small in terms of land area but serve as critically important habitat for both local and migratory animals (Short 2020; Woinarski et al. 2000). Fish and flow dependencies have also been established in the Daly sub-basin (Pusey et al. 2020).

Stygofauna are also widespread in the CLA. These were surveyed in the Beetaloo sub-basin and Roper River catchment, after being identified as a knowledge gap in the Pepper Inquiry (Oberprieler et al. 2021; Rees et al. 2020). The surveys identified a diverse range of species, dominated by crustaceans, including the blind shrimp *Parisia unguis*. The occurrence of the same species across the Georgina, Wiso and Daly basins is evidence of high connectivity throughout the CLA system, underscoring the importance of coordinated management that recognises the importance of cross-basin flows and potential impacts to these.

4.3. Key threats to groundwater dependent values of the CLA

We consider the values described above to be at risk under the existing and emerging approach to the NT's groundwater regulation. This is primarily due to the risk of reducing flows to surface and sub-surface GDEs, through both capture and groundwater level reduction (see section 3), interference with existing water supplies, and other poorly understood risks. These include potential compaction of the aquifer matrix (less common in limestone aquifers than unconsolidated sediments, but nonetheless possible – Laroque et al. 1998), and contamination of freshwater through migration of saline water bodies (Currell and Ndehedehe 2022).

Ecohydrological and modelling studies have yet to determine threshold groundwater elevations required to sustain springs and groundwater-dependent streams and vegetation above the CLA, nor have they determined in detail the extent of reduction in baseflows and water levels (and associated environmental impacts) that may occur at different extraction rates in different regions. Previous numerical modelling has examined the effects of groundwater extraction at different rates on baseflow to the Roper River – e.g. Bruwer and Tickell (2015) modelled extraction of 20% of estimated recharge to the Tindall Limestone from a wellfield near Larrimah and found this would reduce baseflow by ~20% in the long term. More recently, numerical modelling of the CLA system (based on the model reported in Knapton 2020) has been used as one line of evidence to develop the ESY for the Georgina-Wiso WAP. These modelling results (included in the Georgina Wiso Background Report 2023–2031) report 'imperceptible' impacts on river flows from simulated extraction at different rates under historic (to 1970) climate conditions. However, clear documentation of input assumptions and model uncertainty and sensitivity analysis for the reported extraction scenarios are not published, and specific water level gradient, flux, and ecological effects of extraction at the proposed ESY remain undocumented (see Northern Territory Government 2023c & c).

The impacts of future drought periods and/or climatic change, which may result in fundamental shifts in aquifer system water balance and behaviour (as demonstrated during the Millennium Drought and subsequent lack of recovery of several catchments in Australia's Murray Darling Basin – Peterson et al. 2021) must also be considered. Mechanisms to adjust management rules in line with the CLA system's response(s) to climate change must be incorporated into WAPs, in line with the intent of the NWI (Walker et al. 2021).

Given that there are, a) significant Indigenous socio-cultural, ecological and water use values associated with the CLA's groundwater documented in the Daly basin and b) a lack of documentation of the nature and extent of these values in the Georgina and Wiso basins – where there is significant development pressure, and c) substantial risk of harm associated with the current groundwater regulatory regime (sections 3 & 4), we urge a precautionary approach to further development and implementation of WAPs, and other groundwater governance measures.

5. Towards sustainable co-management of groundwater

Efforts to reform water management in the NT warrant action on several fronts, including law reform, improvements to the collective knowledge base, wider transparency, public engagement and sharing of decision-making power with Aboriginal custodians. Some of these issues are identified in the recently published Northern Territory Water Plan (e.g. the intention to create Advisory Councils for strategic water advice and enhancing Aboriginal participation in water management). However, the plan does not delve into water allocation planning processes and the role of water advisory committees in developing WAPs or offer substantive models for sharing decision-making power with Aboriginal people (Northern Territory Government 2023d). Here, we make some key suggestions for a path forward, based on the issues identified in sections 3 and 4:

5.1. A robust and transparent approach to determining sustainable yields

The Arid Zone rule appears to be one of the only cases in Australia where a fraction of total storage is a basis for determining 'sustainable' extraction rates. Reliance

on such measures should (in our view) be phased out in line with increasing understanding of the connections and values sustained by groundwater. Instead, more explicit focus should be given to ensuring 'no deleterious change in groundwater discharges to dependent ecosystems' – noting that knowledge of these dependencies needs significant further research in the NT. In the long term, a more effective way to manage the CLA's groundwater, which would align with contemporary best practice, would involve setting extraction rate limits which ensure:

(a) groundwater flows and levels do not decline in ways that compromise the health of key groundwater-dependent ecosystems (springs, wetlands, stygofauna, and phreatophyte vegetation). This requires a careful analysis of recharge and discharge fluxes, environmental dependencies on these, and the extent of 'capture' by pumping at different rates in different areas. Connectivity of the CLA with rivers and throughflow across sub-basins (e.g. Georgina and Wiso basins to Daly basin) must be thoroughly understood, and extraction rate limits set within a given management area must be sustainable cumulatively, in conjunction with those set in adjacent WAP areas.
(b) the renewability of groundwater resources, preventing ongoing storage depletion and/or detrimental capture of surface flows, e.g. by not exceeding any significant fraction of the recharge and/or discharge. In the Murray Darling Basin (for example), Sustainable Diversion Limits (SDLs) are set based on the rate of diffuse groundwater recharge, and modelling/analysis of the impacts of extracting different fractions of recharge on baseflow to streams, GDEs, water quality and aquifer integrity. In areas where such risks are deemed high, SDLs can be set as low as 5% of recharge; in other 'low risk' areas, the fraction may be as high as 70%, although this is rare (Walker et al. 2020).

The ESY set for the 2023–31 Georgina Wiso WAP equates to approximately one-third of the estimated annual recharge – though it is not specifically stated that the value was determined on this basis. While extraction at this rate is likely to be more protective of ecological and cultural values than allowing 80% depletion of storage over 100 years, the highly variable, episodic nature of recharge in this arid region means that:

(a) the ESY will far exceed recharge in most years, leading to some degree of storage depletion and (through reduced throughflows), capture of water flowing to ecosystems
(b) the recurrence interval for episodic recharge events – which are the dominant source of aquifer replenishment, are currently unknown and may vary with climate change. For example, significant recharge may not occur at all during the term of the plan, and the above (a) effects, accumulated over multiple years, may result in environmental damage.

Further, the estimated average recharge rates cited in the Plan are not underpinned by extensive observational data and should be considered uncertain (Currell and Ndehedehe 2022). Given evidence of strong connectivity throughout the CLA (Oberprieler et al. 2021; Tickell 2022), management within and between declared groundwater allocation plan areas must be carefully coordinated, such that flows between sub-basins and regions (which may cross WAP boundaries) are factored into sustainable yield estimations and ongoing monitoring. Managing by aquifer system boundary, rather than sub-regions that do not align with hydro(geo)logical boundaries, would help to facilitate more coordinated sustainable management.

5.2. Readily monitored and enforceable trigger levels and robust adaptive management

In addition to robust determination of ESYs, protection of GDEs further requires clearly defined water level triggers and/or thresholds, e.g. groundwater elevations required to sustain environmental and cultural values of key groundwater-dependent sites and ecosystems (Noorduijn et al. 2019). Under such arrangements, when threshold levels are approached or crossed, reductions in groundwater pumping would be triggered, in line with management approaches adopted in other parts of Australia and internationally (Thomann et al. 2020). Pitfalls associated with the application of such trigger levels in isolation must be considered – for example, triggers must be set at an appropriate distance from the environmental asset(s) seeking to be protected, to account for time-lags between changes in extraction rates, hydraulic gradients, and flow rates in an aquifer. Triggers based on drawdown at the location of a GDE, set without a clear understanding of water flux (as well as level) requirements, remain potentially risky (Currell 2016). Further, there is a need for such management protocols to account for and be responsive to Indigenous knowledge and risk evaluations along with detailed eco-hydrological studies (e.g. Doody, Hancock, and Pritchard 2019). Regular observations and monitored data relating to ecosystem health should inform ongoing, iterative adjustment of management triggers, in line with stakeholder-agreed objectives (Thomann et al. 2020). Acknowledging these issues, the use of

triggers designed to protect GDEs in conjunction with extraction rate limits holds potential to strengthen management via robust and defensible criteria that can be actively monitored.

5.3. Collaborative governance of water

Sustainable and equitable groundwater co-management must address the inherent rights of Indigenous peoples to make decisions regarding the waters flowing within and through their sovereign territories (Marshall 2017; O'Donnell et al. 2022). Statements in recent media reports and published studies (e.g. Jackson and Altman 2009; Jackson et al. 2008; Nikolakis and Grafton 2022) affirm that traditional owners of the CLA region expect that they have a legitimate basis in terms of recognised rights and interests, for assuming a position of at least negotiating parity with non-Indigenous decision-makers and landowners. Such a claim for parity could be expressed in institutions of 'co-management', or sharing of power and responsibility between government and local communities, including in water sharing arrangements. A report by Hoverman et al. (2012), undertaken in partnership with the NT water department, found that there was substantial opportunity for the development of co-management approaches in the NT.

Models of decision-making and rights recognition that fall under the rubric of co-management could form the basis for discussions about wider catchment management and protections of connected surface and groundwaters in the Beetaloo region. In the lower Murray and lakes region of South Australia, for example, co-management partnerships take the form of contractual agreements with water agencies; they are a means of gaining control over Ngarrindjeri jurisdiction (Hemming et al. 2019). In the Kimberley, heritage listing recognises the Martuwarra (Fitzroy) River as a living, or ancestral, being and there are calls from the Indigenous Martuwarra Council for recognition of pre-existing and continuing legal authority of Indigenous law and more substantive legal protections (RiverOflife et al. 2021). Aotearoa/New Zealand has progressed co-management of freshwaters (Taylor et al. 2021) for example, legislation arising from a treaty settlement explicitly recognises that the Waikato River is a *tupuna* (ancestor) and established the Waikato River Authority composed of Maori and Pakeha representation (Te Aho 2010). More recently, a new Conservation Order for the Te Waikoropupū freshwater springs was enacted, following collaboration between iwi Ngāti Tama ki Te Waipounamu Trust, and local conservationists, who filed a joint legal action (Ministry for the Environment New Zealand 2023). In Canada, First Nations are challenging state assertions of control over traditional territories and weak consultation and assessment processes that ignore cumulative or broader catchment impacts. Curran (2019) explains that Canadian First Nations are establishing administrative and governance structures that express their water laws and jurisdiction. Many of the examples involve the formation of new catchment scale Indigenous bodies and advocates, to assert the right of free and prior informed consent over water licencing.

Such approaches should extend to the production of 'two-ways' hydrological knowledge. Scientific practices of estimating yield and principles of sustainability need to respond to the wealth of Indigenous knowledge of groundwater systems in the Northern Territory. This would also include developing the means to measure and monitor success and act on Indigenous principles and ethics of 'caring for country'. As water management is fundamentally a governance challenge, the priority for reform is to establish a dialogue and build the capacity to negotiate collaborative partnerships, founded on consent, customary law, and plurality of knowledge and values.

Notes

1. Rural and Regional Affairs and Transport References Committee Senate transcript 18/11/2003: https://parlinfo.aph.gov.au/parlInfo/search/display/display.w3p;query=Id:committees/commsen/7147/0004
2. The statements were made in 2022 in response to community opposition to an application to extract groundwater (1,200 ML p.a.) to mine sand near Larrimah (Fitzgerald 2022) and in a meeting of the Mataranka Tindall Water Advisory Committee, 12 August 2021 (https://depws.nt.gov.au/__data/assets/pdf_file/0008/1049453/mataranka-tindall-wac-meeting-11-minutes-and-appendices.pdf)

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From: [redacted]
To: imperial ep187+
Subject: REFUSE Carpentaria Pilot Production EMP
Date: Thursday, 18 April 2024 4:11:46 PM

To whom it concerns,

I submit that the current proposal put forward by Empire Energy be refused outright on the following grounds:

- The greenhouse gas emissions from this project are very significant and Empire Energy has not even attempted to measure the levels that would be produced from the gas that they intend to send downstream from the project via the McArthur River gas pipeline.
- There is a major discrepancy between what they claim will be the daily gas production from the project (25 Terajoules) as opposed to the daily capacity of the pipeline (15TJ). They do not explain this discrepancy nor give any estimation of emission levels if this excess gas were to be burned off.
- The area proposed is a major flood zone and yet the proposal is for waste water to kept in open tanks with a major risk of contamination into the natural environment and waterways, especially during the Top End wet season.
- The volume of water that they plan to extract from the aquifer is way in excess of the current water licences that have been issued and poses another major risk to the environment.
- The land clearing will have an impact on three nationally listed threatened species; the grey falcon, Gouldian finch and the Painted Honeyeater as well as another five species of migratory birds that use the area.

In addition I ask that the project be required to undertake a full Environmental Impact Statement under the Environment Protection Act 2019(NT) and that the project proposal be referred to the Federal Environment Minister under the Environment Protection and Biodiversity Conservation Act (1999) as it is likely to have a significant impact on water resources.

Yours Sincerely,

[redacted]
Jingili, NT 0810

From:	Have Your Say Northern Territory
To:	imperial ep187+
Subject:	Anonymous User completed Carpentaria Pilot Project EP187 Environment Management Plan
Date:	Thursday, 18 April 2024 5:00:22 PM

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Anonymous User just submitted the survey Carpentaria Pilot Project EP187 Environment Management Plan with the responses below.

Given name

[redacted]

Family Name

[redacted]

Location

JINGILI, NT

Stakeholder type

Community member

Email address

[redacted]

Interest area

Social and cultural
Flora and fauna
Water
Waste management
Climate change
Human health

Please provide your comments

I absolutely oppose the above proposal. The cultural, environmental and health risks are far too great without benefit to the community (CEO profiteering does not justify this destruction). There can be no place for fracking on this sacred land.

Tick this box if you wish for your name and contact details to be confidential

Make my name and contact details private

From: [redacted]
To: imperial ep187+
Subject: SUBMISSION - Carpentaria Pilot Project EP-187
Date: Thursday, 18 April 2024 6:40:50 PM
Attachments: [redacted]

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

To whom it may concern,

Find attached the Central Australian Frack Free Alliance's submission regarding Empire Energy's proposed work program on EP187.

Kind regards,

[redacted]
on behalf of the Central Australian Frack Free Alliance

17 April 2024

DEPWS Petroleum Operations Unit,
Northern Territory Government
By email: imperial.ep187@nt.gov.au

SUBMISSION - Carpentaria Pilot Project EP-187

The Central Australian Frack Free Alliance (CAFFA) welcomes the opportunity to comment on the Environment Management Plan submitted by Empire for its proposed works on country overlapping the Carpentaria Highway west of Cape Crawford; exploration permit 187 ('the EMP').

Acknowledgement of Country:

The land where the Central Australian Frack Free Alliance (CAFFA) is based is the unceded sovereign Country of the (Central) Arrernte people. We acknowledge the Arrernte people as the Traditional Owners and Custodians of Mparntwe/Alice Springs and ongoing resilience and resistance in the face of colonialism.

We stand with Traditional Owners and Custodians in the Northern Territory and beyond who seek to protect their Country and water from fracking. We support the self-determination of First Nations people everywhere.

About us:

The Central Australian Frack Free Alliance (CAFFA) is a grassroots community group located in Mparntwe/ Alice Springs organising to protect the NT's water, health, communities and country from the harms of unconventional gas extraction. We have been active over the last nine years in raising awareness within the Central Australian community about the risks posed by this poorly regulated and inherently dangerous industry. The Central Australian Frack Free Alliance opposes fracking and all new fossil fuel projects in the Northern Territory.

Our work has seen CAFFA engaging with the community through market stalls, letterboxing, community surveying and other social events. In taking action, CAFFA stands alongside Traditional Custodians who are fighting to protect water, country and culture. We take our mandate from the people of Alice Springs: 80% stated they do not want fracking in a December 2022 survey, with just 5% in favour.

To build community capacity for opposition to new fossil fuel extraction, CAFFA undertakes a range of activities including:

● Awareness raising: Raising awareness of the risks of fracking through education, media and social media engagement.

● Research: Undertaking qualitative and quantitative research to capture community perspectives and concerns.

● Resource development: community education on the risks of fracking, fossil fuels and the climate crisis.

● Community engagement: Organising and participating in community events and contributing to local life in Mparntwe/Alice Springs.

● Alliance building and solidarity: Establishing new partnerships, contributing to relationships with other groups and networking in local, regional and national contexts to achieve our aims and stand in solidarity with others.

● Policy advocacy: Supporting changes to legislation and policy that promote First Nations sovereignty, oppose new fossil fuel extraction, and protect the environment.

● Direct action: Engaging in direct action in order to oppose all new gas/fossil fuel projects in the Northern Territory, guided by the principles outlined below and our Code of Conduct for Direct Action.

Our Objections:

Climate impacts of the proposed activity contrary to the principles of ecologically sustainable development

The proponent's EMP has failed to meet the approval criteria in section 9 of the Petroleum (Environment) Regulation 2016 (PER) on a number of counts, including:

● The proponent invokes lifecycle greenhouse emissions benefits of gas as a replacement for coal power in undisclosed locations, but does not include assessment of lifecycle emissions from the project, including emissions from sand mining for proppant, transportation to Queensland of waste materials, and downstream use of the gas if beneficial use is pursued.

● The proponent relies on the tired and scientifically bereft argument that gas that may be extracted in commercial quantities as a result of the exploration and appraisal activities contained in this EMP will replace coal fired power in undisclosed locations, thereby resulting in a net climate benefit. This position is severely imperilled by facts, including the following:

a. A new study by one of the world's premier methane scientists finds that gas may be 24 percent worse for the climate than coal in the best-case scenario, thanks to extensive methane leaks at just about every stage of its production, from drilling to transportation. In the worst-case scenario—when LNG makes long journeys on old, polluting tankards—the fuel is 274 percent worse for the environment than coal is.
b. This peer-reviewed academic article published in the journal Nature Energy in 2022 argues that the expansion of natural gas infrastructure hinders a renewable energy future and the natural gas 'bridge' narrative is misleading; that the climate impact of natural gas has previously been underestimated and that

new insights about this are not sufficiently incorporated into energy analyses; and that investments in natural gas make it harder to achieve climate targets due to lock-ins, and carry high economic risks.
c. In 2019, Woodside commissioned the CSIRO to undertake research to support its claim that gas from its Scarborough project would displace coal use in Asia. The report is entitled "Modelling the emission impact of additional LNG in Asia". The report was quietly shelved by Woodside after it concluded that increasing Australian gas supply could prolong coal, displace renewables and increase emissions in Asia without a global carbon price..

We note that under s 24(3) of the EP Act, the ecologically sustainable development principle of improved valuation is described as including, for the purposes of Territory law "Users of goods and services should pay prices based on the full life cycle costs of providing the goods and services, including costs relating to the use of natural resources and the ultimate disposal of wastes." Empire has made no attempt to describe or estimate the full life cycle costs of providing the gas it proposes to extract under this EMP, nor the cost of disposal into the atmosphere of escaping methane and other greenhouse gas emissions.

There is considerable evidence available that global average temperature rise is near to passing the threshold of 1.5 degrees above pre-industrial levels, and institutions such as the International Energy Agency (IEA) have concluded that to prevent this threshold being breached, there is no room for new gas production anywhere in the world.

Imperial's pilot production will have significant impacts on our climate whether the gas is flared, or sold on and burnt by a third party. The "pilot project" nature of this EMP means that it is intended to pave the way for further gas expansion, and when considering this EMP the minister should also consider the future greenhouse gas emissions and climate impacts this EMP is laying the groundwork for. Here in the NT we are deeply vulnerable to the impacts of climate change, with a 2023 study in Nature Journal predicting that much of the NT will be unlivable by 2070 due to climate change if we continue on our current trajectory.

Greenhouse gas emission calculation omissions

Imperial's emissions calculation for this EMP are based on it "using the gas on an appraisal basis" meaning that instead of flaring it onsite, it intends to secure a connection to the McArthur River mine gas pipeline, use its gas plant to process the gas and sell it into the network.

The company claims it will produce 25 terajoules (TJ) of gas/day, but the McArthur River Pipeline only has capacity for 15TJ a day. There's no mention or explanation of this difference in the draft EMP, no estimation of emissions from flaring the excess gas or the downstream emissions from burning it.

Risks to Sacred Sites and Sites of Cultural Importance

Imperial's new wells are directly adjacent to Relief Creek, where a number of artefacts have been found in recent years. The re-evaluation of the importance of cultural heritage artefacts found at the site in 2022 and previously considered "isolated artefacts" indicates the inadequacy of the assessments being conducted for Environmental Management Plans for fracking activities, and the need for additional cultural heritage surveys before any further work is undertaken.

Relief Creek is upstream from Paradise Pools, an important sacred site. **The risks of surface water contamination affecting this important place have not been addressed in the EMP.**

Imperial's environmental track record

A number of reportable / recordable incidents have already occurred on Imperial's existing Carpentaria wells, including a leak in the Carpentaria 1 tank. It is not clear how long this tank was leaking before the leak was identified. The final report identifying the nature of these incidents is "not yet due" including for the reportable incident. Before approving further wells, the NT government should complete the final report and make it publicly available so that we have a clearer understanding of Imperial's environmental track record.

Risks to water

The pilot project crosses Relief Creek and wells are located within the Relief Creek flood-out zone. Following the recent cyclone, this area was inundated with flood water, and road access to wells was cut off. If an incident had occurred during this time, it would have been impossible for companies to access the wells to attend to issues arising from the flooding on the well site. Wells will be located just outside the Relief Creek 1 in 100 year flood zone. Australia has had a series of 1 in 100 year floods in recent years as a result of climate change-induced changes to weather patterns, and just this week the Bureau of Meteorology announced that el nino had ended in Australia, and the country is in store for another la nina. What were once 1 in 100 year floods are now likely to occur much more frquently.

Every well will produce "drill-cuttings" that need to be disposed of and will also produce 35 million litres of fracking flow back water. The wastewater management plan proposes that this contaminated water may be held in open tanks, transferred in trucks, including during the wet season and disposed of in unspecified locations. The lack of specificity about where this water will eventually be stored raises concerns as to where the water will eventually be moved to and which place in the NT will be bearing the brunt of storing contaminated fracking water.

Pepper inquiry recommendations never implemented means ALARP threshold not met

Imperial bases its claims of having reduced impacts to an acceptable or ALARP level on the Fracking Inquiry recommendations being met, despite several crucial recommendations from that Inquiry remaining unmet. Given that the necessary precondition that "all of the recommendations made in [that] Report are adopted and implemented in their entirety" is not met, this test for acceptability of the risks associated with an onshore gas industry is also not met.

Recommendations still outstanding from the Pepper Inquiry include:

● Recommendation 7.12: Requirement that enclosed tanks must be used to hold all wastewater. We note that this EMP includes extensive use of evaporation ponds as a wastewater management tool.

● Recommendation 7.17: Discharge of any wastewater to be prohibited. Despite the prohibition created in the Water Act 1992, we note that this EMP proposes that the operation will include the discharge of wastewater.

● Recommendation 9.8: That the NT and Australian governments seek to ensure that there is no net increase in the life cycle GHG emissions emitted in Australia from any onshore shale gas produced in the NT. The direct greenhouse gas emissions resulting from this

project will increase NT's emissions by more than 3.4% and full lifecycle emissions in Australia have not been estimated.

● Recommendation 7.15: Gas companies must submit details of the locations of all faults that could compromise well integrity. There is limited mention of faulting in the EMP and the risk that encountering faults poses to groundwater.

The EMP relies on the Pepper Inquiry recommendations being implemented in full to support its claim to have reduced environmental impacts ALARP, and with these recommendations not in place this EMP fails to meet the required ALARP threshold.

Impacts on Wildlife

Three nationally-listed threatened species are recorded or likely to be present in the area; the Grey Falcon, Painted honeyeater and Gouldian finch as well as five migratory birds protected under national environment law. The proposed activities will result in the clearing of up to 229 hectares of native vegetation and wildlife habitat, bringing the total cumulative clearing approved in the area for fracking activities to nearly 1,200 hectares.

The EMP does not pay adequate attention to the cumulative risks of the proposed activities

The EMP continues the time-worn tradition maintained by proponents of fracking proposals in the NT of entirely disregarding the requirement to assess "the cumulative effects of those impacts and risks when considered with each other and in conjunction with any other activities or events that occurred or may occur in or near the permit area for the regulated activity" as required by Sch 1, s 3(2)(b) of the PERegulations. The proponent makes no attempt to describe the cumulative climate impacts of exploration and production activities on the environment in which this fracking is proposed to take place, nor is there cumulative impact assessment of impacts on biodiversity and groundwater, beyond mere addition of tonnes of greenhouse emissions, hectares to be cleared and volumes of water to be extracted, none of which describe the "effects" of these impacts.

The EMP further fails to assess "the cumulative effects of those impacts and risks when considered with each other and in conjunction with any other activities or events that occurred or may occur in or near the permit area for the regulated activity" as required by Sch 1, s 3(2)(b), because:

● The recent and anticipated emissions from other proponents' gas appraisal activities in the Beetaloo and broader McArthur Basin area are not included in the cumulative emissions assessment;

● The clearly foreseeable scope 1 emissions impact of the construction of infrastructure required to support a shale gas industry in the Beetaloo – the end goal of Empire's exploration and appraisal program – is not included in the cumulative emissions assessment; and

● The clearly foreseeable scope 3 emissions impact of the combustion of gas sold from Empire's anticipated production of onshore gas in the Beetaloo is not included in the

cumulative emissions assessment.

Inadequate and non-compliant measures to protect water resources

Empire will need to take 950ML (million litres) of water from the Gum Ridge Formation, part of the productive Cambrian Limestone Aquifer (CLA) system which supports culture, nature and communities in the area. They will apply for a licence to extract up to 750ML a year, roughly 9% of the total volume of groundwater allocated to petroleum in the Georgina Wiso Water Allocation Plan. If granted, this 750ML licence would effectively double the volume of water entitlements granted to petroleum companies so far. The impact of this water removal on the flow of groundwater locally and regionally is largely undescribed in the EMP.

The Code of Practice at section C.4.2.2 lists mandatory requirements for produced water and flowback fluid, including that **"All produced water and flowback fluid must be held in above-ground enclosed tanks at all times following release from the petroleum well"** unless in specifically listed circumstances, including being treated for reuse or disposal. The EMP does not achieve this mandatory requirement, and expressly proposes the holding of large volumes of wastewater in open ponds and tanks for the purposes of evaporation. The EMP describes evaporation as a "treatment" process (page 22) but the process of evaporation is in fact the opposite of treatment - concentrating pollutants that are held in the environment, according to the proponent's plans, in open storages, vulnerable to leaks, spills and floods. The evaporation process concentrates contaminants from drilling fluids and flowback and produced water, including potentially radionucleides, which may, once dried, become mobilised by wind.

Full EIS required

This proposal has been submitted to the EPA for assessment by the proponent itself in recognition of the increased risks this pilot project poses.

Given the scale and magnitude of the regulated activities being proposed, including land clearing, exploration through fracking, penetration of important regional aquifers with the potential for inter-aquifer connection should well barriers fail, complex wastewater management systems and hazardous chemicals handling, CAFFA submits that Is required to undertake a full Environmental Impact Statement under the Environment Protection Act 2019 (NT)

Conclusion

For the reasons set out above, CAFFA objects to this exploration and appraisal program. CAFFA submits that the EMP does not comply with legislative requirements for the approval of an Environmental Management Plan and, based on the incomplete and inadequate information provided, is environmentally unsustainable and unacceptable. Therefore the Minister is obliged to reject the EMP and the project.

Sincerely,

The Central Australian Frack Free Alliance
Mparntwe/ Alice Springs, April 17, 2024

From:	Have Your Say Northern Territory
To:	imperial ep187+
Subject:	Anonymous User completed Carpentaria Pilot Project EP187 Environment Management Plan
Date:	Friday, 19 April 2024 8:41:30 AM

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Anonymous User just submitted the survey Carpentaria Pilot Project EP187 Environment Management Plan with the responses below.

Given name

[redacted]

Family Name

[redacted]

Location

ALAWA, NT

Stakeholder type

Community member

Email address

[redacted]

Interest area

Flora and fauna
Water
Climate change
Human health

Please provide your comments

Hi there, We are well aware of the consequences of fracking on the quality of our water, our environment, wildlife, and our health. We have seen in multiple locations around the globe the disastrous consequences of fracking. The NT community has been very clear on their position, for many years now regarding fracking "NO FRACKING IN THE NT". Please respect the community's wish as we are not preoccupied with some instant financial gain, but truly about our future, about the way we treat the earth, about how we look and preserve our environment. This has to stop now, please be mindful, think about the irreversible consequences, and refuse the plan to frack the NT. The Earth, Nature, and Community will Thank You.

From:	Have Your Say Northern Territory
To:	imperial ep187+
Subject:	Anonymous User completed Carpentaria Pilot Project EP187 Environment Management Plan
Date:	Friday, 19 April 2024 12:14:52 PM

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Anonymous User just submitted the survey Carpentaria Pilot Project EP187 Environment Management Plan with the responses below.

Given name

[redacted]

Family Name

[redacted]

Location

LEUMEAH, NSW

Stakeholder type

Community member

Email address

[redacted]

Interest area

Water
Climate change
Human health
Flora and fauna

Please provide your comments

There is no safe future for humans, my children included, with the expansion of gas projects anywhere in the world There are no volume of offsets available that will account for the enormous released of emissions from this or any other fracking project in the Northern Territory or anywhere in the world To approve this project, or any fracking in the NT is at odds with the science that tells us to avoid climate collapse we must end fossil fuel expansion by 2021 (we are already out of time)

From:	Have Your Say Northern Territory
To:	imperial ep187+
Subject:	Anonymous User completed Carpentaria Pilot Project EP187 Environment Management Plan
Date:	Friday, 19 April 2024 12:20:22 PM

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Anonymous User just submitted the survey Carpentaria Pilot Project EP187 Environment Management Plan with the responses below.

Given name

[redacted]

Family Name

[redacted]

Location

BAULKHAM HILLS, NSW

Stakeholder type

Community member

Email address

[redacted]

Interest area

Social and cultural
Flora and fauna
Water
Climate change
Human health
Regulation and compliance

Please provide your comments

I find it morally and ethically unconscionable that the government consider allowing the destruction of habitat, extraction of billions of litres of water and the eventual burning of fossil fuels releasing huge amounts of emissions into the atmosphere. All in the middle of a climate crisis. Allowing this project to go ahead is an afront to the voters who elected this government to take strong and meaningful action on climate change. This project should not be allowed to go ahead.

Tick this box if you wish for your name and contact details to be confidential

Make my name and contact details private

From:	Have Your Say Northern Territory
To:	imperial ep187+
Subject:	Anonymous User completed Carpentaria Pilot Project EP187 Environment Management Plan
Date:	Friday, 19 April 2024 12:26:15 PM

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Anonymous User just submitted the survey Carpentaria Pilot Project EP187 Environment Management Plan with the responses below.

Given name

[redacted]

Family Name

[redacted]

Location

ALICE SPRINGS, NT

Stakeholder type

Community member

Email address

[redacted]

Interest area

Social and cultural
Water
Climate change
Human health
Regulation and compliance

Please provide your comments

There is already a mountain of evidence in favour of NOT allowing fracking to take place in the NT. Please be guided by this truth. Attempts to make the NT financially viable by destroying the environment makes no sense.

From:	Have Your Say Northern Territory
To:	imperial ep187+
Subject:	Anonymous User completed Carpentaria Pilot Project EP187 Environment Management Plan
Date:	Friday, 19 April 2024 12:50:38 PM

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Anonymous User just submitted the survey Carpentaria Pilot Project EP187 Environment Management Plan with the responses below.

Given name

[redacted]

Family Name

[redacted]

Location

BALGOWLAH, NSW

Stakeholder type

Community member

Email address

[redacted]

Interest area

Climate change
Water
Flora and fauna
Social and cultural

Please provide your comments

Please register my strong objection to this and any other project contemplating gas extraction in the NT or any other State, Territory or Country. Our collective future depends on following IEA and IPCC advice that any new fossil fuel approvals from 2021 are incompatible with a habitable future planet. Have you ever read the children's book "Who Sank the Boat" by Pamela Allen? It teaches children about cumulative risk. Unfortunately we adults have failed to heed this simple message, and as a consequence our planning systems assess projects individually with little if any regard to cumulative impacts. The point is that the boat is already sinking, and approvals of this or any other project that facilitates more fossil fuels being burnt are likely to be viewed by the next generation as

acts of inter-generational genocide.

From: Have Your Say Northern Territory
To: imperial ep187+
Subject: Anonymous User completed Carpentaria Pilot Project EP187 Environment Management Plan
Date: Friday, 19 April 2024 1:53:42 PM

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Anonymous User just submitted the survey Carpentaria Pilot Project EP187 Environment Management Plan with the responses below.

Given name

[redacted]

Family Name

[redacted]

Location

POINT LONSDALE, VIC

Stakeholder type

Non Government Organisation (NGO)

Email address

[redacted]

Interest area

Social and cultural
Flora and fauna
Water
Waste management
Climate change
Regulation and compliance
Well integrity

Please provide your comments

Our comments are in the attached submission. This submission has three attachments which we will send via email.

[redacted]

From: [redacted]
To: imperial ep187+
Subject: Objection: Carpentaria Pilot Project EP187 Environment Management Plan
Date: Friday, 19 April 2024 2:06:56 PM
Attachments: [redacted]

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

To the Petroleum Operations Unit
Department of Environment, Parks and Water Security

Please see attached an objecting submission from Lock the Gate Alliance to this draft EMP. This submission has been uploaded using the webform, but is also being emailed to enable the attachment of three appendices.

Thank you

[redacted]
Head of Research and Investigations
Lock the Gate Alliance
[redacted]

LOCK THE GATE ALLIANCE
AUSTRALIANS WORKING TOGETHER TO PROTECT OUR LAND, WATER, AND FUTURE

Reply to: [redacted]
Head of Research and Investigations
[redacted]

18 April 2024

Department of Environment, Parks and Water Security
Petroleum Operations Unit
By email: imperial.ep187@nt.gov.au

Objection: Carpentaria pilot Environmental Management Plan EP187

Thank you for the opportunity to comment on this draft EMP.

The Lock the Gate Alliance is a national collection of grassroots organisations made up of over 120,000 supporters and hundreds of local groups concerned about risky coal mining, coal seam gas and fracking. Several of these groups are located in Darwin, Katherine and Alice Springs, as well as rural and remote areas around the NT. Our members include farmers, traditional custodians, conservationists and urban residents. Together, we have a vision of healthy, empowered communities that have fair, democratic processes available to them to care for land and water.

Lock the Gate objects to this EMP and urges the Department to reject it, on the basis of its unacceptable environmental and social impacts. Despite manifest failures in the adequacy of the information provided with the EMP, it is clear that risks from the project are neither as low as reasonably practicable, nor acceptable.

The proponent's EMP has failed to meet the approval criteria in section 9 of the *Petroleum (Environment) Regulation 2016* (*PER*). The EMP as exhibited does not, under criteria s 9(1)(c) "demonstrate that the activity will be carried out in a manner by which the environmental impacts and environmental risks of the activity will be reduced to a level that is (i) as low as reasonably practicable or (ii) acceptable." Specifically, the EMP fails to meet approval criteria to reduce risks to as low as reasonably practicable (ALARP) or to a level that is acceptable in, for example, the management of fracking wastewater and the management of greenhouse gas emissions, as detailed in the submission.

The draft EMP fails to address "*all the environmental impacts and environmental risks arising directly or indirectly*" from all aspects of the activity and likewise fails to assess "*the cumulative effects of those impacts and risks* when considered with each other and in conjunction with any other activities or events that occurred or may occur in or near the permit area for the regulated activity."[1] Specifically, with regard to these requirements, the EMP:

[1] *Petroleum (Environment) Regulations 2016*, Schedule 1 Part 1 regulation 3(2)(b).

- Fails to engage with the principles of Ecologically Sustainable Development as spelled out in Part 2 Division 1 of the Environment Protection Act 2019, and, indeed, appears unaware that these principles have been articulated in Territory law.
- Provides incomplete and inaccurate information about its emissions of greenhouse gases and no assessment of the indirect climate change impacts of the release of that pollution;
- Provides incomplete information on the water resources in the area and the impact of the activity on that water and the values it supports, including no discussion of the presence or potential impacts of faults in the areas where drilling is to occur and the likelihood of these to provide transmission pathways for fracking fluids;
- Undertakes no modelling of local effects of groundwater removal and provides no discussion of the impacts of groundwater drawdown as a result of abstraction from the Gum Ridge Formation on local shallow aquifers and groundwater dependent ecosystems;
- Fails to detail how it will meet the requirement in the *Code of Practice: Onshore Petroleum Activities in the Northern Territory* (the Code of Practice) for "an auditable chain of custody system" for wastewater tracking;
- Proposes the use of open storages for contaminated wastewater, contrary to the Code of Practice;
- Fails to describe the method of disposal for contaminated drill-cuttings;
- Fails to satisfy Clause 2(c) of Schedule 1 of the PER as it does not describe "*details of any uncertainties or lack of understanding in relation to [the] environment*" particularly for water resources and biodiversity.
- The draft EMP also makes concerning revelations about previous failures to appropriately identify and assess the significance of heritage sites, which requires action.

We attach reviews of the EMP by Professor Matthew Currell, Head of Civil and Environmental Engineering, School of Engineering and Built Environment, Griffith University (**Attachment 1**), Dr Ryan Vogwill and Director and Principal Hydrogeologist and Rachel Hamilton , Senior Hydrogeologist, Hydro Geo Enviro Pty Ltd (**Attachment 2**) and Professor Neil McIntyre, Sustainable Minerals Institute, School of Civil Engineering, University of Queensland (**Attachment 3**).

Principles of Ecologically Sustainable Development

The principles of Ecologically Sustainable Development (ESD) are relevant to the approval decision for a petroleum EMP. The EMP as exhibited fails to consider the principles of ESD as set out in Part 2 Division 1 of the *Environment Protection Act 2019*, which include:

- Decision-making principle: Decision-making processes should effectively integrate both long-term and short-term environmental and equitable considerations;
- The precautionary principle: If there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation;
- Intergenerational equity: The present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of present and future generations;

- Principle of sustainable use: Natural resources should be used in a manner that is sustainable, prudent, rational, wise and appropriate.
- Principle of improved valuation: Persons who generate pollution and waste should bear the cost of containment, avoidance and abatement.

The proponent seems unaware that Territory law has inscribed these specific principles and instead claims “there is no universally accepted definition” of the principles and cites a statement from Australia’s ESD Steering Committee dated 1992. In the very short treatment of ESD principles conceptually in the EMP it is stated that “Further assessment of the consideration of ESD, the environmental values of the CPP Area and the potential impacts and environmental performance standards are presented in Section 6” but no further consideration is made.

As a result, the EMP fails to identify where the activity comes into conflict with these principles. Specifically,

- There is no discussion of the intergenerational inequity of large-scale groundwater removal by this activity, cumulative with other activities, which have the potential, given low recharge rates and interconnectivity of the Cambrian Limestone System to deplete resources to the detriment of future generations and to have indirect impacts on other water users and on groundwater dependent ecology and culture;
- There is no discussion of the impacts of climate change on future generations or the carbon budget context of the direct, indirect and downstream emissions that would result from this activity;
- There is no discussion about the wise and sustainable use of either the groundwater that will be extracted for this project or the gas that will be produced;
- There is no discussion of the proponent’s proposed application to use or sell the gas “on an appraisal basis” and how the proponent will value the downstream emissions that will result from this activity.

Ground and surface water

The EMP provides no assessment of the impact of large-scale groundwater removal anticipated for this project, particularly the consequences of groundwater drawdown as a result of this removal. As Professor Matthew Currell outlines in the attached advice, stating the overall volume of water in an aquifer and comparing it to the volume to be removed does not describe the effects of that removal on local and regional water resources, flows and availability. Professor Currell indicates that:

> “This analysis is insufficient for a robust assessment of groundwater impact and risk. The Georgina Basin is a huge aquifer system, covering hundreds of thousands of square kilometers, of which the Petroleum Lease is only a tiny fraction. Understanding the local impacts of extraction from individual projects involving groundwater extraction in the basin requires detailed analysis of aquifer properties, water extraction scenarios and drawdown, rather than a ‘whole of basin’ approach that only compares extraction to basin-wide estimates of volume and/or sustainable yield.”

Water removal by extractive activities in NSW and Queensland are routinely required to undertake modelling to understand the drawdown effects of groundwater removal. Dr Ryan Vogwill and Rachel Hamilton likewise identify the absence of any assessment of groundwater drawdown impacts on environmental receptors as a result of groundwater abstraction as a major gap in the EMP, including the impact this would have on shallow aquifers that must be present given the presence of groundwater dependent ecosystems (GDEs), but are not identified mapped or discussed in the draft EMP. Specifically, larger pools along the creek that persist during the dry season are likely groundwater dependent and support a higher fauna diversity than surrounding areas. The impact of localised groundwater drawdown following removal of water from the Gum Ridge Formation for this project needs to be modelled and analysed as it could lead to unacceptable impacts.

Professor Currell advises that to fully assess groundwater risks from the proposal, further analysis is required to understand the following effects of groundwater removal, including:

- An assessment of the potential for drawdown to spread to productive bores within 5, 10 and 15km of the activity;
- An assessment of the potential impacts on springs including the extent of drawdown associated with water extraction, and the changes to water balance (including any reduction in groundwater discharge from aquifer units which may sustain springs);
- An assessment of the impact of the magnitude and extent of groundwater drawdown caused by the project's groundwater extraction on groundwater dependent vegetation.

Dr Vogwill identifies that the EMP similarly provides no discussion of the potential impacts arising from permeable underground pathways, including production wells themselves (if there is loss of well integrity or a poor well seal), natural fractures (faults etc) and newly-created fractures. All of these could allow hydraulic fracturing fluids, other fluids (such as saline groundwater) and gases to reach underground drinking water resources. In other parts of the Beetaloo Basin, fracking companies have encountered fractures in the Cambrian Limestone Aquifer system, introducing the risk that drilling and fracking fluid may enter that system.

Regarding well integrity, Dr Vogwill's advice also identifies that the "vuggy and cavernous" units of the Cambrian Limestone Aquifer presents particular risks not described or acknowledged in the EMP because "Cementing the annulus of vuggy and cavernous units can be notoriously hard as cement runs into the porous/vugs in the formation and doesn't seal the annulus where it is placed. This has large implications for well integrity and commonly leads to sections of the annulus not being sealed, potentially providing a conduit for groundwater flow."

Dr Vogwill similarly highlights the lack of any mention of stygofauna or troglofauna, noting that the Cambrian Limestone aquifer is likely suitable habitat for these species, so this is clearly a potential impact that requires assessment.

The project is in the headwaters of two catchments, the Limmen Bight River catchment to the north and McArthur River to the east. The pilot project crosses Relief Creek and the area around it that floods. Wells will be located just outside the 1 in 100 year flood zone, which means they are likely to flood in more extreme events. Dr Vogwill's advice uses publicly available data to show examples of

relatively persistent surface water features in the area of the proposed Carpentaria Pilot not included in the EMP, highlighting the insufficiency of the assessment for understanding the risks and impacts of the project on surface water resources. The conclusion of Dr Vogwill is that the EMP does not provide an adequate assessment of the risks and impacts of this project on ground and surface water resources.

Cultural heritage

We are concerned about the release of this EMP for public comment prior to the follow-up meeting with Traditional Owners in Daly Waters, Eliot and Borroloola that were scheduled in the late months of 2023 but had to be postponed. The draft EMP indicates that meetings of this kind have not taken place since August last year.

The draft EMP also makes concerning revelations about previous failures to appropriately identify and protect heritage sites. Archaeological survey results from December indicate that the cultural heritage artefacts found in 2022 and previously considered “isolated artefacts” are in fact part of a medium density artefact scatter, “the most significant site yet found south of the Carpentaria Highway in EP 187.” The site is referred to in the study as Balbirini 3. It is next to the existing Carpentaria 4 well, just east of Relief Creek, which was drilled over the new year in 2022/23. It appears that this drilling took place on the basis of the archaeological finds being “isolated,” prior to their true significance being revealed nearly a year later in surveys conducted for this project. As a result of this, the Archaeology report recommends the Carpentaria 4 horizontal well development (C4-H) push east into the forested area - away from Relief Creek. This is the first part of the project planned for construction, in July, according to the schedule in the draft EMP.

The re-evaluation of the importance of cultural heritage artefacts found at the site in 2022 and previously considered “isolated artefacts” indicates the inadequacy of the assessments being conducted for Environmental Management Plans for fracking activities. The absence of follow up meetings with Traditional Owners and this evidence of lax or inaccurate previous assessments demonstrates inattention to these values and calls into question the conclusions of the draft EMP that risk of harm has been addressed.

Wastewater management

The environmental risks from management of contaminated wastewater from fracking have not been reduced to as low as reasonably practicable, and are unacceptable. Professor Currell’s advice indicates that, “The likelihood of spills and leaks of fracking wastewater has likely been under-estimated” citing studies of spill and incident rates in shale gas developments elsewhere.

The EMP indicates in its risk assessment that in order to prevent the risk of wastewater harming the environment in the event of extreme rainfall, the proponent will rely on forecasts of significant rainfall events and a calculation of whether there is sufficient freeboard to contain such an event, at which point further control measures, in the form of “engineered tank covers” will be installed on “open-top treatment tanks” with eight hours notice. This does not reduce the risk of contamination and spills to “as low as reasonably practicable” given the proponent does not appear to have

considered covering all storages of contaminated water, not even during the wet season. The presence of fracking chemicals and other contaminants presents an unacceptable risk of spills and accidents, given unpredictable wet season conditions and difficulties of access during those periods.

The EMP Wastewater Management Plan cites a report created for the proponent by Kleinfelder in 2021, reviewing the contaminants present in flowback water at the Carpentaria 1 well. That report states:

> *The calculated annual dose for the combined alpha and beta activity exceeded the 1 mSv/year screening criteria in four of the seven treatment tank samples (2.5 to 10.4 mSv/year). It is noted that the three initial samples were below the screening criteria, with the later samples above the screening criteria, which could suggest NORM build-up of radioactive material within the treatment tank.*

The report also found that, "The evaporation treatment process is anticipated to increase the TDS concentrations and that of other contaminants of concern." This finding underscores why the proposal to hold large volumes of flowback water on site for unspecified periods, in storages that will not always be enclosed, even in the wet season, does not reduce impacts to an "as low as reasonably practicable" or an acceptable level. The longer water is held on site, particularly in open tanks, the greater the risk that spills and leaks will cause environmental harm. Yet the EMP does not discuss the length of time the proponent intends to hold such water on site. The length of time wastewater will be held on site is crucial to understanding the risk presented by that water. We note that a leak incident was reported by Imperial Oil and Gas at the Carpentaria 1 site in September 2023. Carpentaria 1 is quite close to Relief Creek and it is not clear from the preliminary report available publicly what volume of liquid was lost before the leak was detected. That preliminary report indicates that the corrective actions taken by the proponent would be to "temporarily cease evaporation in the Carpentaria 1 tank and the second above ground treatment tank at Carpentaria 2 until investigation complete" and "create an action plan for fluids contained in the Carpentaria 1 tank." The available information is not sufficient to understand whether the source of the leak has been detected and can be fixed.

The method by which the proponent has estimated the holding capacity necessary to withstand extreme rainfall events requires interrogation. It is stated in the EMP that although the usual approach would be to utilise the BOM's Revised Generalised Tropical Storm Method, the maximum duration considered in this method is 120 hours in the coastal zone and to extend it to the required 90 day period "introduces considerable statistical uncertainty in predicting extreme rainfall." A prudent risk-based approach would present the range of this uncertainty, particularly if it indicates the possibility of low-likelihood but high consequence extreme rainfall events. Instead, the EMP states that "utilising probability methods that leverage historical daily rainfall datasets emerges as a viable approach to reasonably forecast a 0.1% [probable maximum precipitation] estimate for 90 days." The proponent uses this method to calculate "the minimum required reserved space to handle a 1 in 1,000-year rainfall event." We note that advice from Professor Neil McIntyre from the University of Queensland about the information provided with the EMP is that, "The estimation of design extreme rainfall is fundamental to the assessment of risks from accidental spills. Without a

precise explanation of the method of estimating design extreme rainfall I cannot conclude that the assessment is adequate."

We note that BOM rainfall data for Tanumbirini, which is not included in the EMP, recorded 1,200mm in the first 90 days of 2024, greater than the 1 in 1000 year wet season 90 cumulative rainfall maximum given for Daly Waters in the EMP, but less than the 90 day cumulative maximum at McArthur River mine (1,400mm). Given this, the proponent's freeboard calculation seems reasonable based on historical data, but there is no discussion in the EMP of the influence of climate change on precipitation extremes. We note in this regard, Professor McIntyre's advice that "the statistical methods employed in the EMP integrate any effects of climate change in recent decades" This is reassuring, but discussion of this context should be provided with the EMP and Professor McIntyre's advice provides some guidance in this regard. In our view, a complete risk assessment would consider and plan for the possibility that the envelope of possible extreme conditions may already have altered. Finally, the assessment is based on the need to hold water over a 90 day period, but it is not clear from the EMP and the waste water management plan how long water may be expected to remain on site.

We provide at **Attachment 3** advice from Professor Neil McIntyre who asserts that while the risks from a project of this nature can be manageable with the application of good practice in planning, design and operation, "*the reviewed EMP documents do not provide the level of information required to confidently conclude that risks are acceptably low or that an adequate assessment has been conducted.*"

Drill-cuttings waste management

The project will produce 600 cubic metres of drill cuttings per well and the destiny of these materials is not clearly articulated in the draft EMP. The proponent cites a study it commissioned to examine the analytes likely to be present in these cuttings, but that report is not made available with this EMP and, unlike the flowback water report, has not otherwise been made public.

Greenhouse gas emissions

The EMP indicates that the company plans to apply to "use the gas on an appraisal basis" instead of flaring it onsite. To do this, the company will need to secure a connection and usage agreement for the McArthur River mine gas pipeline, secure approval from the NT Government and necessary approval under the Native Title and Land Rights Acts. While there is a rough estimate given of the annual emissions that would result should this proposal *not* be successful (~475,000 tonnes per year) there is no assessment provided of this scenario, or discussion of how the company intends to meet the Safeguard Mechanism's zero emissions baseline for shale gas which would apply if emissions from the pilot were greater than 100,000 tonnes in any of the years of operation.

The ability of the company to avoid flaring by securing approval to supply appraisal gas to the McArthur River mine power station is uncertain. The company claims it will produce 25 terajoules (TJ) of gas a day, but the McArthur River Pipeline only has capacity for 15TJ a day, some of which is presumably already contracted. There's no mention or explanation of this difference in the draft EMP

and no estimation of emissions from flaring any excess gas not able to be transported via that pipeline, or the downstream emissions from burning any transported gas. Given that the Pepper Inquiry made clear that shale gas operations in the NT need to be net zero from the outset, including their downstream emissions in Australia, then this is an omission that must be rectified. We note that there were 141,369 tonnes of greenhouse emissions reported from McArthur River mine power station in the most recent reporting year.

Furthermore, the EMP does not explain or describe how emissions calculations have been made and appears to contain errors in this regard. The estimates of fugitive emissions, for example, has the number “18” in the column labelled “total” for emissions estimates and no number in the column for total gas throughput. The number “787” appears out of place in another cell, but is not the total of the emissions numbers provided for each year. The presence of such basic errors indicates that neither the company nor the Department has attended to the accuracy of the greenhouse emissions assessment.

The EMP therefore has not provided sufficient information to meet the relevant regulatory requirements to consider the full direct, indirect cumulative impacts, and the principles of ecologically sustainable development.

The “cumulative impact assessment” in the EMP tallies the expected emissions from other shale gas fracking activities in the area, but it does not contextualise the direct and downstream emissions from these activities within Australia and the Territory’s climate change commitments and emissions reduction trajectories required to achieve the goals of the Paris climate agreement.

Biodiversity

The assertion in the Environmental Assessment Report (Appendix 1) that impacts to biodiversity from proposed activities are considered to be low is not supported by the methodology or impact assessment. The Carpentaria Pilot Project should be refused because it is not consistent with the principles of ecologically sustainable development and it fails to meet approval criteria to reduce risks to biodiversity to as low as reasonably practicable or to a level that is acceptable.

The EMP provides only a superficial overview of the ecological values of the lease area, relies on deficient records and does not offer any effective mitigation measures other than avoidance of some habitat features. Furthermore, the EMP:

- Does not demonstrate alignment with the principles of Environmentally Sustainable Development, specifically the conservation of biological diversity and ecological integrity;
- Is based on inadequate survey effort and unreliable methods;
- Is reliant on SREBA surveys which, far from being comprehensive, represent only an initial and incomplete snapshot of biodiversity in the Beetaloo Basin;
- Is overly reliant on database records and previous surveys, rather than targeted surveys, for flora, fauna and ecological communities to determine likelihood of occurrence;

- Fails to quantify or qualify potential direct and indirect impacts on ecological values;
- Fails to assess cumulative impacts in the context of current and future gas development.

Further basic errors in the EMP indicate the lack of care taken in this assessment. EPBC listed migratory birds, Glossy Ibis, Cattle Egret, Whistling Kite and Rainbow bee-eater are repeatedly labelled as "marine" species, for example.

These are discussed further below.

Inadequate survey effort

The environmental assessment fails to satisfy Clause 2(a) of Schedule 1 of the PER because it does not adequately describe "*the existing environment that may be affected by the regulated activity*," in particular, the likely occurrence and distribution of threatened flora and fauna species in the study area. The field survey is based solely on opportunistic observations that are almost certainly unable to detect rare species. It also fails to meet Clause 2(b) as it does not provide "*details of any particular values and sensitivities of that environment relevant to the activity*."

The environmental assessment conducted as part of the EMP consists of a desktop survey and "targeted" field surveys undertaken on foot and via helicopter and all-terrain vehicle (Section 2.3). The only information describing the methodology indicates that surveys were undertaken in October 2023 during optimal dry season conditions. There are no details regarding survey timing, effort, coverage or limitations. Elsewhere in the report, the field survey is more accurately described as a combination of "opportunistic observations" and "ecological information." Such limited efforts are inadequate and seek only to broadly describe environmental features with no attempt to confirm the presence of threatened flora or fauna. The fact that only doves, pigeons, a Whistling Kite and several Spectacled hare-wallabies were observed opportunistically in October 2023 confirms that this methodology cannot be relied upon to adequately describe the flora and fauna assemblages in the study area, let alone threatened species.

The report's conclusion on page 21 actually spells out that the aim of field surveys was to identify weeds and to describe "key ecological characteristics" and potential constraints. Knowledge of threatened species occurrence is therefore overly reliant on database records, which are widely recognised as being depauperate in the NT and are more likely to indicate absence of survey effort rather than species' occurrence. The environmental assessment also relies on previous surveys that are not appended or referenced, but are only vaguely referred to as "*field surveys undertaken over a 2-year period between 2021-2023*" (pp. 10, 11 and 13, Appendix C). Review of environmental reports undertaken as part of the EP187 seismic and

drilling programs in May 2019[2] and March 2021[3] confirm that those assessments were also based on opportunistic surveys. There has been no attempt in the EMP to address the considerable gaps in the SREBA surveys.

There is confusion around the identification and conservation status of the Common blue tongue lizard (*Tiliqua scincoides*) which is labelled as Data Deficient under the *Territory Parks and Wildlife Conservation Act* (TPWC Act) on page 6 and records for which are mapped in Figures 4 and 5. However, an addendum to Appendix 1 of the environmental report provides EPBC Significant Impact Criteria (SIC) assessment for the Northern blue tongue skink (*Tiliqua scincoides intermedia*) and Merten's Water Skink (*Varanus mertensi*). It can therefore be assumed that the species referred to throughout the report as the "Common" blue tongue is actually the critically endangered Northern blue tongue skink that has been previously recorded within the study area (Section 2.1.1, Addendum to Appendix 1) and Table 8 (Appendix B). Targeted survey guidelines for nationally threatened reptile species are outlined in *Survey guidelines for Australia's threatened reptiles* (Commonwealth of Australia 2011).[4] Without adequate targeted surveys, there is a high risk that habitat for the Northern blue tongue skink will be impacted by the proposed development and that unacceptable impacts will occur. As suitable habitat has been identified and the species has been previously recorded within the study area, it can be considered to be habitat critical to its survival according to Conservation Advice (DCCEEW 2023).[5] In addition, any non-vegetated areas that provide shelter from thermal extremes, fire and predators are also habitat critical to the survival of the species.

The environmental assessment considers the Sharp-tailed Sandpiper as a migratory species only and does not acknowledge that this species was listed as Vulnerable under the EPBC Act in January 2024. As it is likely to occur in the study area (Table 4), it also requires an SIC assessment to be undertaken.

SIC assessments conducted for EPBC-listed bird species Gouldian Finch, Painted Honeyeater and Grey Falcon concluded that there were no significant impacts on these species as they have not been (opportunistically) recorded within the study area since 2021. These species require targeted surveys to be undertaken as outlined in *Survey guidelines for Australia's threatened birds* (Commonwealth of Australia 2010) in order to confirm their likelihood of occurrence within the project area.[6] Another EPBC-listed species, the Northern shrike-tit, that has moderate potential to occur in the study area, requires targeted survey using the *Survey*

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[2] EMP IMP3-4 Carpentaria 1 program, Appendices, 2021. https://depws.nt.gov.au/__data/assets/pdf_file/0009/977355/emp-imp-3-4-imperial-o-and-g-2021-carpentaria-1-program-appendices-01.02-to-05.pdf

[3] EMP IMP4-3 Appendices 1-4 https://depws.nt.gov.au/__data/assets/pdf_file/0003/1048134/emp-imp4-3-appendices-01-to-04.pdf

[4] Department of Sustainability Environment Water Population and Communities, 2011. "Survey guidelines for Australia's threatened reptiles" https://www.dcceew.gov.au/sites/default/files/documents/survey-guidelines-reptiles.pdf

[5] DCCEEW 2023. "Conservation Advice for *Tiliqua scincoides intermedia* (northern blue-tongue skink)" https://environment.gov.au/biodiversity/threatened/species/pubs/89838-conservation-advice-21122023.pdf

[6] Department of Environment Water, Heritage and the Arts, 2010. "Survey Guidelines for Australia's Threatened Birds" https://www.dcceew.gov.au/sites/default/files/documents/survey-guidelines-birds-april-2017.pdf

protocol for the Northern Shrike-tit (Ward et al. 2019).[7]

The fact that 21 plant species previously recorded within the study area (2) or with high (11) or moderate (8) potential to occur are classified as either Near Threatened or Data Deficient, demonstrates that the NT listing process is deficient and cannot be relied upon to accurately quantify or assess ecological values. However, as all of these plants are considered to be significant species under the *TPWC Act* (p 6), they should have been subject to targeted surveys according to the *Northern Territory guidelines for targeted surveys of threatened and significant plant species* (DEPWS 2020).[8] There is a significant risk that some or all of them will be unknowingly impacted by the proposed activities.

The report does not describe or map any significant or sensitive vegetation within the study area although it does highlight that the ephemeral waterway and riparian vegetation associated with Relief Creek provides "significantly higher fauna diversity than surrounding areas." Hollow-bearing trees and ephemeral soaks were identified as potential constraints to development which would be avoided. No details or mapping are provided to demonstrate how significant or sensitive vegetation will be avoided or how closely these areas will be encroached by infrastructure.

The use of opportunistic observations and unreliable databases to determine the presence of threatened flora and fauna species when widely used targeted survey methods are readily available is unacceptable. There is a significant risk that the proposed development will lead to unacceptable cumulative loss of biodiversity in the short-, medium- and long-term because ecological values, including threatened flora and fauna species, have not been adequately surveyed, described or mapped.

Inadequate SREBA surveys

The environmental assessment fails to satisfy Clause 2(c) of Schedule 1 of the PER as it does not describe "*details of any uncertainties or lack of understanding in relation to that environment*." It does not describe any limitations associated with survey methods used or deficiencies in the databases upon which the assessment relied. The biodiversity studies in the SREBA represent a preliminary and incomplete assessment of the conservation values of the Beetaloo Basin. The paucity of ecological data collected in the NT prior to 2018 was noted in the Pepper Inquiry report and in the SREBA and surveys undertaken to date only scratch the surface. Significant additional work is required in order to deliver a confident assessment of the impact of any specific gas development in the Beetaloo Basin, and certainly for this application. There is therefore still considerable uncertainty around the species/communities present, their distributions, their conservation status and their reservation status.

Justice Pepper estimated that, for the Beetaloo Basin, assessment of terrestrial and aquatic biodiversity would take in the order of three to five years to undertake. However, SREBA

[7] Ward et al. 2019. Survey protocol for the Northern Shrike-tit (*Falnunculus frontatus whitei*) https://nt.gov.au/__data/assets/pdf_file/0006/678390/northern-shrike-tit-survey-protocol-2009.pdf
[8] https://depws.nt.gov.au/__data/assets/pdf_file/0008/1294658/northern-territory-survey-guidelines.pdf

surveys were undertaken between June 2020 and May 2022 and included only two wet seasons. They were plagued with limitations including:

- Covid restricted access to some survey sites to a single visit, making seasonal comparisons impossible;
- Fauna surveys were restricted to a single four-night stay and six weeks of camera trapping (five cameras deployed) at each site;
- The survey period included poor wet seasons with no opportunities to extend time frames to include the good wet season of 2022/23;
- Migratory bird surveys were not undertaken;
- Only a limited range of fauna groups was surveyed;
- Aquatic field work was restricted to single visits during two dry seasons.

The SREBA guidelines noted that established sampling methods should be applied that:

- provide sufficiently high detection probability for robust analysis of geographic patterns and detection of change in community composition over time, and
- must not have access or resource constraints (cost, personnel or time) that prevent them from being effectively applied over a large number of sites within the scope of a SREBA.

However, this was not the case for the SREBA, where access constraints associated with Covid restrictions did not result in extended timelines, but instead, ended surveys prematurely, thereby missing important seasonal variation and preventing survey replication. The high number of new species records and apparent range extensions found in the SREBA indicate the lack of previous survey work and systematic monitoring. Of the three targeted threatened species considered in the SREBA, the Northern Shrike-tit was recorded at 37 new sites, Gouldian Finch was detected at 52 new sites and the Yellow Spotted Monitor at 22 new sites. As habitat for these species has been identified in the Carpentaria study area, it is apparent that targeted surveys provide the best opportunity to detect threatened species, augment existing databases and to minimise the risk of significant impacts. The EMP should not rely on SREBA survey data or existing databases and must undertake targeted surveys in order to reduce risks to biodiversity, and particularly threatened species, to as low as reasonably practicable or to a level that is acceptable.

Missing impact assessment

The environmental assessment does not satisfy Clause 3(1)(a)(b) of Schedule 1 of the PER. It does not provide any details regarding the potential direct, indirect and/or cumulative impacts of the proposed activities on threatened species or their habitat. It does not describe any processes used to assess impacts but simply states repeatedly that there will be no environmental impacts. The report does not quantify the total amount of vegetation to be cleared or estimate the area of each vegetation community/habitat type to be removed or how that might impact flora or fauna species. It does not quantify or qualify the habitat loss for those species that have been recorded or that are highly or moderately likely to occur in the

study area. It does not describe or assess potential indirect impacts associated with alterations to groundwater and surface water, habitat fragmentation, road mortality, changed fire regimes, predation or increased noise and lighting.

The report states that "production facility areas" have been sited in order to avoid waterways and drainage lines and that well pads have been moved to avoid ephemeral areas and large landscape trees with "significant" hollows, but this has not been demonstrated. Significant hollows have not been defined. Even if sensitive or significant habitats have been avoided, there is still the risk of significant indirect impacts if infrastructure is located in adjacent areas or affected areas.

Habitat fragmentation is dismissed as an impact risk by repeating throughout the environmental assessment that it will not occur. However the proposed linear development, with its associated pipelines and access roads, will by its very nature fragment what presently appears to be a relatively intact environment. Its intactness is supported by the fact that it is relatively weed-free with only one weed species being detected in October 2023. The species most at risk from fragmentation are sedentary ground-dwelling birds and small mammals such as the Spectacled hare-wallaby, which will be more exposed to the risk of predation. Predation by introduced cats, dogs and foxes has been implicated in the extinction of 16 species of small mammals in the NT. The EMP offers no mitigation measures to control this major threat to NT ground-dwelling fauna.

The EMP has not demonstrated that nationally threatened species will not be significantly impacted nor even confirmed the presence or absence of threatened species. The risk to threatened species has therefore not been reduced to as low as reasonably practicable or to a level that is acceptable.

Cumulative impacts

The environmental assessment does not satisfy Clause 2(b) of Schedule 1 of the PER because it does not consider the incremental loss of vegetation communities/habitat types with respect to their conservation status in reserves or in the face of ongoing development.

Section 3.10 of the main EMP report estimates the total amount of vegetation to be cleared for EP187 and EPs within a 50-km radius to be 969.6 ha. As with all the EMPs prepared to date, the Carpentaria EMP seeks to minimise the amount of clearing by presenting it as 0.01% of the 9,419,700 ha "cumulative study area." This percentage is meaningless in an ecological sense and is highly misleading. It is based on the assumption that all habitats are equally suitable for all species and ignores the fact that these areas will be subject to ongoing clearing for future gas development and other activities given the very poor reservation status in the NT.

From an ecological perspective, cumulative impact assessment needs to take into consideration the conservation status of vegetation communities, which is extremely poor in the NT. Less than

1% of the Sturt Bioregion is protected in reserves (Woinarski et al. 2014).[9] Many of the broad vegetation groups within the Sturt Plateau are poorly represented in conservation reserves including eucalypt forest and woodlands with tussock understorey (0.09%), eucalypt low woodland with tussock grass understorey (0.02%), and Acacia woodland including Mulga (0.48%) (Baker et al. 1995).[10] Of even more concern are the groups that are not reserved at all, including eucalypt woodland with hummock grass understorey, mixed species low open woodland, hummock grassland, tussock grassland and chenopod shrublands.

It is apparent from the EMPs that have been approved or are undergoing assessment that they are impacting particular threatened species disproportionately, including, but not limited to, Gouldian finch, Northern shrike-tit, Yellow-spotted monitor, Painted honeyeater and Spectacled hare-wallaby. The latter species was found to be closely associated with the Lancewood-Bullwaddy vegetation community in Tamboran's ecological assessment of EPs 98 and 117[11] and several individuals were observed in a Lancewood-dominated community in EP 187. This species is listed as Near Threatened and is declining in the NT and is a Critical Weight Range mammal most vulnerable to predation by introduced predators. It is also rare in the Kimberley and Pilbara regions Western Australia and was recommended for listing as Vulnerable in the NT by Ingleby in 1991.[12] Nine species of hare-wallabies are listed on the EPBC Act, demonstrating that this fauna group is particularly susceptible to population decline and range contractions. The primary threats identified for the closely related Barrow Island Spectacled hare-wallaby (*Lagorchestes conspicillatus conspicillatus*) are identified as habitat degradation from commercial infrastructure development and predation by cats and foxes.[13] The Spectacled hare-wallaby is likely to be at high risk of extinction from the cumulative impacts of gas development in the Beetaloo Basin, but is routinely dismissed from consideration as it is not currently listed as threatened in the NT. A conservative approach is therefore recommended when assessing impacts on this species.

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[9] Woinarski J., Traill B. & Booth C. (2014). The modern outback: Nature, people and the future of remote Australia. Report prepared as part of the 'Outback Papers' & co-ordinated by The Pew Charitable Trusts.

[10] Baker B., Price O., Woinarski J., Gold S., Connors G., Fisher A. & C. Hempel (2005). *Northern Territory Bioregions – assessment of key biodiversity values and threats.* Report prepared to accompany the Northern Territory Parks & Conservation Masterplan.

[11] These documents are no longer publicly available as this EMP is still under assessment

[12] Ingleby S (1991). Distribution and status of the spectacled hare-wallaby *Lagorchestes conspicillatus*. *Wildl. Res.* 18(5): 501-519.
https://www.publish.csiro.au/wr/WR9910501

[13] Commonwealth of Australia 2008. Approved Conservation Advice for *Lagorchestes conspicillatus conspicillatus* (Spectacled Hare-wallaby (Barrow Island)
https://www.environment.gov.au/biodiversity/threatened/species/pubs/66661-conservation-advice.pdf

Comments on groundwater risk assessment for Carpentaria Pilot Project Environmental Management Plan: Imperial Oil & Gas EP187

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15th April 2024

Summary

This proposed shale gas exploration project, involving the drilling and hydraulic fracturing of ten new gas wells and associated extraction of up to 950 GL of groundwater for drilling and fracking operations, is located in the eastern Beetaloo Basin, where it is overlain by the Cambrian Limestone Aquifer (CLA).

Key potential risks of the proposed activities include:

1. **Depletion of groundwater** through freshwater extraction from the CLA to support hydraulic fracturing of the wells, and associated impacts on groundwater dependent ecosystems (GDEs) and other water users;
2. **Contamination of soil and groundwater** through:
   - Inter-aquifer leakage of contaminating fluids (including fugitive hydrocarbon migration), through either natural features, such as faults and fractures, or through well integrity breaches;
   - Surface spills and leaks of fracking chemicals, drilling fluids, flowback water and/or hydrocarbons produced by the wells;
   - Leaching and release of contaminants from waste brines produced during treatment of flowback water and other solid wastes generated on site.
3. **Seismicity** - e.g., fault activation that occurs during fracking, triggering increased seismic activity

At present, the EMP is missing important hydrogeological data and other information required to properly analyse these risks (as described below in more detail). As such, the current risk and scientific certainty ratings summarised in Table 6.2-3 are overly optimistic in many cases, and fail to acknowledge significant uncertainties and data gaps.

My analysis – conducted under timing and resource constraints – is not fully in-depth on all of the above matters (e.g., the seismicity risk was beyond the scope of my review). Subjecting the proposal to a more robust assessment - e.g., through referring the matter to the Commonwealth Department of Climate Change, Energy the Environment and Water and IESC would be advisable, to ensure the full array of water risks is properly independently assessed and considered.

Groundwater extraction and potential depletion

The EMP outlines plans to extract approximately 950 ML of groundwater, under a 750 ML/year groundwater extraction licence. This is a considerable quantity of water, comprising approximately 10% of the total allocation set aside for Petroleum activities within the Georgina Basin, under the Georgina-Wiso Water Allocation Plan 2023 (Northern Territory Government, 2023).

Given the substantial quantities of water extraction involved, an important part of the groundwater impact assessment is to estimate the likely extent of the area affected by groundwater drawdown within the target aquifer. This is required so that any other potential water users in the area – including existing water supply bores and groundwater dependent ecosystems – can be identified, and risk(s) to these assessed. This would normally be undertaken using analytical and/or numerical modelling, to calculate and map the anticipated drawdown resulting from extracting at different rates and locations, taking into account the aquifer hydraulic properties. These hydraulic properties are broadly known for the Cambrian Limestone Aquifer (see Tickell, 2022) and depending on the level of accuracy required, they can be estimated at a site-specific scale, using appropriate aquifer testing methods (e.g., pumping tests).

In the EMP, such testing and drawdown modelling is not included. There is instead only a very general assessment of the quantity of water proposed to be extracted (up to 750 ML/year), compared against the total estimated sustainable yield for the entire Georgina Basin (Figure 3.9-1). This analysis is insufficient for a robust assessment of groundwater impact and risk. The Georgina Basin is a huge aquifer system, covering hundreds of thousands of square kilometers, of which the Petroleum Lease is only a tiny fraction. Understanding the local impacts of extraction from individual projects involving groundwater extraction in the basin requires detailed analysis of aquifer properties, water extraction scenarios and drawdown, rather than a 'whole of basin' approach that only compares extraction to basin-wide estimates of volume and/or sustainable yield.

It is plausible that extraction at the proposed rates could lead to direct impacts to groundwater levels in existing bores, reductions in flow to groundwater dependent ecosystems, and/or induced inter-aquifer leakage, which may result in water quality changes (e.g., due to contrasting salinities between the different units). These issues require careful analysis based on local bore drilling, aquifer testing, drawdown estimation and spatial analysis of water quality.

Potentially impacted receptors

There are a number of receptors that could potentially be impacted by extraction of groundwater at the rate(s) put forward in the EMP. These broadly fall into the two categories of

a) Existing bores utilised by groundwater users (e.g. pastoral stations)
b) Groundwater dependent ecosystems.

A search of the NT Government's bore database shows that there are multiple groundwater bores located within a radius of 10 to 15 km from the proposed activities (Including some within 5 km). This includes multiple bores whose purpose is listed as 'production' (i.e., water supply), mostly occurring to the north and west of the PL boundary (e.g., RN035503, RN038188, RN03189, RN040617, RN041009 and RN041273). An assessment of the potential for drawdown to spread to these locations is needed to fully assess groundwater risks from the proposal.

Springs – which are by definition groundwater dependent ecosystems, also occur to the east of the PL, just beyond the eastern edge of the Georgina Basin (Figure 1). For example, Cockatoo Spring, Little Spring and Wee-ak spring are mapped occurring approximately 25 km from the PL eastern boundary. These springs were (according to NT government metadata) identified in the 2009 Gulf water study, by U. Zaar. To assess potential impacts to springs, the extent of drawdown associated with water extraction, and the changes to water balance (including any reduction in groundwater discharge from aquifer units which may sustain springs), must be analysed. A short section of the EMP discusses possible impacts on GDEs, but this does not mention springs. This section identifies that River red gum vegetation along ephemeral waterways is likely to be a GDE, but it is concluded that such vegetation is unlikely to be impacted by the project activities, due to 'buffer areas associated with waterways and drainage lines'. As discussed above, without any assessment or estimation of the magnitude of groundwater drawdown caused by the project's groundwater extraction, it is not possible to assess the full risk to groundwater dependent vegetation (such as the Red gum communities in these drainage lines), which may be sensitive to changes in groundwater levels.

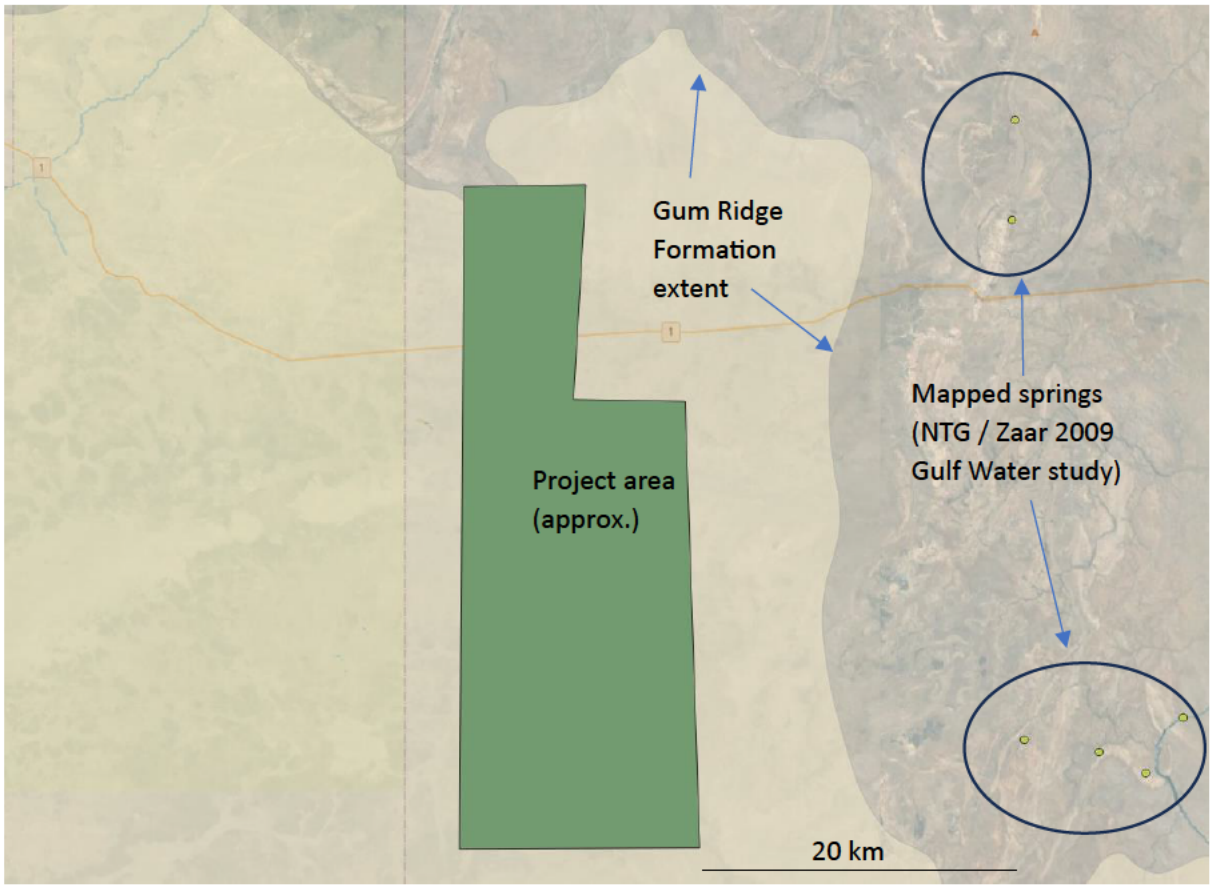

Figure 1 – approximate location of the Petroleum Lease, within which project activities are proposed, the location of mapped springs (from Northern Territory Government's ntspr 2M dataset) and the extent of the Gum Ridge Formation.

Groundwater quality

Section 4.10 of the EMP analyses groundwater chemistry data from the region and includes summarised results of groundwater quality monitoring, for a series of control/impact monitoring bores across the site. While these data are valid to some degree as a description of current groundwater quality (and could potentially serves as a baseline against which to assess any future

changes in groundwater quality relating to project activities), there are limitations in the data and their presentation, which leave ambiguity as to the spatial and temporal variability in groundwater chemistry/quality, and its main controlling processes.

While bore codes and names for the monitoring network are shown in figures (e.g. Fig 4.10-5), full bore construction details including the unit(s) monitored, bore construction type and screen interval depths are not apparent (as far as I could tell from the EMP documents). This means that attribution of the groundwater quality data to the different aquifers and areas within the PL is ambiguous, and the spatial variability in chemistry unclear. Figures 4.10-6 to 10 provide summarised box-plots of water quality parameters. These are fine as an overall summary of parameter ranges, but time-series plots are needed to show the level of variability in different parameters at each bore site over time. The above limitations mean there is limited information regarding the spatial distribution (both laterally, and with depth in different aquifer units and lithologies) and long-term variability of key water quality parameters.

Processes controlling the groundwater chemistry – e.g., evapotranspiration, water-rock interaction, and inter-aquifer leakage, and their relationship to measured water quality variables, are also not analysed in any significant detail in the report. Baseline measurements of groundwater quality must be assessed within the context of understanding of these processes to ensure robust interpretations.

Further important water quality parameters, which are critical for assessing unconventional gas impacts, are also not present in the data. Specifically, dissolved methane and other hydrocarbons, which are present within the target gas reserves and which may in future be potential contaminants of concern due to well-integrity issues, or spills and leaks of flow-back water during hydraulic fracturing are not reported – a significant gap with respect to baseline groundwater quality (e.g., Jackson et al., 2013).

Other key indicators (e.g. metals and radio-nuclides) are presented in section 4-10 only as aggregated totals (e.g. Fig. 4.10-9), meaning it isn't possible for the reader to examine or understand the distribution of individual contaminants within the aquifer system, or their degree of temporal variability through time. Overall, these limitations mean that a robust assessment of groundwater quality risks from the proposed activities is not possible.

Groundwater, soil and surface water contamination risk

Further issues which create uncertainty with respect to risk of groundwater, soil and surface contamination include:

- There is currently a relatively limited understanding of geological structures, rock properties and the biogeochemical environment in which the proposed fracking activities would take place - all of which are critical to a full assessment of well integrity risks. The EMP does not include detailed site-specific analysis of likely permeability and other rock properties of the different units, or analysis of biogeochemical conditions. As noted by Currell and Ndehedehe, 2023, there remains a general lack of understanding of inter-aquifer connectivity between the Beetaloo basin sedimentary rocks, and shallow, high-value Cambrian Limestone Aquifer throughout Beetaloo region. This is a significant issue as these properties and the level of connectivity affect the potential for hydrocarbons to migrate from the target shale resources into shallower aquifers, particularly in the event of well

integrity breaches. Davies et al., (2014) found that, according to global databases, well integrity failures occur in approximately 2 to 75% of oil and gas wells over their lifetime, meaning this risk is relevant to the activity, even if the number of wells is relatively small. Examples of where well integrity issues have led to methane contamination of high-value shallow groundwater resources in areas of shale gas development include Osborn et al., 2011; Darrah et al., 2014, Llewellyn et al., 2015 and Whyte et al., 2021.

- The likelihood of spills and leaks of fracking wastewater has likely been under-estimated. A review by Patterson et al. (2017) of tens of thousands of shale gas wells across four US states indicated that spills of potentially contaminating fluids from unconventional gas (particularly flowback water) occur at rates of between 2 and 16% of active wells per year, with the majority occurring in the first three years of a well's life. Spills are associated with equipment failure, human error and environmental conditions (e.g. extreme weather). Approximately half of spills documented by Patterson et al. were associated with storage and transport of fluids through flow-lines. While the risk assessment (Table 6.2-3) acknowledges a medium level of risk from leakage from wastewater flowlines following control measures, other risk rankings (e.g. risk of fluid or chemical spill during operation or drilling of petroleum wells) appear to be overly optimistic (i.e., under-state the true potential likelihood of incidents) in light of the global data. The use of open-topped storage tanks for hydraulic fracturing flowback fluid also appears risky, even with the proposed measures outlined in Table 6.2-3. This is in part acknowledged in the 'medium' residual risk rating for TE-17. If further changes to project design are not feasible to control the risk of soil and water contamination from uncontrolled leaks and spills of hydraulic fracturing fluids and flow-back, then the overall environmental sustainability of the proposed activities should be carefully considered.

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REVIEW OF THE HYDROGEOLOGICAL AND HYDROLOGICAL IMPACT ASSESSMENT IN THE ENVIRONMENTAL MANAGEMENT PLAN FOR THE CARPENTARIA PILOT PROJECT

PREPARED FOR | Environmental Defenders Office

[redacted]

DATE | 18/04/2024

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Introduction

The Carpentaria Pilot Project (CPP) is an unconventional shale gas project located in the Barkly region of the Northern Territory, 640km south-east of Darwin. The area is located within the Mambaliya Rrumburriya Wuyaliya Aboriginal Land Trust. The project's environmental outcomes in relation to water are to have no significant impacts on groundwater or surface water quality or quantity (as stated in the EMP on page 15).

The CCP area is located on the divide between the Limmen Bight River and Macarthur River catchments, several streams transect the project area. The Cambrian Limestone Aquifer (CLA) is the recognised aquifer system in the CPP Area for water supply. It is comprised of near flat-lying layers of mainly carbonate rocks with an estimated age of 500-510 million years. It comprises two main layers: an upper siltstone-dominated layer (Anthony Lagoon) and a lower limestone/dolostone-dominated layer (Gum Ridge). The groundwater source in the CPP Area is the Gum Ridge Formation (GRF) aquifer which occurs as a vast vuggy limestone aquifer, which can often be cavernous. Up to nine groundwater production bores are planned for construction during the project.

As part of this the following documents have been reviewed in detail with a focus on impacts to surface water and groundwater dependant environmental receptors:

- Environmental Management Plan Carpentaria Pilot Project March 2024 – Imperial Oil and Gas EP187 and
- Appendix 1 – Environmental Assessment Report December 2023 (Environmental Management Plan Carpentaria Pilot Project)

Other references have been reviewed when identified as relevant but not comprehensively.

Initially some background context is provided on the mechanisms by which environmental impacts occur in hydraulic stimulation projects. This is followed by an overall review summary, answers to questions posed by the EDO as part of the expert brief followed by a point by point review of key documents. Note that all page numbers referred to herein are the PDF file's page numbers, not the EMP and appendices page numbering.

The questions posed as part of this expert brief are included below in the relevant section. We have read and agree to be bound by the Expert Code of Conduct. The Environmental Defenders Office briefed us on behalf of the Lock the Gate Alliance.

Hydraulic Stimulation Environmental Impacts - Context and Background

According to the United States Environmental Protection Agency (US EPA 2016), there are five stages to a hydraulic stimulation project and the potential areas of impact to groundwater and surface waters are highlighted:

1. Water Acquisition - the withdrawal of groundwater or surface water to make hydraulic fracturing fluids. Groundwater and surface water resources that provide water for hydraulic fracturing fluids can also support groundwater dependant ecosystems. This is a key issue in arid areas and areas of limited water resources.

2. Chemical Mixing - the mixing of a base fluid to create hydraulic fracturing fluids. Spills of additives and hydraulic fracturing fluids can result in large volumes or high concentrations of chemicals reaching groundwater potentially impacting groundwater and surface water, with the potential to also impact dependant ecosystems where a pathway from source to receptor is present.

3. Well Injection - the injection and movement of hydraulic fracturing fluids through the production well and in the targeted rock formation. Belowground pathways, including the production well itself

if there is an integrity breach, natural fractures (faults etc) and newly-created fractures, can allow hydraulic fracturing fluids, other fluids and gases to reach underground drinking water resources. Given groundwater can also support surface water resources (Winter et al. 1998) this can potentially impact on surface and groundwater resources and dependant ecosystems (Entrekin et al. 2015).

4. Produced Water Handling - the onsite collection and handling of water that returns to the surface after hydraulic fracturing and the transportation of that water for disposal or reuse. Spills of produced water can impact groundwater and surface water.

5. Wastewater Disposal and/or Reuse - the disposal and reuse of hydraulic fracturing wastewater. Disposal practices (such as in unlined or poorly lined pits) can release inadequately treated or untreated hydraulic fracturing wastewater to groundwater and surface water resources, agricultural water quality and subsequently the wider environment.

With regards to shallow groundwater or environmental impact from deep target formation and shallow aquifer connectivity, Reagan et al. (2015) identified five plausible failure scenarios which are:

(1) Extensive vertical fracturing of the formations bounding the reservoir because of inadequate design or implementation of the hydraulic stimulation operation, with the resulting fractures reaching shallow aquifers or even permeable formations connected to these formations.

(2) Sealed/dormant fractures and faults that can be reactivated by the hydraulic stimulation creating pathways for upward migration of gas, hydrocarbons and other contaminants.

(3) Induced fractures/faults that reach groundwater resources after intercepting conventional hydrocarbon reservoirs, which may create an additional pollutant source.

(4) Hydraulic stimulation creates fractures that intercept older, abandoned unplugged wells (or wells with integrity failure) in their vicinity. This can be caused by lack of information about the location and installation specifics of the abandoned wells, or because of inadequate design or implementation of the stimulation operation resulting in excessively long fractures. These aging wells can intersect and communicate with freshwater aquifers, and inadequate or failing completions/cement can create pathways for contaminants to reach the potable groundwater resources.

(5) Failure of the well completion during stimulation because of inadequate/inappropriate design, installation and/or weak cement. In this case, the well itself is the weak link, and it either includes open voids, or is fractured during the stimulation process, or both. Thus, improper cementing and well completion can result in continuous, high-permeability pathways connecting the reservoir with the shallow aquifer, through which contaminants can be discharged towards the surface. Note that the overlying formations may or may not be fractured in this case.

The likelihood of these impact scenarios manifesting will vary on a site by site and case by case basis but Reagan et al. (2015) conclude they are all possible.

Overall Review Summary

Currently the EMP is generic and lacking specifics on the risk to the area's groundwater dependant ecosystems (GDE) and inflow dependant ecosystems (IDE). Once the hydrogeology and surface water hydrology (including environmental features and pathways for contamination) have been rigorously documented then risks can be assessed including determining appropriate responses to

worst case scenarios. The main knowledge gaps and impact assessment shortcomings which are needed to understand the risks to groundwater and surface water (including the environment) are discussed by subject area below:

1. Shallow Aquifer Mapping - Any shallow 'surface' aquifers in the project area have not been discussed. The identification of GDEs in the project area means there must be a water source shallower than the Cambrian Limestone. This water source may not be productive from a water supply context and may not 'produce' water during drilling operations but vegetation will be accessing a shallower system than the Cambrian Limestone which occurs at approximately 60mbgl. The Anthony Lagoon Formation and the Gum Ridge Formation of the Cambrian Limestone aquifer appear to be hydraulically connected (ELA, 2022).

   > *"a conservative and precautionary conceptualisation is recommended, and it should be assumed that there is a high degree of connectivity throughout the CLA and its sub-units. This is especially the case given its karstic nature and potential to be highly connected."* ELA (2022).

   A major knowledge gap is the surficial hydrogeological units that overlie the CLA and how they are hydraulically connected. Water table and potentiometric surface maps need to be developed for all aquifers. Essentially, will water abstraction from the CLA affect water levels or quality in overlying aquifers closer to the surface which could impact on GDE's?

2. Groundwater Abstraction Drawdown – Following on from above the groundwater drawdown impacts on environmental receptors as a result of groundwater abstraction have not been addressed. Groundwater resources that provide water for hydraulic fracturing fluids can also support groundwater dependant ecosystems. This is a key issue in arid areas and areas where there are prolonged periods without rainfall, as at the project site.

3. Geological Structures and Hydrogeological Pathways - Hydraulic fracturing can impact aquifers by activating fracture pathways for groundwater/hydraulic stimulation fluids to propagate. Permeable underground pathways, including the production well itself (if there is loss of well integrity or a poor well seal), natural fractures (faults etc) and newly-created fractures, can all allow hydraulic fracturing fluids, other fluids (such as saline groundwater) and gases to reach underground drinking water resources. Structural geological controls, particularly those that might be reactivated are unclear and need to be mapped.

   There also needs to be mapping of the water table and other potentiometric surfaces for the aquifers to be drilled/hydraulically stimulated to allow for correct siting of monitoring bores upgradient (for background levels) and downgradient (to detect leakage).

   > *"the faulting that is responsible for the orientation of surface drainage as well as the springs at Hot Spring Valley (not part of the CLA) is likely to be deep-rooted and may provide a connection between the Beetaloo Sub-basin to the surface."* ELA (2022).

4. Well Integrity – The integrity of the wells annular seals are of particular importance in this setting. The CLA is described as vast vuggy limestone aquifer, which can often be cavernous. This type of geology provides difficult conditions for drilling, cementing and installing annular seals, heightening well completion and failure risk.

5. Chemical Spills - During operation high volumes of hydraulic fracturing flowback fluid and wastewater will be transferred between the well pads and water handling system using

buried high-density polyethylene flowlines (up to 60km of flowlines). Flowlines will also be used to transfer water to well pads for use as make-up water for hydraulic fracturing operations. Spills of additives and hydraulic fracturing fluids can result in large volumes or high concentrations of chemicals reaching groundwater and/or surface water, with the potential to also impact dependant ecosystems. Disposal practices (such as in unlined or poorly lined pits) can release inadequately treated or untreated hydraulic fracturing wastewater to groundwater and surface water resources and subsequently the wider environment. The susceptibility of the area to bushfires and flooding means chemicals need to be handled accordingly but the location of environmental receptors (including but not limited to IDEs and GDEs) has not been definitively assessed.

6. Environmental Receptors for Surface Water and Shallow Groundwater Contamination - These have not been adequately identified. Maps showing the location IDEs and GDEs need to be presented. This should be backed up by an assessment of groundwater travel times to the closest downgradient GDE receptors. IDEs and GDEs are shown on the Bureau of Meteorology GDE Atlas but should be refined with local scale analysis which should include remote sensing to identify areas of high plant water use, such as normalized difference vegetation index (NDVI) or Normalized Difference Water Index (NDWI), to help identify these areas. Water table mapping (see point 1 above) will also help identify areas of shallow groundwater. Water Observations from Space data could also help identify IDEs and GDEs, it is out of scope for this to be completed as part of this review but a scan of these data on Geoscience Australia's National Map web portal indicates a number of surface water features that are inundated 20% of the time are present with some features inundated 50% of the time. These type of hydrological features (wetlands) are relatively common in the braided fluvial system that runs through the middle of the project area, in particular Relief Creek and its immediate tributaries. Examples of these features are provided in Figure 1 noting this is not an exhaustive assessment. Currently risk to the environment are only explored in a generic sense, but need to be addressed for individual features in the context of both surface water and groundwater. The NT Government's strategic regional environmental and baseline assessment' (or SREBA) for this area (ELA, 2022) provides a good high-level regional assessment of the hydrology and hydrogeology but this project needs to develop the local scale equivalent, i.e. with greater detail.

7. Stygofauna or Troglofauna - There is no mention of stygofauna or troglofauna. The CLA is likely suitable habitat for these species and they could be impacted.

   > *"The common occurrence of stygofauna across the region and between different sub-units also supports the conceptualisation of a high degree of connectivity of the CLA system." ELA (2022).*

8. Flood risk - The risk of flooding causing the sites of above ground activities (including pipelines) to be compromised needs to be more holistically and robustly assessed. The predicted extent of flooding has been provided but insufficient detail on the modelling is presented (Figure 4.9 in main EMP referral page 198). No assessment of water velocities (that can cause erosion which could compromise ponds and other surface infrastructure) has been provided. A sensitivity analysis for this modelling is required to assess its applicability. The digital elevation model used in the flood modelling appears to be from the Shuttle Radar Topography Mission which is known to have accuracy issues at a local scale. A local scale Light Detection and Ranging (LiDAR) dataset should be used in areas where flooding could interact with all of the surface activities and infrastructure.

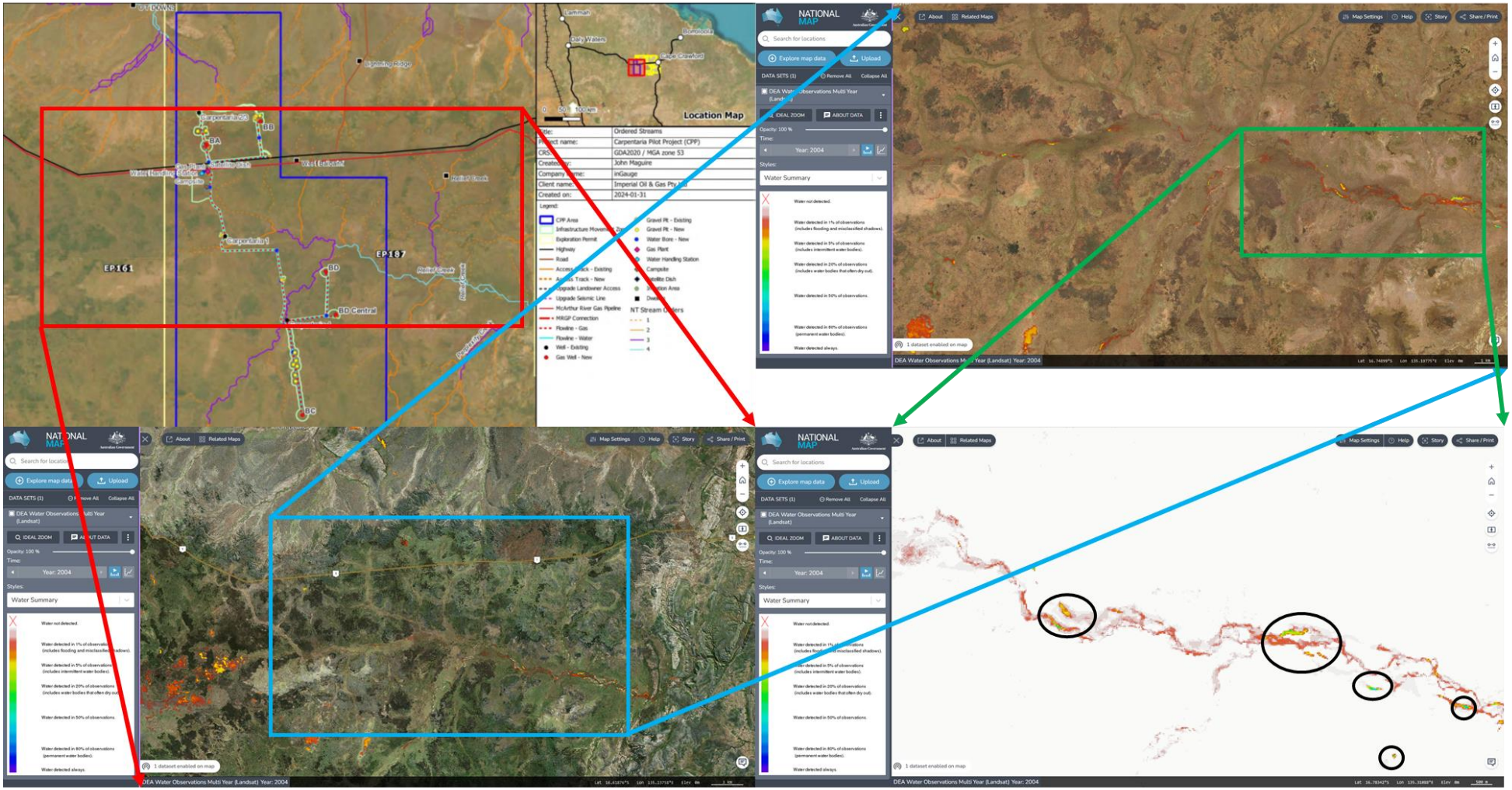

Figure 1 - Examples of surface water features identified using the Water Observations from Space data. Top left image is 4.9-2 from the EMP page 194. Other panels show approximate areas of progressive magnification. The black circles in the bottom right show examples of relatively persistent surface water features.

Answers to Questions Posed in the Brief

a. Describe the sensitivity and quality of the groundwater, surface water and soil resources that may be potentially impacted by the Project.

Answer - The area has abundant sensitive groundwater resources that could be impacted by this project. The CLA and the shallow (unnamed) aquifers are of greatest concern from surface activities, well failure and shallow deep connectivity due to hydraulic stimulation. Although not an area of extensive surface water resources per se there are ephemeral creeks (including persistent but ephemeral pools) that become active after heavy rainfall and are likely important sites hoisting biological and cultural values. These areas will be sensitive to contamination but the risks are currently unclear (discussed more below). Any area of soil that receives contamination (via either surface or groundwater processes) could be negatively impacted but this is area is not seen as having high value agricultural soils. The natural environment will however be sensitive to soil contamination from spills or leakage. This risk is greatest near the well pads.

b. Whether, in your opinion, the EMP provides an adequate assessment of the environmental impacts and/or environmental risks of the Project to:

i. groundwater;
ii. surface water; and
iii. soil.

Answer - No the EMP is predominantly generic regarding environmental impacts and needs considerable expansion as detailed herein. A lack of impact potential needs to be demonstrated, not merely assumed with a generic risk assessment.

c. If applicable, describe any environmental impacts and/or environmental risks of the Project, which are not addressed in the EMP, to:

i. groundwater;
ii. surface water; and
iii. soil.

Answer - This is unclear as the EMP is too generic and lacking specifics on the area's GDE and IDE features. Once the hydrogeology and surface water hydrology (including environmental features and pathways for contamination) have been rigorously documented then risks can be assessed including determining the response to worst case scenarios.

d. Whether, in your opinion, any mitigation measures proposed in the EMP in relation to the environmental impacts and/or environmental risks of the Project to groundwater, surface water, and/or soil are adequate. If not, please describe what other or further mitigation measures you consider necessary.

Answer - Similar to the answer to question (c) above, this is unclear as the EMP is generic and lacking specifics on the area's GDE and IDE features. Until the hydrogeology and surface water hydrology (including environmental features and pathways for contamination) have been rigorously documented and impacts assessed (including worst case scenarios, such as well integrity failure) determining mitigation measures is premature. Further mitigation measures will be required but they cannot be determined until the EMP is substantially revised.

Specific Document Review

Environmental Management Plan - March 2024

Itemised Comments

Page 3 – "… Such work includes 388 km of 2D seismic acquisition, the drilling of four petroleum wells (two horizontal and two vertical), and the hydraulic fracturing (HF) of three of those wells."

> Comment – What monitoring was done on these previous wells in regard to groundwater, hydraulic fracturing fluid migration, well integrity and structural controls? There should be data that could be incorporated into the next stage of the project.

Page 6 – "Multiple wells may be drilled off each well pad. The well's true vertical depth (TVD) to the target shale is approximately 1,600 m; the lateral length of the horizontal section can reach up to 5 km, although are typically 3 km."

And

Figure 3.4 -3

> Comment – Since the development and reduced cost of horizontal drilling techniques lower well densities are more typical, with multiple wells starting from the same drilling site or pad, as is planned at CCP. Although this reduces pad and well density in the landscape, this potentially puts greater pressure on the sites in terms of likelihood of impact due to the increased failure potential in the vertical portion of the well hole. This increased well density increases the risk of impact as greater numbers of wells are present to potentially fail and requires increased industrial activity (vehicle movement, spills, pipelines etc) during construction and operation of these well fields. This increases the potential spatial scale and magnitude of impact when compared to conventional oil/gas wells. Can wells on the same well pad be hydraulically fractured safely simultaneously or does this increases risk of well integrity failure? The extent of these drilling and hydraulic stimulation operations needs to be combined with an understanding of the structural geology of the area.

Page 11 – Table 3: "The CPP Area is located within the Mambaliya Rrumburriya Wuyaliya Aboriginal Land Trust (NT Portion 5706). There are no settlements within the CPP Area. The closest dwelling is West Balbarini, which is 1.3 km east of the CPP Area."

> Comment – Are there any other environmental features which are of importance to the First Nations people? Creek lines and rivers on either side of the project support numerous GDEs. Impacts to groundwater and surface will likely impact cultural values and the social surrounds of the native people. Stakeholder engagement is well documented but have the direct and indirect effects of the project (e.g. groundwater drawdown affecting riparian vegetation or permanently drying ephermal/permanent pools) been communicated and investigated?

Page 14 – "Based on an assessment including the persistent, bioaccumulative, and toxic (PBT) nature of the chemicals, a hazard quotient (HQ) of less than one was determined for all considered chemicals. On this basis, no further management controls are deemed necessary…."

And

"… This risk assessment is conducted using a quantitative evaluation of the risks based on the potential complete exposure pathways…"

Comment – Hazard quotients are designed for quantifying risks to human health. The risks to ecosystems and the ecological toxicity to the environment also need to be considered. For example, copper sulphate can be highly toxic to aquatic species and can bioaccumulate in the food chain. Given the potential adverse effects of some of these Tier 2 chemicals on surface and groundwater the risk assessment, quantitative evaluation and potential complete exposure pathways should be scrutinised further.

Page 85 – "The new location for BD still appears to be within the modelled flood zone, but the ground assessment (as per above points) verified that the modelling in this location is not reflective of the site conditions."

Comment – This raises questions about the modelled flood zone and the accuracy of this modelling. How accurate is the digital elevation model etc? During ground-truthing assessments were on ground conditions typically inline with the model or not? What is the model's sensitivity/uncertainty for flooding predictions?

Figure 3.3-6 to 3.3-10

Comment – This flood modelling needs further exploration. Map 4 of this series has significant flooding (0.5-1m) on the BD well pad. All other maps have flooding mapped adjacent to pads (within 500m). Flooding controls and shutdown/evacuation procedures will need to be well planned to avoid adverse environmental and infrastructure incidents. Some questions that need more exploration are: Can operations be paused? If hydraulic fracturing has begun, can it be shut down during the process if a natural disaster occurs? Can flowlines (pipelines) be flooded safely and not exposed/compromised? Is there telemetry data to check underground flowlines pressure data to detect leaks while offsite. If a major leak is detected during a flood, how will this be dealt with?

Also, by mid-century extreme rain events in the Northern Territory are projected to become more intense and recent trends show increased rainfall between December to February (Climate Change in Australia 2024 - https://www.climatechangeinaustralia.gov.au/en/changing-climate/state-climate-statements/northern-territory/). Have these climate change trends been accounted for in current flood modelling? Insufficient detail on flood modelling is presented to evaluate how robust it is.

Figure 3.3-16 to 3.3-20

Comment – SREBA Type 2 and Type 3 GDE's are mapped within a 1km radius of several water bores and streams. These are also potential receptors for shallow contamination. The effects of groundwater abstraction on these ecosystems requires better evaluation. Groundwater drawdown contours, aquifer testing, hydrostratigraphy and groundwater modelling (that has been calibrated and undergone a sensitivity analysis) are needed.

Page 122 – "Hydraulic fracturing…. typically involves injecting a viscous slurry of water and sand under high pressure into a target formation via the well. This process is intended to create new fractures in the rock and increase the size, extent, and connectivity of existing natural fractures."

Comment – Creating new fractures and increasing the size, extent and connectivity of the natural fractures has large implications for groundwater flow and conduits underground. A high-level understanding of these structural connections and controls needs to be obtained to enable a robust risk assessment to be undertaken. Flow pathways can be created during

fracturing and can lead to contamination of aquifers with fracturing fluid or other contaminants e.g. deep saline groundwater mixing with fresh groundwater. These shallow deep connectivity issues are essentially not explored in this EMP.

Page 123 – "Groundwater monitoring at each existing well pad has been conducted in accordance with relevant regulations since 2019 (see Section 4.10). There has been no detectable change in groundwater quality or the level of the Gum Ridge Aquifer on EP 187 at any of the groundwater bore monitoring bores since operations began in 2019. The Gum Ridge Aquifer is part of the larger Cambrian Limestone Aquifer."

Comment – The groundwater monitoring network is not sufficient. A network of nested piezometers or a set of monitoring bores (targeting different aquifer units at each site) should be established. Connections between the formations above and below the CLA need to be better established. A hydrograph of groundwater levels at each current monitoring site would be a helpful inclusion.

Page 124 – "…a sub-surface aquifer protection zone sits below the CLA aquifer basement at the CPP Area and the target Velkerri formation. This aquifer protection zone comprises rock greater than 900 m thick, which is 150% of the Code's protection zone requirement of 600 m [clause B.4.13.2 (l)]. This protection zone ensures there is no potential for a connection between the much deeper shale hydraulic fracture operation and the base of the overlying CLA aquifer."

Comment – What geological unit/s make up this protection zone? Figure 3.5-1 shows a basic geological cross-section, little information about these geological units is provided. In relation to this review structural features are very relevant e.g. faults or fractures that could create flow pathways during hydraulic fracturing. More information about this protection zone is required and it should be noted that a connection between the deeper shale and the CLA aquifer could also be created by a well that leaks due to a failure of well integrity or poor construction. The cavernous and vuggy nature of the CLA magnifies these risks as aquifer hydraulic conductivities will be relatively high for this unit and cementing operations will be challenging, especially obtaining an annular seal across the CLA.

Page 134 – "Assessment of HF chemicals that may be used downhole during the activity did not identify any Persistent-Bio-accumulative-Toxic (PBT) chemicals in terms of measured PBT criteria that may pose a risk to human health. In addition, the concentration of CoPC in the HF fluid system is extremely low (mg/L or ppm) and any potential toxicity effects to local fauna are therefore negligible."

Comment – The PBT criteria has been used in relation to human health risks. Even though chemicals of potential concern are extremely low in concentration this does not necessarily mean effects on fauna are negligible. If large quantities of fluid end up in surface water or groundwater systems this could equate to a toxic amount, particularly if we consider bioaccumulation effects and long-term timeframes.

Page 135 – "The GRF occurs as a vast vuggy limestone aquifer across the Beetaloo, which can often be cavernous."

Comment – Well integrity during installation and operation in this GRF unit will need particular care. Cementing the annulus of a vuggy and cavernous units can be notoriously hard as cement runs into the porous/vugs in the formation and doesn't seal the annulus where it is placed. This has large implications for well integrity and can lead to sections of

the annulus not being sealed, potentially providing a conduit for groundwater flow. An assessment of the extent of any possible contamination from well failure or surface activities is required.

Page 136 – Figure 3.9-1 and "This maximum potential increased groundwater extraction (0.75 GL/year) by Imperial is not considered to have a significant impact on available groundwater in the GRF aquifer"

Comment – Imperial's proportion of the Georgina Groundwater Allocation is relatively small and should therefore have minimal impact on the available groundwater across the Basin. However, availability of groundwater, i.e. groundwater depths, at identified environmental receptors (e.g. GDE's) could have larger impacts near the site. Important riparian vegetation along ephermal creek lines, rooting depths, vegetation health surveys and wet and dry season water levels need to be understood so water abstraction can be undertaken responsibility. Essentially impacts at a local scale could be significant and need to be assessed.

Page 137 – Table 3.9-2

Comment – Annual potential extraction is substantially below the groundwater licence volume applied for (i.e. 750ML/a). Why is a 750ML/a licence being applied for, when the highest estimated potential groundwater extraction in a year is 414ML?

Page 138 – "a significant impediment to the recycling of HF flowback in several major shale developments in North America has been the extremely high level of chlorides in the flowback, more than ten times seawater concentrations. This project will test recycled fluids and expects to be able to extend this capability as the project develops."

Comment – It is our understanding that that four wells have already been drilled with three undergoing hydraulic fracturing. Onsite information regarding the chemical nature of the flowback fluid and subsequent potential recycling of this fluid should be available and analysed. These wells should have been monitored to assess leakage etc.

Page 174 – Figure 4.3-2

Comment – There are a lot of waterholes east of ''Carpentaria 1' along the Relief Creekline. No information is provided on these waterholes and if or which aquifer they are connected to. Are they permanent and are they groundwater dependant? See Figure 1 above.

Page 177 – "As surface water diminishes throughout the dry season, many seasonal waterholes become dry season water refuges, thus putting additional pressure on riparian vegetation…. In the prolonged absence of rain, the availability of green leaf matter is very low. Under these conditions, animal condition declines as animal growth is dependent on plant growth. In the absence of rain, herbivores attempt to survive through complex strategies"

Comment – During the dry season groundwater and these waterholes are of particular importance to native fringing flora as well as resident and transient fauna. Potential drawdown from groundwater extraction at the project needs to be quantified and modelled to allow a thorough assessment of impacts in these GDE areas along with spill and shallow contamination risks.

Page 178 – “This protection zone ensures there is no potential for a connection between the much deeper shale hydraulic fracture operation and the base of the overlying CLA aquifer.”

> Comment – The use of the word ensure here is very definitive language in the context of the impact assessment provided. Natural connections could exist. Connections could be created during fracturing within the protection zone. The fracturing process is intended to create new fractures in the target rock and increase the size, extent, and connectivity of existing natural fractures. Given this is the aim of fracturing, connections being created in the protection zone is not unlikely. Also note that no structural mapping of existing fractures and faults have been presented.

Page 198 - Figure 4.9—5 Flood Modelling Within the CPP Area, Draining to the North and South from the Crest of Favenc Range on Carpentaria Highway

> Comment - More detail on and more outputs of this flood mapping are required. What is the digital elevation model that has been used? If it is the SRTM (Shuttle Radar Topography Mission) dataset it has substantial inaccuracies and low resolution in the context of site-specific flooding assessments. The use of a high-resolution LiDAR dataset is recommended. With respect to other model parameters (surface roughness, climate scenarios etc) what was used and were any sensitivity analyses conducted to assess the uncertainty of this modelling? There also needs to be an assessment of flood water velocities in the context of all infrastructure (including pipelines) to ensure that erosion and subsequent failure (with release of contaminates) cannot occur.

Page 201 – “The Bukalara sandstone formation lies directly below the Gum Ridge formation at CPP. The formation is characterised by intergranular spaces that are mainly filled with white kaolinitic clay, but minor sections have moderately good intergranular porosity. Porosities range from poor to fair (6 to 18%), and permeability is commonly low at less than a few millidarcies (md). Bore logs indicate the strata consists of a firm to hard, white, fine to medium grained quartz sandstone. The only relatively deep water bore to intersect the Bukalara Sandstone beneath the CLA in the eastern Beetaloo region is RN041679 at the Carpentaria 1 well site, constructed by Imperial for monitoring the Bukalara at the request of DEPWS. The formation was encountered between 108 and 178 m and only yielded 0.5 L/s. The drill cuttings and gamma log indicated that the sandstone is interbedded with numerous shale beds at that site [S TICKELL, 2022B]

> Comment – The hydraulic connection of the Bukalara Sandstone and the CLA need to be quantified and the request of DEPWS to construct this monitoring bore could predominantly be for this purpose. What information has been gathered during existing monitoring and what does it imply regarding groundwater/aquifer connections?

Page 202 – ‘’Only a small number of inter-aquifer pumping tests have been undertaken to help establish the degree of connection between the Anthony Lagoon and Gum Ridge Formations”

> Comment – Water quality and water level observations from these two aquifers imply they are potentially hydraulically connected at Carpentaria 2/3. Additional aquifer tests to investigate connectivity were scheduled for 2023. Were these tests carried out? What did the results conclude?

Page 212 – ". None of the existing non-Imperial bores are within 1 km of potential well pads as required by the Code."

> Comment – Imperial owned bores within a 1km radius need to be considered also for monitoring. Hydraulic stimulation creates fractures that intercept older, abandoned unplugged wells (or wells with integrity failure) or their vicinity. These aging wells can intersect and communicate with freshwater aquifers, and inadequate or failing completions/cement can create pathways for contaminants to reach the potable groundwater resources. This needs to be considered for these risks to be managed.

Page 231 – "The water table at CPP well pads has consistently been measured to be >50m BGL, dependent on topography. Generally, where groundwater is within 20m of the land surface, some native plants may access and use groundwater"

> Comment – The CPP well pad groundwater bores have targeted the Cambrian Limestone Aquifer. Shallower or 'perched' surface aquifers and aquifers along creeklines, have not been addressed adequately regarding GDE impact assessment. These need to be assessed and groundwater levels mapped.

Page 231 - These will not be impacted as CPP site selection has complied with LCG buffer areas associated with waterways and drainage lines."

> Comment – This statement implies that because a land clearing guideline buffer has been put in place for waterways and drainage lines that no impacts will occur. This statement does not consider groundwater drawdown from operations propagating into these buffer zones or chemical spills/leaks. This needs considerably more work.

Page 256 – Table 6.2-2

> Comment – Risks #7 and #8 only mention risks to surface water, if this surface water infiltrates the surface it becomes groundwater. Groundwater should probably be included here for completeness. Also, groundwater abstraction and resulting drawdown should be included as it presents a risk to GDEs. This risk assessment is generic.

Page 287 – "Should wet season weather monitoring indicate floodwater inundation is possible, a window of opportunity exists to ensure freeboard is in place, the transfer of fluids has been completed if required and the safe shutdown of ancillary equipment has been completed."

> Comment – Does this window of opportunity provide adequate time to shutdown operations and store fluids safely? How long can fluids be stored safely if no site access occurs for a prolonged period?

Page 300 – Table 6.3 -5

> Comment – No significant groundwater drawdown that affect GDE's should be added to this groundwater environmental quality table.

Page 304 – Table 7.1 – 1

> Comment – Is there a water licence operating strategy/plan or the like? A plan to manage groundwater?

Page 332 – Table 8.2-2

> Comment – Groundwater monitoring is listed as quarterly. Groundwater level data should be collected more frequently. This will allow a more proactive approach if levels start trending down due to groundwater abstraction or start mounding due to hydraulic fracturing operations. A minimum four to six weekly frequency is recommended with preferably daily logger data at least initially.

Page 333 – Table 8.2-2

> Comment – The Rehabilitation Management Plan mentions vegetation ground cover and canopy height surveys. These should be conducted annually to assess vegetation condition temporally and spatially and be combined with vegetation density/persistence remote sensing. This table only states these surveys will be done prior to construction. Ideally these vegetation survey should measure vegetation 'health' across the area. Remote sensing is required to understand to understand where GDEs and IDEs are.

Appendix 1 – Environmental Assessment Report - December 2023

General Comments

Within the CPP project area the waterways and riparian areas offer potential habitat for a range of conservation significant species. There has been a large focus on buffer zones for clearing around creek lines and riparian areas, however other impacts such as groundwater drawdown, have not been mentioned. This needs substantial expansion as per comments herein.

Itemised Comments

Page 27 – "Provides water (in wet season) and larger pools in the dry season."

> Comment – These larger pools are likely groundwater dependant and support a higher fauna diversity than surrounding areas. Groundwater drawdown and potential for contamination in these areas needs to be managed to prevent impacts to these important riparian areas. Known permanent and ephermal pools should be monitored. The groundwater hydraulics and aquifer connectivity of these riparian areas and pools needs to be understood to enable potential impacts to be managed. Potential surface water contamination pathways also need to be assessed across a range of surface water flow events, not just for floods.

Page 27 – "These will not be impacted as the exploration will adhere to the LCG buffer areas associated with waterways and drainage lines"

> Comment – These will not be impacted by clearing but could be impacted by groundwater drawdown, hydraulic fracturing leaks and fracturing fluid or wastewater spills (either via surface water pathways or by groundwater contamination).

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THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

CREATE CHANGE

18 April 2024

[redacted]
Solicitor
Environmental Defenders Office

Dear Emma,

Carpentaria Pilot Production EMP and EPA referral

This letter follows your request for my independent expert advice on the above matter.

I confirm that I have read the Northern Territory Supreme Court's Practice Direction No 6 of 2015: Expert Reports (PD 6) and the Code of Conduct and I agree to be bound by it.

The documents that I have referred to during preparation of this advice are (file names as provided):

- Referral form
- Referral-report-imperial-part1
- Referral-report-imperial-part2
- Referral-report-imperial-part3
- EMP-IMP5-1-reduced-redacted-resubmitted-070324
- 01-Appendix-01-Environmental-Assessment-Report(compressed)-Redacted
- 06-Appendix-Imperial-Wastewater-Management-Plan
- Code of Practice: Onshore Petroleum Activities in the Northern Territory, 31 May 2019
- EPBCA Significant Impact Guidelines 1.3

Due to the short time-frame for preparing this advice I have not been able to undertake a site visit or request supplementary information.

My advice is provided below in three parts: Summary of findings; Responses to questions raised in the Expert Brief; and Other matters.

My consideration of soil is limited only to the potential for contamination of soil from spills of wastewater (not land clearance and other activities).

Summary of findings

The surface water and soil-related risks from the proposed Carpentaria Pilot Project (CPP) are principally associated with potential accidental releases, leaks and spills of chemicals and flowback water, and potential flooding of facilities. These risks are manageable by application of good practice in planning, design and operation of the CPP. The proposed approach to design and operation of wastewater and water storages and other infrastructure is likely to be adequately conservative with respect to preventing weather-related spills. However, the reviewed EMP documents do not provide the level of information required to confidently conclude that risks are acceptably low or that an adequate assessment has been conducted.

Due to the relatively short timeframe of the proposed CPP (2025-2029), and hence the limited potential effect of climate change relative to historical variability, it is not necessary to explicitly consider climate change in assessing impacts. This may change if an extension to the CPP is proposed.

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CRICOS Provider 00025B
TEQSA PRV12080

The scope in the Expert Brief did not include groundwater and I have not reviewed risks to groundwater in detail; however, there are omissions from the reviewed EMP documents related to groundwater management that may be a concern.

Responses to questions raised in the Expert Brief

a) Whether, in your opinion, the EMP provides an adequate assessment of the environmental impacts and/or environmental risks of the Project to:

i. surface water; and

ii. soil.

The EMP has identified and assessed the relevant impacts that could arise through accidental releases, leaks and spills of chemicals and flowback water, including the potential sources, pathways and receptors of contaminants.

Due to time constraints, I have not examined in detail the methods or evidence relied upon for all elements of the surface water and soil risk assessments, in particular the local hydrological and soil characteristics of the project area and how they may affect pathways of contaminants. My review has focussed on the assessment of potential spills from water storage tanks and flooding of infrastructure, which I regard as the key sources of risk to surface water and soils. I cannot conclude that the assessment of these risks is adequate due to lack of information provided in the documents, specifically:

The EMP lacks a clear description and illustration of the proposed water management system. A reasonable understanding of water management system is important to understand the risks of spills from wastewater storages. The Water and Wastewater Management Plan (WWMP) should include a node-link water system diagram that describes: the type of storage (freshwater, wastewater untreated, wastewater treated, greywater, cover, uncovered, floating cover); flow rates between storages under design conditions; water sources, locations and type of treatment; and references to the relevant wet weather triggers. At present, it is too difficult for the reader to understand the flows of water and wastewater that affect storage levels, too difficult to relate terms in the reports to locations and roles of tanks (for instance “treated water storage tanks” are referred on page 18 of the WWMP but it is unclear where they are and whether they have a role in wet weather contingencies), and too difficult to follow which tanks will be covered and which will not. Without this information I cannot conclude that spill risks have been adequately assessed.

The EMP says “However, for compliance with this EMP, regulatory standards require operators employ a 0.1% Probable Maximum Precipitation (PMP) estimate over a 90-day period” (page 29 of the WWMP). The reason for using a 90-day period and how the 0.1% annual exceedance probability rainfall total has been estimated has not been presented, nor is there clarity as to whether and how the PMP has been used – contrary to what is implied in the WWMP, the PMP is not the same as the 0.1% annual exceedance probability rainfall. The reference to BOM (2023) on page 30 of the WWMP is not helpful in this regard because the rainfall estimation tools on that website do not cover 90-day periods. The estimation of design extreme rainfall is fundamental to the assessment of risks from accidental spills. Without a precise explanation of the method of estimating design extreme rainfall I cannot conclude that the assessment is adequate.

Flooding due to catchment runoff is a potentially significant environmental risk due to potential erosion of the bund and potential ingress of water into the well pad. Page 87 of the Referral Report Part 2 shows well pad “BD” to be within the predicted 100-year ARI flood; however, according to that report, on-ground inspection proved “the modelling in this location is not reflective of the site conditions”. Detailed justification is not provided. The potential for flooding of the well pads is critical to understanding potential surface water impacts of the CPP as well as understanding risks to CPP operations. Therefore, more evidence should be provided that the proposed location of well pad BD is not exposed to the 100-year ARI flood. This might consist of an extended description of why the on-ground survey concluded that the flood modelling results were inaccurate and photographs. Without further evidence, I cannot conclude that the assessment is adequate.

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b) If applicable, describe any environmental impacts and/or environmental risks of the Project, which are not addressed in the EMP, to:

i. surface water; and

ii. soil.

The EMP has not omitted any environmental impacts and/or environmental risks to surface water or soils that I consider to be material.

c) Whether, in your opinion, any mitigation measures proposed in the EMP in relation to the environmental impacts and/or environmental risks of the Project to surface water and/or soil are adequate. If not, please describe what other or further mitigation measures you consider necessary.

The EMP generally proposes adequate risk mitigation measures.

An exception is that no information is provided about surface water monitoring. Water quality monitoring is normal good practice where there is a risk of contamination from project activities. Such monitoring allows the impacts of the project to be determined relative to baseline water quality, especially following a spill or accidental release of wastewater. The Referral Report Part 3 p106 includes "Baseline and ongoing seasonal surface water quality monitoring of selected perennial waterholes near CPP area will be conducted as part of monitoring overall isolation, containment, and integrity in the CPP Activity (Section 6.2 of the EMP – Environmental Performance Standards)". However, no information about proposed locations, frequencies and water quality parameters is provided. A map showing monitoring locations plus a table listing parameters and monitoring frequencies, including a baseline period, should be included.

Page 33 of the WWMP explains the trigger action response plan for drawing down water levels in open tanks if significant rainfall is forecasted: If the Bureau of Meteorology (BOM) 7-day forecast predicts a "significant rainfall event" exceeding 300 mm over four days for the CPP Area, Imperial plans to ensure that freeboard will be maintained as follows…". Due to the limitations of relying on rainfall forecasts, which are not always accurate, this should be supplemented by a trigger related to measured water levels.

Also, referring still to page 33 of the WWMP, it is unclear what is meant by "If no tank at the WHS has sufficient freeboard, tanks on the well pads may be used". It is unclear what well pad tanks are being referred to and the basis for assuming that they will have capacity to store excess water. Without this information I cannot conclude that the measures for controlling excess water are adequate.

d) Whether, in your opinion, the EMP provides an adequate assessment of how climate change may affect:

i. the management of wastewater produced by the Project; or

ii. any other environmental risk or environmental impact of the Project relevant to your area of expertise.

The EMP does not provide an assessment of how climate change may affect wastewater management or environmental impacts, which is appropriate. Although climate change is expected to increase rainfall extremes (e.g. Fig 1 below from Moise et al. 2015), within the timeframe of the proposed CPP (2025-2029 as indicated on p57-58 of the EMP) these increases will be small compared to historical variability. Not adjusting for climate change over this short project period is in line with guidance in Part 1, Section 6 of the Australian Rainfall and Runoff Guide (Ball et al. 2019), which is the relevant guidance. Climate change may already be producing wetter weather in this region, as shown in Figure 10 of Heidemann et al. (2023) (not reproduced here due to copyright, but the link is provided below). However, the statistical methods employed in the EMP integrate any effects of climate change in recent decades. Instead of considering 140 years of historical rainfall at the Daly Waters Gauge (as in page 31 of the WWMP), including only the last 60 years would weight the design rainfall to more recent decades, which would more conservatively allow for historical climate change. However, general best practice is to use the full available historical record.

If a CPP project extension is proposed, climate change may need to be explicitly considered.

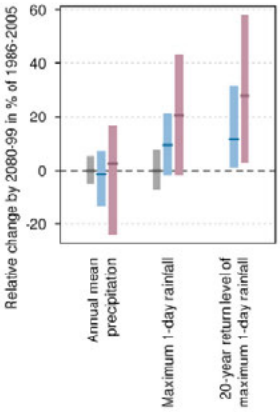

FIGURE 4.3.7: PROJECTED CHANGES IN MEAN RAINFALL, INTENSITY OF ANNUAL MAXIMUM 1-DAY RAINFALL AND INTENSITY OF THE 20-YEAR RETURN VALUE FOR THE 1-DAY RAINFALL FOR THE SOUTHERN SLOPES CLUSTER (SEE TEXT FOR DEFINITION OF VARIABLES). CHANGES ARE GIVEN IN % WITH RESPECT TO THE 1986-2005 MEAN FOR RCP4.5 (BLUE) AND RCP8.5 (PURPLE). NATURAL CLIMATE VARIABILITY IS REPRESENTED BY THE GREY BAR. BAR PLOTS ARE EXPLAINED IN BOX 4.2.

Figure 1. Projected percentage change in mean rainfall in northern Australia (Moise et al. 2015)

e) If applicable, describe any additional environmental impacts and/or environmental risks of the Project, which are not addressed in the EMP, resulting from the effects of climate change on:

i. the management of wastewater produced by the Project; or

ii. any other environmental risk or environmental impact of the Project relevant to your area of expertise.

This is addressed by the answer to (d).

f) Whether, in your opinion, any relevant mitigation measures proposed in the EMP are adequate having regard to the effects of climate change, if any, on:

i. the management of wastewater produced by the Project; or

ii. any other environmental risk or environmental impact of the Project relevant to your area of expertise.

If not, please describe what other or further mitigation measures you consider necessary.

This is addressed by the answer to (d).

g) In your responses to paragraphs (d) to (f) above, please consider:

i. any current effects of climate change in the Northern Territory; and

ii. projections of any future effects of climate change in the Northern Territory during the life of the Project, or during the life of any relevant environmental impact or environmental risk of the Project (if such may persist beyond the operational period of the Project).

This is addressed by the references to Moise et al. (2015) and Heidemann et al. (2023). For additional context, Figure 2 below shows large uncertainty about whether wet season rainfall total, which is most relevant in terms of the EMP's 90-day criterion for fixing freeboard, will increase or decrease under future climate.

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Recent climate data sets exist that can be used to update the data shown in Figures 1 and 2; however, this requires extracting and processing data and the time constraints of providing this advice did not permit this to be done.

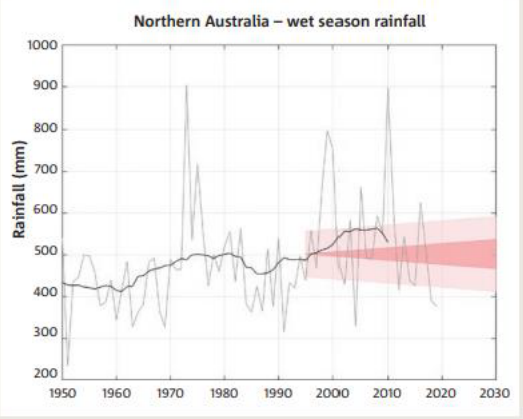

Figure 2.11. Total wet season rainfall in northern Australia as a whole (north of 26°S) for each year since 1950 (thin line) and the underlying trend (thick line) with the projected range of change for 1986–2005 to 2020–2039 under any emissions scenario from Climate Change in Australia added as a pink range. The decadal variability is shown as a feint pink band. (The trend uses a 20-year moving average (Hawkins et al. 2020), observations are from AWAP.)

Figure 2. Historical and projected wet season rainfall totals in northern Australia (NESP ESCC 2020)

Other matters

The scope in the Exert Brief excluded groundwater and so my advice does not address potential groundwater impacts in any detail; however various issues may be worth noting:

- The reviewed EMP documents do not address the potential for cumulative impacts to water levels in groundwater bores on neighbouring properties due to the proposed CPP and other gas projects, except noting that they are more than 1 km from the activity.
- The reviewed EMP documents exclude a conceptual hydrogeological model showing the main hydrogeological units, their relation to the CPP wells/bores, and flow pathways. This may be regarded as an essential requirement in an environmental assessment of unconventional gas projects.
- The reviewed EMP documents exclude lithological details from the existing boreholes in the project area, while noting the requirement of the code that "A key requirement of the Code in relation to groundwater monitoring in the Beetaloo is the guideline requirement for an accurate lithological log of rock from the water supply bore at a well pad".
- The reviewed EMP documents show baseline groundwater quality data from 10 samples from four bores, with no information about the period over which the samples were taken. Samples should be taken over at least one year, ideally two years, to capture any effects of hydrological variability. Baseline data will need to be collected from proposed bores with an adequate baseline period.

If these issues are of concern, I recommend that a groundwater expert is consulted.

References

Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors) 2019. Australian Rainfall and Runoff: A Guide to Flood Estimation, Book 1 - Scope and Philosophy, Commonwealth of Australia (Geoscience Australia). http://www.arr-software.org/pdfs/ARR_190514_Book1.pdf

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https://www.climatechangeinaustralia.gov.au/media/ccia/2.2/cms_page_media/168/MONSOONAL_NORTH_CLUSTER_REPORT_1.pdf

NESP Earth Systems and Climate Change Hub. 2020. Climate change in the Northern Territory: state of the science and climate change impacts. NESP ESCC Hub, Melbourne
https://depws.nt.gov.au/__data/assets/pdf_file/0011/944831/state-of-the-science-and-climate-change-impacts-final-report.pdf

Heidemann, H., Cowan, T., Henley, B. J., Ribbe, J., Freund, M., & Power, S. (2023). Variability and long-term change in Australian monsoon rainfall: A review. WIREs Climate Change, 14(3).
https://doi.org/10.1002/wcc.823

[redacted]

DRAFT

From: [redacted]
To: imperial ep187+
Subject: Submission against ep187
Date: Friday, 19 April 2024 2:16:59 PM
Attachments: [redacted]

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

[redacted]

Palmerston
NT 0830
[redacted]

Imperial.ep187@nt.gov.au

Dear Minister,

My objections to this application are varied due to the many concerns which the application highlights.

Environmental Impacts and potential human health effects.

With reference to their Table listing the Chemicals and possible effects on humans and the effects on the Environment.

Appendix 06 Waste and Wastewater Management Plan IMP 5-1

Table 4—3 Summary of Activity Drilling Waste Analysis.

As their list states that there is no Adverse Impact on several of these chemicals (the last Row). I have researched and found information from various sources to suggest otherwise on a couple of these chemicals.

Table 4—3 Summary of Activity Drilling Waste Analysis

Barium† 795 5.7 ± 2.5 85 ± 70 0.4 ± 0.2 Barium derived from the barite mud additive, generally considered non-toxic. Leachate concentrations are higher in the cuttings but are not considered to pose a risk**. No adverse impact.**

Chromium† (Total) 25 0.1 ± 0.1 63 ± 6 < LOR Chromium concentrations are higher in background soil (similar process to iron enrichment). Chromium is slightly more mobile from cuttings. No Manganese† 122 0.1 ± 0.0 74 ± 37 0.1 ± 0.1 Cuttings and background soil essentially indistinguishable. Low toxicity at observed concentrations. **No adverse impact.**

Chromium

Heavy metals are defined as metals with relatively high density and atomic weight, and their various applications have raised serious concerns about the environmental impacts and potential human health effects. Chromium is an important heavy metal that is involved in biological metabolism, but Cr exposure can induce a severe impact on occupational workers or public health. In this study, we explore the toxic effects of Cr exposure through three exposure routes: dermal contact, inhalation, and ingestion. We propose the underlying toxicity mechanisms of Cr exposure based on transcriptomic data and various bioinformatic tools. Our study provides a comprehensive understanding of the toxicity mechanisms of different Cr exposure routes by diverse bioinformatics analyses.

Industrial wastes containing Cr are known as major sources of soil and water pollution and, hence, can have a severe impact on public health.

Which they have listed below.

Dermal exposure to Cr for the general public can occur from dermal contact with certain consumer products or soils that contain Cr. Construction workers can be exposed to Cr in cement. Can also cause contact dermatoses and ulceration.

Respiratory exposure to Cr mainly occurs in industrial workers. The inhalation of Cr is associated with an increased risk in lung cancer, based on numerous observations in occupational epidemiology studies. Among workers with increased lung cancer risk, nasal irritation and perforation have also been reported.
Furthermore, lung cancer occurred more often in workers in the chromate-producing industry than in control subjects.

Adverse Effects of Cr on Gastrointestinal Tract
Cr is a well-known carcinogen in the respiratory tract and can cause lung cancer in occupational workers.

Ingestion of Cr through drinking water can form Cr-DNA adducts and induce DNA damage (Int J Mol Sci. , 2023). Metastasis, which was also found to be a common potential toxic mechanism of all exposure routes of Cr, is well-known to be involved in the development of various diseases and cancers.

Table 1

Potential toxicity mechanism, biological processes, and hub genes of Cr exposure dependent on different exposure routes.

Exposure Route	Potential Toxicity Mechanism	Biological Process (BP)	Hub Genes
Dermal contact	DNA damage, metastasis, immune system disorder, allergic reaction	RNA modification, sterol biosynthesis process, DNA replication, intrinsic apoptotic signaling pathway	CXCL8, PTGS2, FOS, HMOX1, ATF3, IRS1, E2F1
Inhalation	DNA damage, metastasis, cell cycle alteration, immune system disorder	Ribosome biogenesis, rRNA metabolic process, cell–substrate adhesion, macrophage cytokine production	TLR4, TGM2, TNFRSF11B, BDKRB1, KIT, ZEB1

Exposure Route	Potential Toxicity Mechanism	Biological Process (BP)	Hub Genes
Ingestion	DNA damage, metastasis	Nucleotide biosynthesis process, nucleotide phosphate biosynthesis process, alcohol metabolic process, steroid metabolic process	VEGFA, EGFR, APP, SGK1, JUN, TLR2

(Int J Mol Sci. , 2023)

“Flowback waters and produced waters, also referred to as flowback-produced waters from unconventional gas exploration can contain a large variety of chemicals. Some of these chemicals are additives that form the injected hydraulic fracturing fluid, to maintain well stability and conditions.

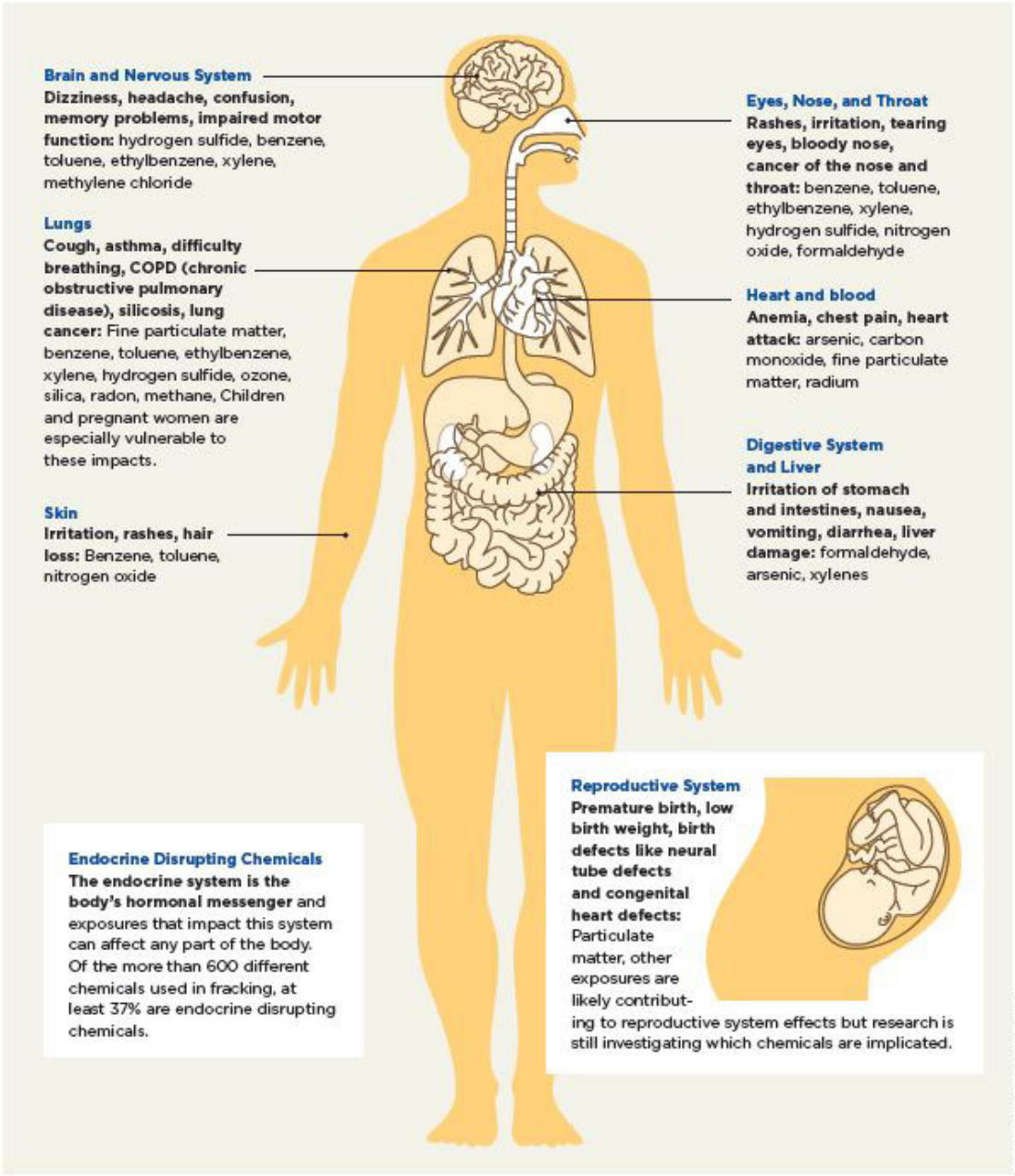
A portion of the chemicals that return in flowback-produced water can be of geogenic origin, because there is a large variety of chemicals found in flowback-produced water from unconventional gas extraction, a preliminary literature review was performed, resulting in three chemicals of concern to investigate further: barium Ba, *o*-cresol, and sodium chloride NaCl.

“Barium is highly reactive and can be found as a variety of salts. Mineral deposits containing Ba can be exposed to injected hydraulic fracturing fluids and returned to the surface in flowback-produced water. It is a common drilling additive, commonly referred to as *barite*, barium, sulfate, $BaSO_4$. The ion Ba^{2+} is a muscle poison at concentrations of 0.009–0.162 mg/kg Ba^{2+} as $BaCl_2$ (reported as 0.0001–0.0018 mM/kg $BaCl_2$) introduced into cerebrospinal fluid, resulting in tetanic spasms and convulsive seizures due to central nervous system stimulation. In humans, an oral dose of 3.82 mg/kg Ba^{2+} as $BaCl_2$ (reported as 5.8 mg/kg $BaCl_2$) causes paraesthesia, muscle weakness, and flaccid paralysis).

(Mixture Toxicity of Three Unconventional Gas Fracking Chemicals, Barium,O-Cresol, and Sodium Chloride, to Freshwater Shrimp Paratya australiensis , 2022)

FIGURE 1

Health Effects of Chemicals Associated with Oil and Gas Development



This image indicates the common symptoms and health impacts known to be linked to chemicals associated with unconventional oil and gas development, including some of the chemicals captured in air samples as part of this project.

NOTE: For a description of health symptoms associated with specific chemicals, see the Agency for Toxic Substances and Disease Registry at *http://www.atsdr.cdc.gov/substances/ToxOrganSystems.asp*.

Also, from Yale News. Chemicals in fracking fluid and wastewater are toxic. This is particularly important as the fluids will enter the underground reserves, i.e. aquifers.

The research team evaluated available data on 1,021 chemicals used in fracking, a process that recovers oil and natural gas from deep within the ground by using a mixture of

hydraulic-fracturing fluids that can contain hundreds of chemicals. The process creates significant amounts of wastewater and fractures the bedrock, posing a potential threat to both surface water and underground aquifers that supply drinking water, note the researchers.

While they lacked definitive information on the toxicity of the majority of the chemicals, the team members analyzed 240 substances and concluded that 157 of them — chemicals such **as arsenic, benzene, cadmium, lead, formaldehyde, chlorine, and mercury — were** associated with either developmental or reproductive toxicity. Of these, 67 chemicals were of particular concern because they had an existing federal health-based standard or guideline, said the scientists, adding that data on whether levels of chemicals exceeded the guidelines were too limited to assess.

Our systematic screening approach identified a list of 67 hydraulic fracturing-related candidate analytes based on known or suspected toxicity. Incorporation of data on potency, physicochemical properties, and environmental concentrations could further prioritize these substances for future drinking water exposure assessments or reproductive and developmental health studies.

“We focused on reproductive and developmental toxicity because these effects may be early indicators of environmental hazards. Gaps in our knowledge highlight the need to improve our understanding of the potential adverse effects associated with these compounds,” said Elise Elliott, a public health doctoral student and the paper’s first author.

The researchers determined that wastewater produced by fracking may be even more toxic than the fracking fluids themselves. This led the researchers to conclude that more focus is needed to study not just what goes into the well, but what chemicals and by-products are generated during the fracking process.

However, the practice may come with a significant public health consequence, warn critics of fracking, noting that the process has the potential to contaminate drinking water supplies with toxic chemicals. Air pollution, greenhouse gas emissions, and small earth tremors from the drilling and waste disposal processes are also cited as concerns.

The researchers determined that wastewater produced by fracking may be even more toxic than the fracking fluids themselves. This led the researchers to conclude that more focus is needed to study not just what goes into the well, but what chemicals and by-products are generated during the fracking process.

(A systemetic evaluation of chemicals in hydraulic-fracturing fluids and wastewater for reproductive and development toxicity, 2017)

I believe the cumulative effects of drilling these 10 new wells needs to referred to the Federal Environmental Minister under the Environment Protection and Biodiversity Conservation Act 1999 because of the significant impact on water resources.

Appendix 6 Imperial Wastewater Management Plan

4.8.1.

Remote telemetry systems will be installed to allow for remote monitoring and response to alarm activation. These will include a water level sensor, a leak detection sensor and possibly a camera. HF fluid will be transferred to above ground tanks at the WHS for re-use. Above ground tanks at the well pads will typically be interconnected through the HF flowline (subsurface HDPE pipework) to the WHS. As an additional contingency measure, if it becomes necessary to manage wastewater in the above-ground tanks, wastewater fluid may be transferred between on-site above-ground tanks or off-site for disposal, using trucks.

How will this be possible during a cyclone or particular year when we have a very wet “wet” season?

How will this be achieved if you are unable to bring the trucks into the site?

Greenhouse Emissions.

Does Empire have a contract with McArthur River Mine and what does this entail for fugitive emissions which will be produced? How will they be accounted for?

Culture.

The activity should be subject to a full Environmental Impact Statement before proceeding due to the inadequate assessment of Cultural Heritage Artifacts undertaken in 2022, where they were considered *isolated artifacts*. This does not diminish the importance of Cultural Artifacts being found or yet to be found.

This activity should also be subject to a Full Environmental Impact Assessment, that explores the cultural values of the affected ecology, water and landscapes and gives Traditional Owners the power to grant or refuse consent to the proposed activities.

This activity, in its entirety, is a danger to Nature and Humans alike. There is no mention of the affects to downstream communities of fish and wildlife during contamination after flood events. We now know that cumulative affects to river systems, humans and emissions, air pollution and accidents do occur, and they cannot be undertaken with the certainty of no damage to the environment. There will be damage, and this cannot be minimised because of the nature of the beast. Therefore, it must not be undertaken.

[redacted]

[redacted]

[redacted]

Gray NT 0830

From:	Have Your Say Northern Territory
To:	imperial ep187+
Subject:	Anonymous User completed Carpentaria Pilot Project EP187 Environment Management Plan
Date:	Thursday, 18 April 2024 10:40:04 PM

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Anonymous User just submitted the survey Carpentaria Pilot Project EP187 Environment Management Plan with the responses below.

Given name

[redacted]

Family Name

[redacted]

Location

ANULA, NT

Stakeholder type

Community member

Email address

[redacted]

Interest area

Flora and fauna
Climate change
Water
Human health
Social and cultural
Regulation and compliance
Waste management
Chemicals

Please provide your comments

I ask that the Carpentaria Pilot Production EMP is refused because the impacts and risks of the project are too significant. Specifically, the full lifecycle greenhouse gas emissions from the project will be substantial, but Empire doesn't even attempt to quantify them. They acknowledge that emissions from the project would equal approx 475,000 tCO2-e per annum if they flared all the gas, but they do not estimate the downstream emissions if

the gas is transported elsewhere via the McArthur River Gas Pipeline, as they propose. Furthermore, The company claims it will produce 25 terajoules (TJ) of gas a day, but the McArthur River Pipeline only has capacity for 15TJ a day. There's no mention or explanation of this difference in the draft EMP and no estimation of emissions from flaring the excess gas. Other important factors include; -Serious risks of flooding leading to pollution and environmental damage, because the project is in the headwaters of two catchments, and crosses Relief Creek and the area around it that floods. -Wells will be located just outside the 1 in 100 year flood zone, which means they are likely to flood in more extreme events and be at greater risk with climate change. -The waste management plan proposes that some of the 35 million litres of contaminated fracking wastewater at each well may be held in open tanks, even during the wet season and transferred in trucks to be disposed of in unspecified locations, risking spills and leaks. -The re-evaluation of the importance of cultural heritage artefacts found at the site in 2022 from what was previously considered "isolated artefacts" to recognition as a site of greater significance indicates the inadequacy of the assessments being conducted for Environmental Management Plans for fracking activities. Cultural sites and landscapes should be fully protected. -Empire plans to take up to 950 million litres of water from the productive Cambrian Limestone Aquifer system which is facing growing extraction pressure and which is essential to support culture, nature and communities in the area. -The water licence they intend to apply for equates to roughly 9% of the total volume of groundwater allocated for fracking the Georgina Wiso Water Allocation Plan, and doubles the volume of water entitlements granted to gas companies to date. - The risks of aquifer connectivity between the deeper aquifers where fracking will occur and shallower aquifers relied on by communities is poorly understood, and there are risks of cross-contamination and depressurisation. -The proposed clearing would take the total area of clearing approved for fracking to date to 1,200 hectares, and poses a risk to three nationally-listed threatened species that are recorded or likely to be present in the area, the Grey Falcon, Painted honeyeater and Gouldian finch as well as five migratory birds protected under national environment law. I ask that the Carpentaria Pilot Production EMP is refused because it is polluting, uneconomical, unwanted and just plain stupid in view of the current climate crisis.

From: [redacted]
To: imperial ep187+
Subject: Comment on EMP for Imperial's Carpentaria Pilot Project - EP 187
Date: Friday, 19 April 2024 2:18:44 PM

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To whom it may concern,

Please find a recorded submission on Imperial's EMP for EP 187 from Gurdanji Senior Traditional Owner [redacted], recorded in Borroloola on 15 April 2024.

You can find the submission [redacted]

Thank you for considering it.

Regards,

[redacted]

[redacted]

From: [redacted]
To: imperial ep187+
Subject: Comment on EMP for Imperial's Carpentaria Pilot Project - EP 187
Date: Friday, 19 April 2024 2:26:28 PM

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To whom it may concern,

Please find a recorded submission on Imperial's EMP for EP 187 from Yanyuwa Garrawa Gudanji woman [redacted], recorded in Borroloola on 16 April 2024.

You can find the submission [redacted]

[redacted] for considering it.

Regards,

[redacted]

[redacted]

From: [redacted]
To: imperial ep187+
Subject: Comment on EMP for Imperial's Carpentaria Pilot Project - EP 187
Date: Friday, 19 April 2024 2:30:39 PM

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To whom it may concern,

Please find a recorded submission on Imperial's EMP for EP 187 from [redacted], recorded in Borroloola on 17 April 2024.

You can find the submission [redacted]

Thank you for considering it.

Regards,

[redacted]
Contact person
Nurrdlainji Native Title Aboriginal Corporation

From: [redacted]
To: imperial ep187+
Subject: Comment on EMP for Imperial's Carpentaria Pilot Project - EP 187
Date: Friday, 19 April 2024 2:56:03 PM

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

To whom it may concern,

Please find a recorded submission on Imperial's EMP for EP 187 from [redacted] and [redacted], Traditional Owner from the Karranjini group, recorded in Borroloola on 16 April 2024.

You can find the submission [redacted].

Thank you for considering it.

Regards,

[redacted]

From: [redacted]
To: imperial ep187+
Subject: Comment on EMP for Imperial's Carpentaria Pilot Project - EP 187
Date: Friday, 19 April 2024 3:00:56 PM

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

To whom it may concern,

Please find a recorded submission on Imperial's EMP for EP 187 from [redacted], Garrawa and Gudanji man, recorded in Borroloola on 16 April 2024.

You can find the [redacted]

Thank you for considering it.

Regards,

[redacted]

From: [redacted]
To: imperial ep187+
Subject: Submission from Nurrdalinji Aboriginal Corporation - EMP for Imperial's Carpentaria Pilot Project - EP 187
Date: Friday, 19 April 2024 3:53:52 PM
Attachments: [redacted]

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

To whom it may concern,

Please find attached a submission from Nurrdalinji Native Title Aboriginal Corporation in response to Imperial's EMP for EP 187.

Thank you in advance for considering it.

Regards,

[redacted]
Chair, Nurrdalinji

Nurrdalinji Native Title Aboriginal Corporation
ABN: 32 608 508 769
ICN: 9392

DEPWS Petroleum Operations Unit
PO Box 3675
Darwin NT 0801
By email: imperial.ep187@nt.gov.au

19 April 2024

Dear Colleagues,

Comment on EMP for Imperial's Carpentaria Pilot Project - EP 187

Nurrdalinji Native Title Aboriginal Corporation (Nurrdalinji) was established by native title holders of the Beetaloo Sub-basin/ Barkly regions, and was registered with the Office of the Registrar of Indigenous Corporations on 9 October 2020. Our name "Nurrdalinji" is an Alawa language word meaning "mixed tribe", which reflects the fact that our membership is drawn from a wide area and several different language groups.

Nurrdalinji is an important vehicle for us to express our concerns and to protect the interests of our members and native title holders in the Beetaloo Basin region. We formed Nurrdalinji to act as a clear and faithful voice for native title holders frustrated by the quality and adequacy of the Northern Land Council's (NLC) advice and representation of our interests, most recently in relation to fracking on our country.

Our members have native title and traditional interests across the Barkly and Roper regions of the Northern Territory, including in the EMP area of Exploration Permit 187, held by Imperial.

Please accept the following comments on Imperial's EMP made on behalf of Nurrdalinji Aboriginal Corporation and its members.

Lack of adequate consultation and informed consent

Imperial claims in this EMP that it *"respects the principle of Full, Prior and Informed Consent (FPIC) as recognised in the United Nations Declaration on the Rights of Indigenous Peoples"*.

Yet to date, our people have had limited and very unsatisfactory engagement with Imperial about its plans to frack our country as set out in the EMP.

Imperial has advertised a number of meetings but never taken the time to properly judge if people understand the full scale of work planned and whether our people properly consent to the works, or not.

In particular, it is evident from the extract below from Appendix 10 of the EMP that Imperial has not completed anticipated consultations as required for the EMP, and most importantly, as required to ensure free, prior and informed consent.

Imperial admits in Appendix 10 that a second round of meetings were planned to discuss the important annual work program - *a "comprehensive overview of proposed activities and work methods*" - but these meetings were never actually held. It is unclear when this will occur, or if they will occur. A promise of future consultation before work begins, and 'best efforts' is not sufficient consultation for the purpose of signing off on the EMP.

This extract is emblematic of the approach Imperial and the NLC take to consultation - a tickabox process to be stepped through. This EMP should not be approved until proper consultation has been proven to have occurred and that there is consent. It is not enough that Imperial 'promise' consultation will occur. Who will hold Imperial to account for any failure to do so?

> In August 2023, the NLC facilitated group meetings that included Traditional Owners for EP 187 and other Aboriginal people interested in the Activity. Four separate meetings were held across various regional locations as detailed in the Key Consultation Activity Summary **Section 2.4.4**.
>
> Imperial submitted its Annual Work Program (AWP) to the NLC to support consultation requirements on 10 October 2023. The AWP provides a comprehensive overview of proposed activities and work methods.
>
> The NLC had meetings originally scheduled to be held with Traditional Owners in November 2023; however, these meetings were postponed by the NLC, requesting further time to review the information that was provided by Imperial. These meetings were subsequently rescheduled for December 2023. Unfortunately, unforeseen circumstances of cultural significance outside of the NLC and Imperial's control caused these planned meetings to be postponed again.
>
> Imperial is continuing to work with the NLC to prioritise the rescheduling of meetings required for the purpose of consultation related to this EMP as soon as practicable. Imperial has made its best endeavours to engage with the stakeholders and will continue this engagement effort. Imperial understands its stakeholder requirements and takes this responsibility very seriously. No activity relating to the EMP will be undertaken until consultation has been completed.

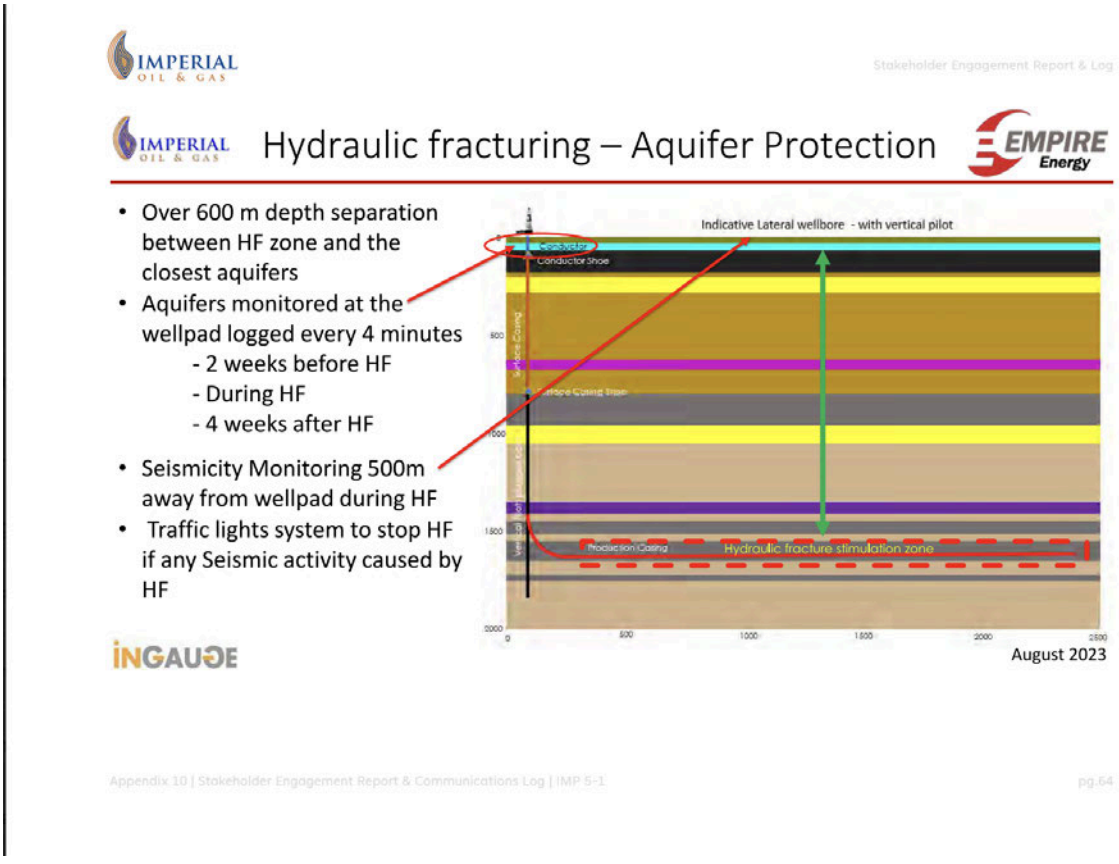
EMP extract, Appendix 10, p 11

Imperial claims that it is committed to *"Ensuring Traditional Owners and other Aboriginal stakeholders are engaged throughout the process and providing culturally appropriate methods of communication."* (EMP, p.240)

Contrary to this claim, Imperial has not engaged comprehensively with native title holders affected by the EMP and there is no partnership between Imperial and affected native title holders.

There is widespread confusion and concern among native title holders about what Imperial is planning to do in the short and longer term, what the risks are to their country, land and water and even how Imperial even obtained consent to frack their country in the first place.

It is plain to see from the information provided to Traditional Owners and included in this EMP at Appendix 10, Appendice 4.1 from page 41 that it is not easily understandable, even for those with a tertiary level of education.



An example of one of the slides used in August 23 to explain to TOs 'aquifer protection', Appendix 10, page 64

The EMP downplays the risks of fracking - saying the works will have no significant impacts on sacred sites, community, health, climate and water (p 15).

Key risks are identified but quickly cast aside. To give an example of a matter which goes to the heart of concerns for us is the potential loss or poisoning of water. Imperial's General Information Booklet, which it has relied on widely for consultation purposes, says: *"It is unlikely the CPP will contaminate aquifers or surface water."* (Appendix 10, p 346).

This is at odds with the views of respected water scientists such as Professor of Environmental Engineering Matt Currell, who when examining baseline water studies in the Beetaloo Basin on which the NT government relies on to claim there will be no harm has warned that: *"at present, it is not possible to properly assess the risk of contamination and over-extraction of Northern Territory water due to fracking."*

"Our analysis shows that there are significant and critical gaps in the knowledge base underpinning fracking approvals in the Northern Territory.

"Further studies are required to fill these knowledge gaps. To proceed on the current evidence base would be unwise, and may risk valuable aquifers, rivers and springs."[1]

No interpreters are present at meetings, as recommended by the Pepper Inquiry, for example for those held in August 2023. The elders had to rely on younger family members to have even some hope of understanding the material, presented in text heavy power points which were explained in a hurried and incomprehensible way.

It is clear from talking to those directly impacted by the proposed fracking that most, if not all Traditional Owners have no clear or comprehensive idea of what drilling is planned, where, how many wells, what royalties and jobs may result and what the long term activities of Imperial will be when full production goes ahead.

Imperial has been meeting families one by one, at times concentrating its efforts on elders with questionable capacity or family members who it understands may be open to promises of royalties or money for their families.

Imperial and the NLC have provided no opportunity for all families to meet together to discuss their concerns and wishes. This is not the traditional way of decision-making in our communities. A meeting together of all impacted Traditional Owners is long overdue and universally called for.

Imperial's storyboards included in Appendix 10 claim *'We operate with the consent of Traditional Owners'* (p.317)

This is not correct. It is clear that there is no free, prior or informed consent from those whose country will be fracked. The reality is that no one in meetings from

[1] See here.

Imperial, either representatives of Imperial or the NLC, ever asks Traditional Owners if they wish for activities spelt out in this EMP to go ahead - yes or no? Imperial presumes that consent is given.

If Imperial or the NLC asked whether or not people wanted fracking they would be in a position to identify consent has genuinely been given. The following are written extracts from video statements recorded of significant family members with cultural authority in Borroloola from 15-17 April 2024. *(Full videos submitted as separate submissions via Nurrdalinji Native Title Aboriginal Corporation and also available here]*

- **Gurdanji Traditional Owner [redacted] from McArthur River** who has full knowledge and understanding of country, dreaming and ownership and has been taken on trips by successive gas companies to survey his country for cultural significance, when asked in Borroloola on 15 April 2024 if Imperial has ever asked him if he wanted 10 new extra wells drilled for its Carpentaria Pilot Project said:

  “Well, they talked to us about the wells but they didn’t ask really if we were happy about it…so I’m not really happy with the wells that go down - the next ones, I am going to say ‘no’.”

- **[redacted], Yanyuwa Garrawa Gudanji woman**, when asked in Borroloola on 16 April 2024 if Imperial has ever asked her if she wants 10 new extra wells drilled for its Carpentaria Pilot Project said:

  “They never asked if we want drilling on that country, they just gave us information and all that but they never asked, we never gave them permission to drill or put gas anywhere…. for the first well that they did we didn’t really give permission for that either, and no I don’t give permission for another 10 more wells. We already angry and hurt for our country already from that one well there.”

  "There have been meetings with individual families, I think it's very important that when we having meetings like this to be all together, all at once, so we all on the same page and we all going you know stepping forward or backwards together, making decisions together not individually cause it doesn't affect individual families it affects everyone.”

  "..I'm gonna step up and look after my country and fight really hard because I want my kids and my family to have what I have and to experience what I'm experiencing now. I want them to experience, 20 years from now, the same thing: no land destroyed or touched."

- [redacted], **Traditional Owner from the Karranjini group** who speaks for Rrumburriya side, Balbarini, Carpentaria, the Mambaliya Rrumburriya Wuyaliya Aboriginal Land Trust when asked in Borroloola on 16 April 2024 if Imperial has ever asked him if he wants 10 new extra wells drilled for its Carpentaria Pilot Project said:

  "We didn't want fracking there [on EP 187] in the first place…We just need to get on top of this fracking mob, before it gets a lot worse. Keep our water clean."

- [redacted], **whose country includes the OT/Binda area who has been taken on trips by Imperial to survey land for cultural significance** (Archaeological Survey Report, Appendix 2, page 1) when questioned by phone in Katherine on 19 April 2024 (audio[redacted] if Imperial has ever asked him if he wants 10 new extra wells drilled for its Carpentaria Pilot Project said:

  "As far as I am concerned myself, they never asked me anything…"

  When asked if he wants the new wells drilled there he said, *"No!".*

- [redacted] **son,** [redacted], **speaking from the Karranjini group with permission from his father and who has been taken on trips by Imperial to survey land for cultural significance** (Archaeological Survey Report, Appendix 2, page 1) said**:**

  "People went and signed an agreement without reading the questions on the paper they agreed for and then, after 2015, 4 years later, I came back and found there was a gas company about to explore for gas…They [Imperial] are not telling us what's gonna happen in the next 3 to 4 years…They've got that 10 year lease, I don't know how it's going to be done for…I don't really know much about that gas company, I just wanted that cultural heritage and wanted country to be untouched but since then its been touched, its been digged, its been drilled, its been tested.

- [redacted], **Garrawa and Gudanji man, connected [to EP 187] through his grandfather explains he is a Wuyaliya man, also Nimirinki and Jungai for his country, Gugu and uncle mob, through the mines and back towards Carpentaria and Cape Crawford, McArthur and the Carpentaria Land Trust, and is tied into through family, the Raggetts,** said when being interviewed in Borroloola on 16 April 2024:

  "We haven't even had a chance to talk among ourselves as custodians and as jungai for the land trust and give our verdict on this EP 187 and the wells that they're going to explore, and that's destruction to me, contamination…"

""I've seen all the sites where they're gonna put that new wells at and it's not a good spot because that's all cultural area"

"We're yet to have a proper consultation meeting, we have not had yet, the Gudanji people for that country."

Imperial has not engaged with affected native title holders in the way that it claims to deal with stakeholders, or in the way it should under the *Petroleum Act* regulations. Imperial has not even acknowledged the existence of native title holders in the area of EP 187.

If Imperial's EMP is now approved, it will have been approved without any adequate consultation with or involvement of affected native title holders and Traditional Owners.

Imperial identifies the NLC as a significant stakeholder (p 17). The EMP says *"Imperial will engage through the NLC as the representative body under the Aboriginal Land Rights (Northern Territory) Act 1976 (Cth)."*

We state the obvious again: Imperial deals with the Northern Land Council without our knowledge or involvement. In doing so, it has failed to meet its own stated standards as well as the requirements of the *Petroleum Act* regulations.

Imperial's consultation documentation submitted as part of this EMP contains evidence of a number of conversations and correspondence with NLC. The NLC is not a stakeholder for the purposes of the *Petroleum Act*. The native title holders affected by EP 187 are stakeholders, not the NLC. The NLC is merely the representative of the native title holders for the time being, and should only act in accordance with our informed instructions. When Imperial talks with the NLC it is not talking with affected native title holders, especially when the NLC is not keeping our people adequately informed of Imperial's plans.

Cultural heritage concerns

The country that Imperial wants to frack under the EMP is rich in our cultural heritage, artefacts and sacred sites.

Imperial had archeologists survey the pilot project area, including Relief Creek, with Traditional Owners. This is reported on in an incomplete manner in the main EMP document, with sentences apparently redacted or missing (p 234).

The full archeological report notes what is called a highly significant archaeological

site - Balbarini 3 - an artefact scatter near the Carpentaria 4 well. The findings include various tools, axe heads, spears and grinding stones.

The report states "*Mitigation measures should be instigated for expansion to the east of Carp 4, as more artefacts may be found. A systematic survey would be required within the cultural heritage exclusion zone, with artefact relocation to a possible keeping place elsewhere within Balbirini 3"*. This area is right next to the existing Carpentaria 4 well pad which Imperial wants to expand. Archaeologists recommend another survey and moving these artefacts, without proper work done to understand the implications of doing this.

Since the report Traditional Owners we spoke to raised concerns that some of these artefacts have already been moved with no permission.

[redacted] **son,** [redacted] **speaking from the Karranjini group with permission from his father and who has been** taken on trips by Imperial to survey land for cultural significance (Archaeological Survey Report, Appendix 2, page 1) when asked to explain what was found out there last year (2023) said (see full video here)**:**

> *"When surveying the EMP site … we found a few artefacts [last year], and since then we've been looking for them, we went back they've been moved, maybe from someone that lives out there, or by the pastoral mob that works out there. We don't know who moved them but I'd like to get around that, more information [about] who moved them.*
>
> *"Where we found them, we left them on the ground. We're not too sure about who went back there and grabbed 'em and moved them. Even talking with those inGauge mob, 'cause when they found them they said we're going to stop…. cause they're the first mob that takes the lead, inGauge, and then Empire Energy comes behind them. I think they're ahead of the drill rigs on site."*

In relation to the moving of artefacts, [redacted]**, an elder from the Karranjini group, on 17 April 2024 in Borroloola said** (see full video here):

> *"I don't want them to move anything from there, any rocks or something else. I care about that country, I worry about my country. It's very dangerous, you know - a lot of people behind me - the mermaid travelled from Groote Eylandt and I got a lot of people behind me. In case they move anything from there, that's making big problem."*

[redacted]**, whose country includes the OT/ Binda area, who was taken on trips by Imperial to survey land for cultural significance in October 2023** (Archaeological Survey Report, Appendix 2, page 1) when asked by phone in

Katherine on 19 April 2024 (audio [redacted] if he knew about the artefacts found he said: *“No!”,* while noting [redacted] did show him photos of the artefacts from the area on his phone. When asked if he was worried about moving the artefacts, he said: *“Yeah, yeah, I am!”.*

[redacted], referred to above, when interviewed in Borroloola on 15 April 2024 also expressed great concern that they may have been or will be moved.

There are no details provided as to how Imperial will ensure either these known sites or potential additional sites will be protected from its activities.

We are worried that the company or others may have committed an offence under the Northern Territory Heritage Act and recommend the Northern Territory Government direct heritage officers organise a survey of the impacted area before the EMP is approved. In addition, Traditional Owners would like information about who removed the artifacts, when and where the items have been taken to.

Traditional Owners are now requesting a cultural heritage management plan be put in place alongside an independent archaeologist to review findings of Ellengowan Enterprises and survey the area.

This is further evidence of Imperial treating important mitigation processes, such as protection of important archeological sites, as tick-a-box formalities. The question now is whether the NT Government is prepared to enforce its own rules, or whether it has become a meaningless rubber stamp.

Water

Imperial plans to draw 950ML of water from the Gum Ridge Formation, part of the Cambrian Limestone Aquifer (CLA) system which is critical to our culture, helps our plants and animals to survive and gives up drinking water. We cannot put this at risk. Water is life. Once this water is damaged or depleted, there is no going back.

Imperial plans to get a licence to extract up to 750ML a year, roughly 9% of the total volume of groundwater allocated to petroleum in the Georgina Wiso Water Allocation Plan. If granted, this 750ML licence would effectively double the volume of water entitlements granted to petroleum companies to date.

This EMP does not explain in detail the impact of removing this water. Although these aquifers, which lie like lungs under our country, are vast, their recharge is slow and the behaviour of water in them is largely unknown, which means the impacts of water depletion is uncertain.

Given limited knowledge of the CLA, we are asking that a full Environmental Impact

Statement is required that properly investigates the hydrological properties of the aquifer, its cultural and ecological values and the impact of this water removal on those values.

Flooding/work in the wet season

Imperial plans to undertake work during the wet season (December to March). Its area of activity is a flood plain. The risks of flooding is very well known. This photo is below taken from a flyover on 22 March 2024 at the time of the extreme wet and Cyclone Megan.

Carpentaria 2 and 3, flyover, 22 March 2024, showing impact of cyclonic induced flooding

The significance of flooding risk is recognised by Imperial in this EMP, for example by admitting general flooding across the activity footprint within the Carpentaria Project Pilot Area may result in damage to infrastructure, including roads access tracks, stormwater management infrastructure, fencing and the gas handling network." (p 196)

The project sits in the headwaters of two catchments, the Limmen Bight River catchment to the north and McArthur River to the east, and crosses Relief Creek and the area around it that floods. Wells will be located just outside the 1 in 100 year flood zone, which means they are likely to flood in more extreme events.

The waste management plan notes that contaminated wastewater will be held in open tanks, even during the wet season, and transferred in trucks to be disposed of in unspecified locations, risking spills and leaks.

The risk of overflowing of fracking water is very real. No amount of work to deal with heavy rains and cyclones, including a wastewater management plan, will manage the risks of chemicals and polluted water poisoning our country, animals, plants and sacred waters.

Figure 14. UAV imagery of Carp 4 and its proximity to Relief Creek.

This image (from Imperial's Archeological report) shows the close proximity of Carp 4 to Relief Creek, which flows to Paradise pools, a registered sacred site. Traditional Owners are concerned any poisoned water could flow through to this highly significant area. We have seen similar poisoning by Tamboran Resources of the sacred waterway, Newcastle Creek, during floods at its exploration well Maverick 1.

Birds, plants and animals

This area proposed for fracking will be locked up and we will have even more difficulty accessing our country, restricting our ability to practice our culture which includes visiting country with our children and grandchildren.

The works will clear up to 229 hectares of native vegetation and habitat for birds, plants and animals. If the plans are approved, this will see a total clearing approved in the area for fracking to be almost 1,200 hectares.

This EMP notes that there are three nationally-listed threatened species recorded or

likely to be present in the area, including the Grey Falcon, Painted Honeyeater and Gouldian Finch as well as five migratory birds protected under national environment law. There are many vulnerable, endangered and critically endangered species in the area of work.

Climate change

Imperial says it plans to apply to "use the gas on an appraisal basis" meaning that instead of flaring it onsite, they want to secure a connection to the McArthur River mine gas pipeline, use their gas plant to process the gas and sell it into the network. Imperial will need a formal agreement with us to sell gas from exploration and build compressor and pipeline infrastructure.

Imperial says in the EMP it will produce 25 terajoules (TJ) of gas a day, but the McArthur River Pipeline only has capacity for 15TJ a day. There is no mention or explanation of this difference in the EMP, and how this difference will be accounted for, no estimation of emissions from flaring the excess gas or the downstream emissions from burning it

Imperial are telling our people this is good for community health and for reducing the climate impacts. The reality is that mining and burning this gas will create, with all other fracking in the Beetaloo Basin that is proposed, a 'carbon bomb' that cannot be offset.

Already it is getting hotter on our country, making it much harder to live there. The rains and cyclones and bushfires are becoming more frequent and intense. We cannot afford for this project to go ahead. We cannot move and do not want to leave our country in the face of our country, based in the Beetaloo Basin region, becoming unlivable.

Jobs and economic benefits

All of us bear the risks of fracking, yet companies like Imperial, as well as the NLC, only want to talk about economic benefits, not risks.

Yes, our communities need jobs and economic opportunities, but fracking is not the answer. Fracking companies and NLC should not use our economic needs as a justification to put us, our land and our waters at risk. We do not want fracking. We say no to these proposed works being approved. We do not believe the gas companies when they tell us there will be jobs and other economic benefits. The faint promises of jobs are reflected in statements such as these in the EMP: "*As the Activity continues, Imperial will continue to work with Aboriginal people and the community to explore the opportunities to consider how local employment can be maximise."* (p 150). And in this following slide which is an insult to Traditional Owners

who are attracted to these (unsubstantiated) claims of job creation:

TO presentation, Appendix 10, p 103.

Likewise, while Imperial is talking a lot about royalties from the sale of gas, it's unclear exactly what kind of money families may get and how to know if it's a good deal.

Broader concerns about fracking

Our concerns about fracking are not new. When the Pepper Inquiry asked us how we feel about fracking some years ago, most of us said we opposed it. We know from our brothers and sisters in Queensland and the United States that large-scale fracking is a dirty and intrusive business which could poison our country and the life that it supports. None of the information we have received since the Pepper Inquiry had allayed our concerns about fracking, yet now it is permitted again.

Under the EMP Imperial intends to carry out a range of activities which will affect our country and our waters, including land clearing and water use. We worry about the risk of spills and leaks of chemicals and wastewater. We worry poisoned water will get into springs, creeks, rivers and sacred waterways. We worry that large amounts of chemicals will be used, many of them poisonous.

Country will be damaged and sacred sites, including those as yet recorded or registered, will be put at risk. Large areas of country will be broken up and industrialised for gasfields. The project will involve the clearing of big areas of bush for roads, gas pipelines and processing plants. Poisons will be released into the air, putting human health at risk. The work will create more ignition sources for bushfires and disruption of traditional burning programs.

Conclusion

For all of the reasons set out in this submission, we urge the Northern Territory Government to listen to our people and refuse to approve Imperial's Carpentaria Pilot Production EMP.

Imperial has not met requirements for approval set out in the *Petroleum (Environment) Regulations 2016.*

Impacted native title holders do not consent to this work and the impacts and risks of the project are too significant.

We ask that Imperial be required to, in relation to this project:

- undertake a full Environmental Impact Statement under the *Environment Protection Act 2019* (NT), including exploring the cultural values of our country, water and culture
- have its water plans referred to the Federal Environment Minister under the *Environment Protection and Biodiversity Conservation Act 1999* because it is likely to have a significant impact on water resources.

We also seek your Government's support to change the intended temporary Top End (Default) PBC arrangements that continue to enable the NLC to not properly represent our wishes or lock us into arrangements that we don't want.

We seek your Government's help as a matter of urgency.

Yours sincerely,

Chair, Nurrdalinji Native Title Aboriginal Corporation

From: [redacted]
To: imperial ep187+
Subject: objection
Date: Friday, 19 April 2024 4:09:23 PM
Attachments: [redacted]

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

please find attached

[redacted]

Attention: Petroleum Operations unit, Department of Environment, Parks and Water Security

Re: objection to the Environmental Management Plan for the Carpentaria Pilot Project covering 'exploration' permit 187

I object to the finalisation of this EMP because:

- significant areas of harm and community concern are poorly addressed;
- proposed activities extend beyond exploration to encompass commercial production - of particular interest given the volume of environmental recommendations from the scientific inquiry which are required 'before production';
- the development of these wells is a significant step towards broadscale exploitation of the Beetaloo Basin, which would be an insult to Nature;
- this in turn will scaffold the greater insult of the Middle Arm Development (MAD) gas precinct, a highly contentious and widely ambitious scheme that would vastly overwhelm NT Governments management capabilities – environmentally, economically and socially.

Process

OK this time it's on me. I've had a very busy month, so haven't had much time to devote to this important process.

So I've based this response off the former one (for Tamboran's two EPs). I haven't read the entire application, so I probably missed important detail :(

Climate impact

I welcome Empire's recognition of the high risk of significant climate impact.

Climate impact remains a sustained focus of ongoing public dissent towards the new industrial threat of shale fracking, recognised as one of five key issues raised by the community through the Pepper Inquiry. These concerns span fugitive methane emissions, cumulative impact from use of shale gas as a source of energy generation and other industrial activities. The inquiry fielded advice that embarking on massive new fossil fuel exploitation is inconsistent with a carbon budget approach to Australia's international and domestic commitments to emissions reduction.

The Inquiry's final report assessed the unmitigated risk to climate change for life cycle GHG emissions as moderate to high, contingent on production scale. A range of recommendations (9.1 to 9.7) directly address these, moderating risks associated to methane emissions to a medium rating.

Acknowledging that further mitigation of the risk of methane emissions is necessary, alongside other greenhouse gas impacts, the final report further offered:

> **Recommendation 9.8**
>
> *That the NT and Australian governments seek to ensure that there is no net increase in the life cycle GHG emissions emitted in Australia from any onshore shale gas produced in the NT.*

Since then there has been considerable ongoing public scrutiny and media controversy over the mechanisms by which governments may attempt to meet this requirement. The Commonwealth and other state governments have publicly denied NT Government claims that other jurisdictions might carry the can for offset costs, which researchers at the Australia Institute warn could rapidly become not only financially prohibitive but also practically unavailable on the domestic carbon market. In recent weeks, a multi-dimensional scandal aired questions as to the role of a gas-industry double agent employed in the (now former) Chief Minister's department in cabinet decisions to abandon an NT policy that would give regulatory form to recommendation 9.8

Empire state an intention to side-step the significant carbon burden of their planned activities via the perverse appraisal provisions under the revised Petroleum Act.

I strongly oppose the recent regressive legislation which invites this wilful blurring of the modes of exploration and production. Yet given this regrettable context, it remains outrageous to consider the EMP could be finalised with this, the single-most significant management proposal for the highly controversial feature of climate impact, withheld explicitly outside the Plan. This action requires further definition, including contingencies, particularly for the highly likely scenario that arrangements for on-selling appraisal gas run behind the exploration schedule.

At the very least, this Draft should not progress without detailed contingency provisions – though it would clearly be wiser to shelve this application until the requirements for an approval to conduct recovery on appraisal are considered.

Proposed monitoring is vastly inadequate for what is a major risk and highly controversial feature of this new industrial process.

The Draft only addresses monitoring emissions at infrastructure (flares, vents and leaks) and of these, only leaks require a response. 6 monthly leak detection of surface infrastructure is grossly inadequate. The response for minor leaks has no escalation / contingency: this could result in 5.30 months of unaddressed major leak.

Instead, the proponent should implement as standard continuous monitoring of infrastructure. Point based instruments can effortlessly implement continuous methane monitoring with accurate, validated measurements at scale. Events from this monitoring can gather data on trends, trigger investigations on incidents and shore up estimates.

The EMP notes that
In addition to monitoring emissions from drilling, stimulation and well testing activities, baseline assessments have been completed by CSIRO in the vicinity of the lease pad
But to what end? The Draft offers no detail of further landscape measurements, only infrastructure. But fugitive emissions are not limited to infrastructure.

The SREBA describes:
natural surface emissions of greenhouse gases from Beetaloo Sub-basin formations.

Proposed activities may exacerbate these existing natural GHG sources, or open new ones.

The SREBA identified options for regional surveys, mobile and static, combining *"optical gas analysers … to continuously measure ambient methane concentrations",* and *"flux chambers to measure the flux from possible geologic seeps"* – yet the Draft is silent on landscape monitoring.

GISERA have set a standard, deploying ground based stations for continuous monitoring of atmospheric greenhouse gas concentrations in the Surat Basin to estimate fluxes (primarily

methane) from the region. The proponent should pursue best-in-class practice for monitoring landscape-wide emissions associated with these Beetaloo leases. Exploration is by definition a more experimental industrial phase. It is therefore highly appropriate that Empire should be more curious about any impact their activities may have on landscape-wide fugitive emissions.

References

as described.

Contact

[redacted]

From: Have Your Say Northern Territory
To: [redacted]
Subject: Anonymous User completed Carpentaria Pilot Project EP187 Environment Management Plan
Date: Friday, 19 April 2024 4:18:49 PM

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Anonymous User just submitted the survey Carpentaria Pilot Project EP187 Environment Management Plan with the responses below

Given name

[redacted]

Family Name

[redacted]

Location

LEE POINT, NT

Stakeholder type

Community member

Email address

[redacted]

Interest area

Social and cultural
Flora and fauna
Water
Human health
Well integrity
Climate change
Regulation and compliance
Waste management
Chemicals
Other (please specify) - unmanaged catastrophic run-away climate chaos; corporate corruption of local democratic institutions by foreign exploiters; greed; stupidity; and any alternatives

Please provide your comments

I tried already but had to switch browsers not sure if its related but GA triggered a CSP on submit `Content-Security-Policy: The page's settings observed the loading of a resource at https://www google-analytics com/g/collect?v=2&tid=G-V0DGDXBL7Y&gtm=45je44h0v875884994za200&_p=1713508722294&gcs=G1-0&gcd=13l3p3l3l5&npa=0&dma=0&cid=268328238 1713508722&ul=en-us&sr=1440x900&lps=1&pscdl=noapi&_eu=AEA&_s=2&sid=1713508722&sct=1&seg=1&dl=https%3A%2F%2Fhaveyoursay nt gov au%2Femps-under-assessment%2Fsurveys%2Ftitle2&dr=https%3A%2F%2Fwww google com%2F&dt=Carpentaria%20Pilot%20Project%20EP187%20Environment%20Management%20Plan%20%7C%20Have%20Your%20Say%20Northern%20Territory&en=scroll&epn percent_scrolled=90&_et=55569&tfd=61960 ("connect-src") A CSP report is being sent `

[redacted]

[redacted]

From: [redacted]
To: imperial ep187+
Subject: Imperial hopes to frack up the outback, but I hope we can progress with a safe climate
Date: Friday, 19 April 2024 4:23:14 PM
Attachments: [redacted]

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Dear NT Gov people,
Please accept my attached submission and have a lovely day whilst the climate is still habitable.

and think of the magnificent flocks of budgies

we will protect NT

[redacted]

Imperial Oil & Gas's Carpentaria Pilot Project
draft Environmental Management Plan IMP 5-1 should be rejected.

Some comments by [redacted], Darwin April 2024

Thank-you for taking my instructions and I look forward to hearing your sensible response to disallow ruining our only safe climate. Catastrophic climate change is inevitable if we allow fracking in the Beetaloo and besides the suffering, the economic disaster of attempting to cope with it will make any puny profits from this uneconomic enterprise extremely paltry.

Methane is such a potent greenhouse gas any new activity that releases it should be banned.

Methane has over eighty times the warming power of carbon dioxide over the first twenty years after it's released into the atmosphere.

I note there is an effort to avoid the (largely symbolic) large emitters policy and to appear to be making an effort to only bring about catastrophic climate change and not apocalyptic climate change, whilst attempting to take a sneaky profit.

But it comes with the threat: "*If the well is brought online before the CGP is commissioned it is likely that the well will be cleaned up to a local flare for a minimal period. In this case the flow would be diverted via the separator to the local flare instead of the CGP.*" Table 5—1 Emission Descriptions and Controls

This should be grounds for the whole EMP to be dismissed. The government granted and the (selected) Traditional Owners were duped into accepting only an "exploration" license. The *Carpentaria Gas Plant* (CGP) is a mechanism to sell the gas. Clearly it is in no one's interest to flare the gas - that it's so potent it's best to release many thousands of tonnes of carbon dioxide instead of the potent methane should spell a warning to leave it safely underground. If the EMP cannot be dismissed then surely there can be a requirement that the well cannot be brought online until the CGP is commissioned.

But there is no production license and if the plan is to explore to such a level, it's clearly not really exploring and as such should be rejected.

As about 30% of today's global warming is driven by methane from human actions, much greater efforts should be made to avoid releasing it.

Monitoring for methane leaks should not be done on the prescribed seriously minimal timeline, with most aspects only being revisited annually. These days, not only can we detect methane from satellites, there are affordable personal detectors. All staff should wear these and fixed detectors should give daily readouts. At a very bare minimum, leak detection surveys could be done quarterly when the compressor stations and pneumatic devices are tested. This would provide more jobs! But as methane leaks are an apparent reason we now have a dangerously warming climate, the minimum should be a much shorter timespan.

Imperial claims it will produce 25 terajoules (TJ) of methane a day, but the McArthur River Pipeline only has capacity for 15TJ a day. Shockingly this detail is omitted from this draft EMP, giving another reason to outright reject it. I could see no estimation of emissions from flaring the excess gas or the downstream emissions from burning it. A more complete outline of possible greenhouse gas emissions should be made. And what is the greenhouse gas contribution of the fifo workers travel?

Weeds of National Significance and/or rating for eradication or control should be eliminated.

I see mention on page 229 that in 2022 the SREBA found an astounding 111 weed species "*within the CPP Area*" And casually went on to elaborate that *"This included 32 species listed under the Weeds Management Act 2001. 12 of which are Class A weeds (to be eradicated) and 20 are Class B weeds (growth and spread to be controlled)."*

Consequently, I expected an outline of a plan to eradicate at least 32 species of weeds, and control the other 79 weeds wherever they occur on the entire. However the attached misnomered "Weed Management Plan" revealed shoddy attempts at monitoring and mitigation but no detail for schedules to destroy known infestations of any weeds. Instead there is a fascination with what weeds were there before Imperial took over management, as if it is not a reasonable goal to improve at least one aspect of this country.

If you think I'm exaggerating using the word shoddy, read this: *"Existing weed distribution not known due to: insufficient survey effort, survey effort conducted at wrong time of year, persons undertaking survey not familiar with / unable to identify declared weed species." (Page 6)*

Then there seems to be a suggestion that having a Queenslander as the proscribed Imperial Weed Officer is adequate. Clearly there are so many weeds that having staff on the ground that can actually kill the weeds and until the seedbank is exhausted is vital. I'm sure that when Pepper recommended: "gas companies must have a dedicated weed officer for each gas field" she didn't mean an annual fifo whilst having surveys done at the wrong time of year (like October) by personnel who don't know what they are looking for!

Insist the WMP be rejected until there are schedules to eliminate all the weeds from the entire Exploration Permit. The clearing of a further 225 hectares means that there should be an enhancement of the uncleared areas. Seeking to eliminate the weeds would be a good contribution to that aim.

Water is life

I recommend the assessment crew go on a trip to see this gorgeous sunburnt country. It is lush and biodiverse and so special. There are so many lovely trees and bushes, grasses and herbs, insects, birds, lizards, and mammals.

This example on page 214 defines the trees well:
"The following vegetation communities were identified within or near the CPP Area from SREBA GIS data layers [DEPWS, 2022]:
*• **Silver Box** (Eucalyptus pruinosa) low open woodland on imperfectly drained clay soils with tussock grass understorey - monoculture stands are found on low-lying floodplain areas.*
*• **Glossy leaved box** (E. chlorophylla) low open woodland where clay content becomes lighter loam with tussock grass understorey.*
*• **Bloodwood** (Corymbia spp.) open woodland on sandy clay with tussock grass understorey.*
*• **Woollybutt** (E. miniata) open woodland on rapidly draining, deep sandy soils.*
*• **Snappy gum** (E. leucophloia) low open woodland on rocky, gravelly soils on the margins and slopes of Cainozoic duricrust in Gulf Falls & Uplands.*
*• **River Red Gum** (E. camaldulensis) riparian vegetation along ephemeral waterways and fringing topographic depressions which form ephemeral "soaks".*
*• **Lancewood** (Acacia shirleyi) provide the thickest vegetation cover in the landscape."*

But it is a fragile ecosystem reliant on there being replenishable groundwater. Some years there is virtually no rain and it's frequently baking out there. To survive, most of the flora and fauna require the groundwater to be able at

times to quickly overflow into surface creeks and springs. Huge extraction of groundwater will inevitably drop the watertable so that it is in stress. When dry years come, it is likely to be catastrophic. Climate change means the reliability of rainfall is even more unreliable. Apparently Imperial assumes that they will be granted the right to extract 750ML of precious groundwater every year. This could well see the deaths of many of these tree communities. Trees provide the basis for faunal abundance as well.

The NT should not be treated as a sacrifice zone. This is not a barren desert. Yet.

The assumption the project will be granted this level of water should be abandoned. At very least, it must be referred to the Federal Environment Minister under the Environment Protection and Biodiversity Conservation Act 1999 because it is likely to have a significant impact on water resources.

Toxic water is death

Some 350 million litres of flowback water is expected to be returned to the surface after fracking. I am not convinced there is a sensible plan to safely manage it. Pepper recommended that any toxic water should be covered to ensure that fauna are not attracted to it. This must be stipulated.

I am also very concerned about the 95% of toxic water that is left underground and is likely to contaminate the groundwater for all life, for all time. This is clearly also a seriously good reason to deny Imperial the right to make this area of the NT a sacrifice zone.

The impacts of this project are so huge it should have an EIS

If indeed the project is not simply rejected in full, as it should be, a full Environmental Impact Statement under the Environment Protection Act 2019 (NT) would be a better way to assess the appropriateness of this dangerous project.

The First Nations demand fracking be banned

Lastly, I again heard the Traditional owners speaking loud and clear that they are adamant they do not give consent for their country to be fracked. Please listen. We must respect our elders and with many tens of thousands of years caring for this country, we must respect their wishes: ban fracking.

From:	Have Your Say Northern Territory
To:	imperial ep187+
Subject:	Anonymous User completed Carpentaria Pilot Project EP187 Environment Management Plan
Date:	Friday, 19 April 2024 4:24:33 PM

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Anonymous User just submitted the survey Carpentaria Pilot Project EP187 Environment Management Plan with the responses below.

Given name

[redacted]

Family Name

[redacted]

Location

CHARLES DARWIN, NT

Stakeholder type

Community member

Email address

[redacted]

Interest area

Flora and fauna
Water
Social and cultural
Climate change

Please provide your comments

Greenhouse emissions ● Empire says it plans to apply to “use the gas on an appraisal basis” meaning that instead of flaring it onsite, they want to secure a connection to the McArthur River mine gas pipeline, use their gas plant to process the gas and sell it into the network. ● The company claims it will produce 25 terajoules (TJ) of gas a day, but the McArthur River Pipeline only has capacity for 15TJ a day. There’s no mention or explanation of this difference in the draft EMP, no estimation of emissions from flaring the excess gas or the downstream emissions from burning it. Culture ● The re-evaluation of the importance of cultural heritage artefacts found at the site in 2022 and previously considered “isolated artefacts” indicates the inadequacy of the assessments being

conducted for Environmental Management Plans for fracking activities. ● This activity should be subject to a full Environmental Impact Statement that explores the cultural values of affected ecology, water and landscapes and gives Traditional Owners power to grant or refuse consent to the proposed activities. Groundwater ● Empire will need to take 950ML (million litres) of water from the Gum Ridge Formation, part of the productive Cambrian Limestone Aquifer (CLA) system which supports culture, nature and communities in the area. ● They will apply for a licence to extract up to 750ML a year, roughly 9% of the total volume of groundwater allocated to petroleum in the Georgina Wiso Water Allocation Plan. If granted, this 750ML licence would effectively double the volume of water entitlements granted to petroleum companies so far. ● The impact of this water removal on the flow of groundwater locally and regionally is largely undescribed. ● Although these aquifers are vast, their recharge is slow and the behaviour of water in them largely unknown, which means the impacts of water depletion is also uncertain. ● Given limited knowledge of the CLA, a full Environmental Impact Statement is required that properly investigates the hydrological properties of the aquifer, its cultural and ecological values and the impact of this water removal on those values. Surface water ● The project is in the headwaters of two catchments, the Limmen Bight River catchment to the north and McArthur River to the east. ● The pilot project crosses Relief Creek and the area around it that floods. Wells will be located just outside the 1 in 100 year flood zone, which means they are likely to flood in more extreme events. ● Every well will produce “drill-cuttings” that need to be disposed of and which have elevated concentrations of some metals and other elements of concern. ● Every well will also produce 35 million litres of fracking flow back water and the handling of this water creates the risk of spills and accidents that could contaminate soil or surface waters. ● The wastewater management plan proposes that this contaminated water may be held in open tanks, transferred in trucks, including during the wet season and disposed of in unspecified locations. Wildlife ● Three nationally-listed threatened species are recorded or likely to be present in the area, the Grey Falcon, Painted honeyeater and Gouldian finch as well as five migratory birds protected under national environment law. ● It will clear up to 229 hectares of native vegetation and wildlife habitat, bringing the total cumulative clearing approved in the area for fracking activities to nearly 1,200 hectares.

From: Have Your Say Northern Territory
To: imperial ep187+
Subject: Anonymous User completed Carpentaria Pilot Project EP187 Environment Management Plan
Date: Friday, 19 April 2024 4:26:53 PM

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Anonymous User just submitted the survey Carpentaria Pilot Project EP187 Environment Management Plan with the responses below.

Given name

[redacted]

Family Name

[redacted]

Location

WEST END, QLD

Stakeholder type

Non Government Organisation (NGO)

Email address

[redacted]

Interest area

Water
Climate change

Please provide your comments

See attached submission

[redacted]

ACN 114 027 986
PO Box 190, Surry Hills, NSW 2010

19 April 2024

Department of Environment, Parks and Water Security
Petroleum Operations Unit
By email: imperial.ep187@nt.gov.au

Submission: Carpentaria Pilot Project EP187 Environment Management Plan

Thank you for the opportunity to comment on the draft Carpentaria Pilot Project EP187 Environment Management Plan (EMP).

GetUp is an independent movement of over 1 million members who care about climate justice, economic fairness, and First Nations justice. Our members are everyday people from across the country and include Traditional Owners from across the Northern Territory.

We recommend the Carpentaria Pilot Production EMP is refused on the basis of the unacceptable impacts of the project on water and the climate.

We also recommend the project is required to undertake a full Environmental Impact Statement under the *Environment Protection Act 2019* (NT). The draft EMP fails to address the direct and indirect environmental impacts and risks of the project.[1]

The project also should be referred to the Federal Environment Minister under the *Environment Protection and Biodiversity Conservation Act 1999* because of the likely significant impact on water resources.

If you have any questions or concerns, please do not hesitate to contact me.

Sincerely,

Amy Gordon

Chief Campaigns Officer GetUp
M 0492 123 896
E amy@getup.org.au

[1] Petroleum (Environment) Regulations 2016, Schedule 1 Part 1 regulation 3(2)(b), *The Northern Territory Government*, 22 June 2023.

Water

Water is life for all of us. But for remote First Nations communities, water is culture, song lines, sustenance – survival.

Fracking poses grave risks to water through the high potential for chemical contamination of aquifers including methane contamination in drinking water, cross contamination of adjoining aquifers, management of toxic wastewater, and significant volumes of water use in an arid landscape.[2]

The Carpentaria Pilot Project will produce millions of litres of toxic wastewater and faces serious risks of flooding that will have grave impacts on both ground and surface water.

The project is in the headwaters of two catchments, the Limmen Bight River catchment to the north and McArthur River to the east. The pilot project crosses Relief Creek and the area around it that floods. Wells will be located just outside the 1 in 100 year flood zone, which means they are likely to flood in more extreme events.

Empire Energy plans to take 950ML (million litres) of water from the Gum Ridge Formation, part of the productive Cambrian Limestone Aquifer (CLA) system which supports culture, nature and communities in the area.

Given limited knowledge of the CLA, a full Environmental Impact Statement is required that properly investigates the hydrological properties of the aquifer, its cultural and ecological values and the impact of this water removal on those values.

Empire Energy plans to apply for a licence to extract up to 750ML a year, roughly 9% of the total volume of groundwater allocated to petroleum in the Georgina Wiso Water Allocation Plan. If granted, this 750ML licence would double the volume of water entitlements granted to petroleum companies so far.

The project will also produce 35ML of toxic wastewater per well and the handling of this water creates the risk of spills and accidents that could contaminate soil or surface waters. Every well will produce "drill-cuttings" that need to be disposed of and which have elevated concentrations of some metals and other elements that can have grave impacts in water.

The wastewater management plan proposes that this contaminated water may be held in open tanks, transferred in trucks, including during the wet season and disposed of in unspecified locations.

---

[2] Is fracking good for your health? An analysis of the impacts of unconventional gas on health and climate, *The Australia Institute,* November 2013.

Climate change

Communities across the Northern Territory are already feeling the impacts of extreme floods, fires and heat. Changes in weather are impacting fishing and hunting for First Nations people.

Fracking gas is a major contributor to greenhouse gas emissions causing escalating climate change.[3] Fracking in the Northern Territory could result in up to 1.4 billion tonnes of emissions.[4]

There will be substantial emissions from the project that have not been quantified by Empire Energy.

Empire Energy says it plans to apply to "use the gas on an appraisal basis" meaning that instead of flaring it onsite, they want to secure a connection to the McArthur River mine gas pipeline, use their gas plant to process the gas and sell it into the network.

The company claims it will produce 25 terajoules (TJ) of gas a day, but the McArthur River Pipeline only has capacity for 15TJ a day. There's no mention or explanation of this difference in the draft EMP, no estimation of emissions from flaring the excess gas or the downstream emissions from burning it.

Recommendations

We recommend:

1. The Carpentaria Pilot Production EMP is refused on the basis of the unacceptable impacts of the project on water and the climate.

2. The project is required to undertake a full Environmental Impact Statement under the *Environment Protection Act 2019* (NT).

3. The project also should be referred to the Federal Environment Minister under the *Environment Protection and Biodiversity Conservation Act 1999* because of the likely significant impact on water resources.

[3] Ideas and perspectives: is shale gas a major driver of recent increase in global atmospheric methane? *European Geoscience Union, Volume 16, Issue 15,* 14 August 2019.
[4] 96 Leading Australian Scientists & Experts Call for NT Fracking Ban, *The Australia Institute,* 3 May 2023.

From: Have Your Say Northern Territory
To: imperial ep187+
Subject: Anonymous User completed Carpentaria Pilot Project EP187 Environment Management Plan
Date: Friday, 19 April 2024 5:30:18 PM

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Anonymous User just submitted the survey Carpentaria Pilot Project EP187 Environment Management Plan with the responses below.

Given name

Protect Big Rivers

Family Name

Incorporation

Location

KATHERINE, NT

Stakeholder type

Non Government Organisation (NGO)

Email address

[redacted]

Interest area

Social and cultural
Waste management
Chemicals
Flora and fauna
Climate change
Regulation and compliance
Well integrity
Human health
Water

Please provide your comments

No provision for additional attachments, need to be able to attach more. I will email them.

[redacted]

Submission
Imperial Oil and gas
EMP 187
19th April 2024

Protect Big Rivers (PBR) is a community-based incorporation based in the Big Rivers Region of the Northern Territory. Our members are Territorians concerned about our future water and climate security.

Members of the Big Rivers region are already very familiar with contaminated drinking water, unrelated to hydraulic fracturing. We live with ongoing PFAS contamination of our children, our aquifer, our swimming holes, our rivers, and our wild caught food supplies. We have the highest PFAS levels in Australia in our bloodstreams.

We live with the knowledge that it is unlikely we will be able to prove that our autoimmune diseases, diabetes, high cholesterol, renal cancers, testicular cancers, low birth weight babies, or thyroid problems are directly attributable to our PFAS ingestion, despite peer reviewed medical data that now attributing all these diseases to PFAS. Our small, mobile population is unlikely to be 'statistically significant' from a medical point of view; but to the unwell individuals, each illness is heartbreakingly significant.

Public Health is a critical function of Government. In the Big Rivers Region, this includes the responsibility of protecting our climate, our clean water, our food supplies, and the unique cultural value of water that our Aboriginal members share. Whilst much cultural knowledge is protected, it is critical that Government and fracking companies recognise that threatening water and the environment, threatens Aboriginal culture in the Territory to its core. It is 'ground zero'.

In addition to the threat to water this fracking proposal presents a serious climate threat to our region. This EMP effectively represents production under the guise of exploration, to enable the industry to expand without all the checks and balances that a production approval would require. It is important that the company is subject to the scrutiny that would apply as if it were the 60 horizontal well production plan. This is what this exploration effectively enables.

CLIMATE IN OUR REGION

As can be seen on the table below Katherine has a 30-year historical average of 7 days per year over 40 degrees. In 2019 Katherine experienced 54 days over 40 degrees. On a high

emissions scenario, that this project increases the likelihood of, Katherine will experience the 2019 year as an average year by as early as 2036.
In 2019 our region experienced severe drought, massive dust storms, the lowest aquifer levels on record, the loss of swathes of big trees and fish kills. For this to become an average year within a decade is truly terrifying.

In 2019 we saw our communities suffer as doctors, nurses, teachers, veterinarians, lawyers, real estate agents, chefs, and other service staff packed up and left town. Each year, the build-up comes earlier and is more brutal. The effect of these critical staff issues becomes more apparent by the year. Remaining staff become overworked and burnt out, leading to poorer outcomes in their lines of work. Anecdotal examples of the impact of climate staff losses in our town are not limited to the following examples, but include:

- There was a long period with no GP service in town. This meant ED became the GP. Junior doctors felt scared and unsupported and become less likely to choose regional practice in the future. Patients with cancers were misdiagnosed on multiple presentations to ED, and by the time diagnosis was made were in advanced stages of metastases.
- Many remote clinics now run temporary staff on a permanent basis. This was not previously the case. This leads to a loss of continuity of care for patients and risks things being lost in translation.
- A lack of lawyers in critical areas e.g., Katherine Women's Legal Service and NAAJA. Here domestic violence and Territory Families matters are a large proportion of the work. These agencies now have had to close shop for lack of lawyers for periods of time. This leads to vulnerable women and children, unable to seek legal advice, and an increased removal of children from their parents with the long-term ripple effects of that trauma impacting everyone.
- Territory families staff turnover creates less likelihood of kinship carers being found for vulnerable children and burn out in this sector means there is less sensitivity in handling children and their mothers.
- Teacher losses mean that children have multiple teachers over time. With high staff turnover pastoral care suffers and children fall through the cracks in the system ending up on the streets.
- Term 4 at Katherine High is called 'fight season'. Increased heat sees whole communities on edge with violence erupting more frequently.

Small towns rely on community relationships to get things done well and efficiently. This is particularly the case where racial and socioeconomic division is prominent. A great many problems can be worked out easily if relationship is present. Without it, poor decisions are made, disproportionately affecting the marginalised and poor. With the climate becoming harsher social problems are being magnified, and a negative feedback loop has been established – more heat leads to more staff losses, which leads to leads greater burn out and social dysfunction, which in turn leads to more staff losses.

Imperial states there would be 475,000 tCO2-e per annum if the gas was flared. However, they make no attempt to look at the full life cycle emissions for this project or the greater gas play this production represents. In promotional talks in the region Empire Energy has

stated these well pads will eventually house 10 horizontal wells per pad. Thus, with the new well pads in action this project represents up to 60 wells. Again, the cumulative creep warned about in Pepper.

The company claims it will produce 25 terajoules (TJ) of gas a day, but the McArthur River Pipeline only has capacity for 15TJ a day. There's no mention or explanation of this difference in the draft EMP and no estimation of emissions from flaring the excess gas. The existence of a large and polluting mine in nearby, should not be a justification for a fracking project. To stay under 1.5 degrees, we must half emissions by 2030. 15% of any CO2 emission will still be in the atmosphere in 10,000 years' time. It is imperative that large mines such a McArthur River Mine transition to alternative and renewable sources of energy as soon as practicably possible. Allowing this project to profit from gas exploration slows the move towards renewables and feeds a climate future that renders the NT uninhabitable.

Table A2. Annual number of days over 35°C and 40°C. Towns shaded green are in the Monsoonal North cluster and towns shaded orange are in the Rangelands cluster. Value is average of eight models and range is lowest and highest model value. (Source: www.climatechangeinaustralia.gov.au)

Threshold	Historical (1981–2010)	2030 (2016–2045)		2050 (2036–2065)		2090 (2075–2104)	
		RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5
MILIKAPITI							
35°C or above	6	23 (13 to 39)	28 (14 to 50)	41 (24 to 67)	65 (34 to 102)	70 (42 to 102)	205 (155 to 250)
40°C or above	0	0	0	0	0	0	0
DARWIN							
35°C or above	47	107 (80 to 133)	118 (82 to 156)	139 (108 to 172)	176 (136 to 209)	184 (152 to 214)	288 (256 to 317)
40°C or above	0	0	0	0	0	0	5 (1 to 11)
JABIRU							
35°C or above	135	191 (169 to 214)	198 (172 to 224)	212 (187 to 233)	238 (203 to 267)	243 (219 to 266)	310 (284 to 332)
40°C or above	2	7 (3 to 11)	8 (3 to 13)	12 (5 to 21)	21 (8 to 31)	19 (9 to 28)	70 (29 to 111)
NHULUNBUY							
35°C or above	7	17 (12 to 22)	19 (14 to 27)	26 (18 to 35)	38 (23 to 53)	38 (26 to 51)	121 (80 to 173)
40°C or above	0	0	0	0	0	0	0
BATCHELOR							
35°C or above	86	142 (119 to 160)	153 (124 to 180)	168 (144 to 193)	199 (168 to 226)	205 (177 to 229)	291 (261 to 318)
40°C or above	0	1 (1 to 2)	2 (1 to 3)	2 (1 to 4)	5 (2 to 8)	5 (2 to 7)	32 (10 to 53)
PINE CREEK							
35°C or above	110	159 (137 to 176)	169 (146 to 188)	179 (160 to 197)	208 (181 to 231)	211 (187 to 230)	282 (253 to 309)
40°C or above	1	4 (1 to 6)	4 (2 to 9)	7 (3 to 12)	14 (5 to 22)	12 (5 to 20)	57 (17 to 90)
KATHERINE							
35°C or above	157	200 (178 to 214)	208 (189 to 220)	216 (198 to 231)	240 (218 to 255)	242 (225 to 255)	298 (274 to 320)
40°C or above	7	19 (11 to 27)	22 (14 to 35)	28 (18 to 39)	43 (24 to 57)	38 (21 to 51)	101 (54 to 138)

FREE PRIOR AND INFORMED CONSENT

In relation to informed consent we must emphasise that timeframes of this consultation period are extremely disappointing. If the government is seeking true informed consent, local decision making, and community feedback, then releasing this document when the most affected town or Borroloola was experiencing 1;100-year

flooding, evacuation, social dislocation, and exhaustion is quite frankly revolting and insensitive. Sadly, now par for the course, it is inconsistent with good policy, and speaks to the lack of correct consultation that has plagued the onshore unconventional gas industry in the Territory.

Few, if any, residents of Borroloola are aware of the significant impending gas production development on their doorstep as thorough consultation has not occurred nor have the requirements of the Pepper Inquiry been met. Regional Aboriginal knowledge of surface and spring water flow across is essential to development of a true environmental management plan. This has not occurred, and many of the recommendations regarding consultation from the Pepper Inquiry have also not been met.

Pepper Recommendation 11.5

That interpreters be used at all consultations with Aboriginal people for whom English is a second language. Interpreters must be appropriately supported to ensure that they understand the subject matter of the consultation. Despite this Pepper Inquiry recommendation many residents of Borroloola are very concerned that no translators have been present at meetings, and that senior people in their community, with ultimate decision-making authority, continue to have little understanding of the nature or scale of this industry.

Pepper Recommendation 11.6

That in collaboration with the Government, Land Councils and AAPA, an independent, third-party designs and implements an information program to ensure that reliable, accessible, trusted, and accurate information about any onshore shale gas industry is effectively communicated to all Aboriginal people who will be affected by any onshore shale gas industry. That the program be funded by the gas industry. Again, many members of Protect Big Rivers, including Borroloola residents, highlight that this is an ongoing problem. The work has not been conducted adequately and people across the board feel they are ill-equipped to make decisions about their country in relation to this industry. This problem was noted to be unresolved during the SREBA social and cultural study where the author states quite clearly. *'Many people did not feel they have been consulted adequately. There is not widespread understanding of what onshore gas development will look like, or what impacts it may have for the region. It is felt that only those directly impacted have had the industry explained to them. There is a desire for more "neutral", "factual" information.'* And *'Even some of the people who have been highly engaged feel conflicted or confused because they are hearing "two very different sides to the story". It was explained how information is needed that can empower local people to raise their concerns about (onshore gas and any other) proposed development or to make suggestions for how to improve practices.'*

The work required to assist the most affected communities to understand the inherent risks of this industry, and to protect country, culture, water, and climate for future generations, remains incomplete. People request that unbiased information is presented in person, in open community meetings, with adequate notice to invite family members and other interested parties who may be working away. It is imperative that this occurs before a project of the scale proposed in this EMP is approved.

POPULATION HEALTH

The cumulative negative impacts of exploration creep were highlighted in the Pepper Inquiry. This 10 well EMP reflects exploration creep, that can quickly lead to 60 wells with no increase in surface footprint. Therefore, this EMP requires robust consideration at a population health level.

In 2023 a medical publication synthesised the emerging peer reviewed medical literature highlighting the human health implications of the oil and gas industry, 'The Haswell Report'. It is now well documented that people exposed to oil and gas operations experience 'significant harm'. Much of this information was unavailable at the time of the Pepper Inquiry. The report is attached.

It is critical that new studies related to the potential harm caused by shale gas production are considered more robustly prior to approving this EMP.
From medical literature we know exposure to shale fracking can cause,

- reproductive harms and interference with development of unborn babies, including higher risks of low birth weight, pre-term delivery and spontaneous abortion.
- higher risk of severe birth defects
- increases in depression, anxiety and social withdrawal, especially among young and pregnant women
- higher risk of acute lymphoblastic leukemia.
- higher injury and fatality rates due to increased heavy vehicle traffic
- increases in sexually transmitted infections associated with the industry's mobile workforces
- more severe asthma in children requiring more medical treatment, emergency department visits and hospitalisations
- higher hospitalisation and death rates due to heart attacks, heart failure, respiratory diseases and some cancers

To even begin to assess the population health impacts of this industry it is critical to have a robust health baseline. The SREBA health studies form an inadequate baseline by their authors own admission, failing as:

- Symptoms commonly associated with gas fields – sore eyes, nosebleeds, skin rashes and headache are transitory and self-managed illnesses so will be underrepresented in health clinic presentations.

- Low population numbers making the population health data not statistically significant.

- No health monitoring or survey plans have been developed.

- It was 'very much a first step and requires engagement into an implementable plan'.

Much has been said of the Haswell Report data coming from poorly regulated gas fields in the USA, which will not compare to the NT's 'world class regulatory regime' and remote context. However, a systematic analysis of the adverse health findings contained within the Haswell Report show they are consistent across diversities of landscape, geography and location of gas plays, the quality of the regulatory regime overseeing them, the people and population density.

Many of the pathways of exposure to industry toxins remain poorly understood and incomplete.

When health problems are identified and investigated, more contamination pathways are found. It is therefore critical that exposure pathways are rigorously considered and contextualised to the people, culture, and practices of the country they are taking place on, prior to the adverse cumulative health impacts of the industry being experienced. This has not occurred in this EMP and as a result there significant are human contamination risk pathways that remain incomplete, particularly in relation to people's diet and cultural practices in the region.

Prior to any further exploration taking place in the McArthur Basin, it is critical that adequate baseline health data is compiled. The SREBA Health Studies must be completed in a more comprehensive way and be fit for purpose prior to any further exploration creep. These wells are only 1.7km from a residence. It is worth noting that traditional owners living adjacent an earlier exploration well in this Carpentaria play have experienced an unusually low birthweight baby and a heart disease fatality within the last 2 years. Those residents could smell the well from their home.

CHEMICAL RISK ASSESSMENT

PBR is concerned that the chemical risk assessment process is not robust enough to ensure protection of the people, animals, and environment of the McArthur region.

- the company states *"Additional updates to this HHERA are possible in the future, with the evaluation of any additional proposed chemicals/revised chemical concentrations, and this will be undertaken where applicable."* From this statement companies can pick and choose chemical cocktails with simple amendments, not open to public scrutiny, as and when they choose. This makes a mockery of the chemical risk assessment opened to the public for scrutiny. Why bother commenting on suites of highly toxic chemicals, when the company can simply change to even more toxic chemicals without further public consultation.
- Chemical risk assessments have applied to unconventional gas fields internationally for over 2 decades, yet adverse health outcomes related to the industry are well documented.
- The use of private consultancy firms for chemical risk assessment creates inherent bias. Additionally, there is cause for concern when the stakes are so high and when a risk assessment consultant states "*EHS Support has made no independent verification of this information beyond the agreed scope of works and EHS Support assumes no responsibility for any inaccuracies or omissions*."
- The chemical risk assessments relate largely to worker exposure, rather than chronic exposure pathways of soil, air, water, wildlife, and traditional food chains.

- Risk assessments assume that accidents will be minimal and that potential for contamination of the environment is therefore small. Accumulated incidences from early exploration activities have already demonstrated this is not the case.
- The Tier 1 & 2 chemical risks have been assessed by the consultant based on the understanding of exposure pathways. However, the consulting company and the fracking company have no knowledge of people's cultural pursuits in relation to the land, water, medicine, and food sources. It is therefore impossible for them to assess whether chemical exposure pathways in the region are complete or incomplete. Despite this, they have classified chemicals as Tier 1 stating "*when the potential for complete exposure pathways was assessed to determine the potential for risk (an incomplete pathway precludes an exposure occurring and an associated potential risk). In this context, site setting, and management protocols associated with the action were evaluated, and if the pathway was incomplete, a Tier 2 assessment was not deemed to be warranted".*
- Many chemical toxicities are classified based on acute OR chronic grounds, rather than both. Consistent reasoning behind this method of assessments seems unclear.
- Remoteness and extreme weather conditions increase the risk attached to the process considerably yet is poorly considered.
- "Implementation of the management controls within the EMP, which ensures the well site is located away from surface water (the current location is greater than 2.5 km away from the major tributary, precluding a surface release from impacting surface water)," totally underestimates the surface water flow in the region when it is pumping yet form part of the Tier 1& 2 classification system.
- "*Maintenance of access control restrictions during hydraulic fracturing activities that will prevent access by the public, livestock and large native fauna*", but fails to mention how access control to the drill sumps for flora and fauna, including avian species, will be maintained over time.

It is imperative that an independent chemical risk assessment is performed by the regulator or a federal government EPA. It should not be beholden on individual people submitting to highlight the risks of individual chemicals to the regulator or Minister. This is a job of governments who have public health as one of their critical roles.

We use a single chemical here as an exemplar of deficits in the chemical risk assessment. This concern would be duplicated many times over if the document were examined more thoroughly.

- (3S,6S)-3,6-dimethyl-1,4-dioxane-2,5- dione is classified as a Tier 1 chemical of little concern by the chemical risk consultant.
- the consultant notes *'data from degradation testing according to standard methods are not available. However, there is evidence that PLA can undergo degradation via isolated and variable bacterial populations. Given the plasticine nature of the polymer and its high molecular weight, bioconcentration, bioaccumulation, and sorption are not expected to be appreciable'* – "not expected to be" is not assurance enough to protect out water or people.

- On deeper investigation we find that

- Department of Health and Human Services (HHS) considers 1,4-dioxane as reasonably anticipated to be a human carcinogen.
- Environmental Protection Agency (EPA) established that 1,4-dioxane is a probable human carcinogen.
- International Agency for Research on Cancer (IARC) has determined that 1,4-dioxane is possibly carcinogenic to humans.

We have no faith that the chemical risk assessment related to these chemicals is adequate.

CONTAMINATION RISK TO WATER RESOURCES

Protect Big Rivers has significant concerns about surface and ground water contamination related to fracking in our region**. *It is essential that this project is referred to the Federal Minister for the Environment to consider the impact to water resources under the water trigger.***

In relation to contamination risk Specifically we note in the EMP that the distinction between Tier 1 and Tier 2 chemicals was in part made on the basis of *"Implementation of the management controls within the EMP, which ensures the well site is located away from surface water (the current location is greater than 2.5 km away from the major tributary, precluding a surface release from impacting surface water)." pg. 10 Appendix 8 EMP.*

Protect Big Rivers recently flew over the region. Based on this fly over it is clear that any surface release of fracking wastewater or site storm water is able, in continuous streams, make its way to major tributaries. Therefore ***the 'management controls' above, that determined Tier 1 & 2 chemical classification needs to be reconsidered to reflect the true dangers of these chemicals to our waterways.***

Relief Creek is a massive floodway rather than a distinct creek. Recent heavy rains related to Cyclone Megan in March 2024, allowed for a clearer picture of proximity of these wells to the creek and the extent to which surface water flows and fills this country. We have attached a link to the video of Relief Creek on March 22, 2024, to give assessors a clearer picture of the extent of this 'creek'.

This EMP was released for community consultation on the same day as the Protect Big Rivers flyover occurred. It is a shame that the valuable 'ground truthing' Imperial discusses related to flood modelling could not occur during this event as all sites were inaccessible and the Carpentaria Highway was closed to traffic.

Figure 1 Relief Creek adjacent Carpentaria 4 well

The lack of adequate flood mapping was discussed in the SREBA final report stating,

"the generally flat topography in the area means that accurate flood modelling will require more precise topographic data than is currently available for the region (although mapping of the extent of surface water was undertaken for the Aquatic Ecosystems SREBA domain). Thus, detailed surface water studies are more appropriately undertaken by the petroleum industry during the initial impact assessment and infrastructure planning stages of individual projects, once areas of interest are more accurately defined." Regional Report SREBA pg. 97

The risk of surface water contamination is exacerbated by:

- the propensity for massive rainfall events in the region,
- the knowledge that surface spill incidents are relatively common on well pads
- the lack of baseline soil testing and soil and surface water testing on these sites to date.

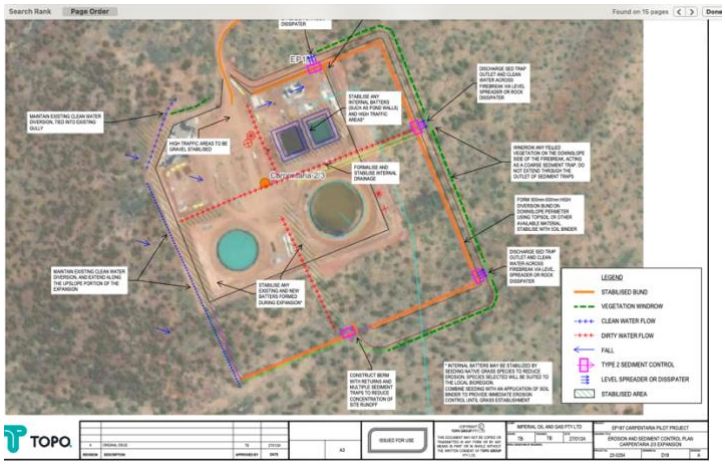
The picture below highlights how surface water has not been contained on the Carpentaria 2/3 site during recent heavy rain. Bund walls are clearly breached, and water is flowing from the site. As such the evaluation of Tier 1&2 chemicals needs to be made assuming that surface water may become contaminated by fracking chemicals.

In the event of a catastrophic fluid loss on site the EMP speaks to a 'secondary containment including bunding to 110% of its capacity." Pg 267. It is clear from this photograph that such bunding is notional rather than realistic.

Figure 2 Carpentaria 2/3 well

Appendix 5 has an image associated with this well (below). There are 5 separate places where water from the well pad will be permitted to leave the site. The EMP states

Significant volumes of water are expected to run from the compacted pad during heavy tropical storm events in the wet season. This stormwater will be drained from the well pad to erosion and sediment controls on the downslope perimeter constructed in accordance with the Erosion and Sediment Control Plan (Appendix 05). This would seem to indicate that regular surface water sampling by the regulator during the wet season is critical if the people and environment downstream of these operations are to be protected. The idea that a sediment dam can protect water from contamination on these sites is ludicrous given the volumes of water that can and do flow in this region and the fact that spills, and even deliberate water dumping, are commonplace in this industry.



Far more detailed research also needs to occur in relation to **Inter-aquifer interconnectivity**. "O*nly a small number of inter-aquifer pumping tests have been undertaken to help establish the degree of connection between the Anthony Lagoon and Gum Ridge Formations [S TICKELL, 2022A]. Tests at Hayfield Station in 2015 and Tanumbirini Station in 2019 did not observe any connection. Pump tests at Carpentaria 2/3 have also been inconclusive to date. Additional tests to investigate connectivity between these formations are scheduled for 2023 [S TICKELL, 2022A]. The use of organic biodegradable water tracing dye (e.g., Rhodamine WT), which is used widely in environmental water studies, in combination with pump tests, could provide further understanding of probable aquifer connectivity."*

A thorough analysis of this work is critical. There are many springs in the area. The origin of each of these springs needs to be clearly determined, particularly given the company expects a retrieval rate of only 5% of the water, leaving nearly 100,000,000L of highly toxic water under the ground per well.

The project also uses nearly 1 billion litres of water every year. The notion of safety or sustainability due to a percentage of water compared to the Georgina Wiso Allocation (GWWAP) is not logical. The GWWAP is considered by most in the region to be entirely unsustainable and significant local drawdown is expected with the extraction proposed. The effects of this level of extraction on aquifer levels and spring flow in the region is unknown and could present enormous problems for those who value the spring for food, water, and cultural reasons.

TRAFFIC

The 2024 wet season has shown significant problems with NT remote road infrastructure. The increased heavy vehicle traffic attached to this EMP will further deteriorate our regional roads. Road closures have far-reaching effects on remote communities including a lack of store supplies, including food and a general lack of service provision for education, prolonged ambulance transfer times, a redirection of council staff etc. Much of the highway collapse this wet season was centred around locations where fracking vehicle traffic was highest both on the Carpentaria and the Stuart Highways.

The Pepper Inquiry Recommendation that DIPL levy a tonnage fee to fracking companies has not been implemented, thus taxpayers continue to fund road infrastructure damaged by these companies. This is yet to be implemented.

THREATENED SPECIES

Given the SREBA studies were deficient in relation to terrestrial and aquatic biodiversity because

- no wet season aquatic studies were performed.
- terrestrial studies took place over 2 extremely dry years skewing the distribution and populations of animals.

It is critical a more detailed study is commissioned by an independent agency prior to this program beginning. It is known that three nationally listed threatened species are likely to be present in the area, the Grey Falcon, Painted honeyeater, and Gouldian finch. The area is also visited by five migratory birds protected under national environment law.
If Australia is being serious about no more extinctions, then it starts with projects like this.

Please find the Haswell Report and a video of Relief Creek in flood to add to this submission.

[redacted]

From: [redacted]
To: Onshoregas DEPWS
Subject: Carpentaria EMP
Date: Friday, 19 April 2024 5:49:17 PM
Attachments: [redacted]

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

HI,
The have your say site would only allow 1 attachment. Please find Haswell Report and flood video attached.
Flood video represents Relief Creek due west of Carpentaria 4. It shows the impossibility of even reaching these wells should an accident occur during a storm event. Also if an accident occured it would be impossible to mobilise any heavy machinery or even walk on the well pads such is the nature of flooding.
Please find these attachments and comments to supplement our submission.
Please confirm receipt and admissibility via this email address, given the online portal would only accept 1 attachment. .

[redacted]
PO Protect BIg Rivers

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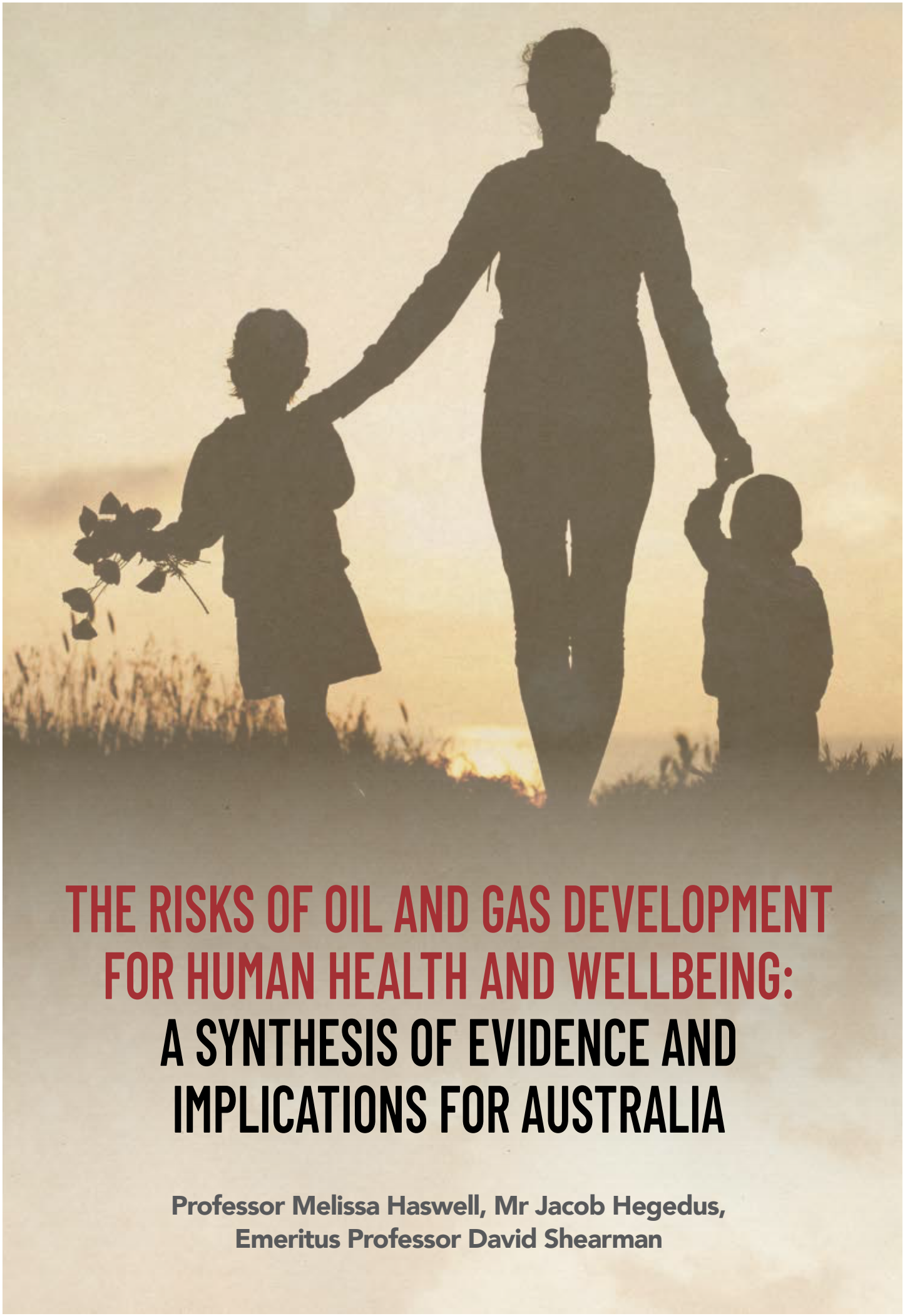

THE RISKS OF OIL AND GAS DEVELOPMENT FOR HUMAN HEALTH AND WELLBEING: A SYNTHESIS OF EVIDENCE AND IMPLICATIONS FOR AUSTRALIA

Professor Melissa Haswell, Mr Jacob Hegedus,
Emeritus Professor David Shearman

We respectfully acknowledge the Jinibara, Peramangk, Gadigal, Turrbal and Yugara, Gubbi Gubbi, Bundjalung, Gumbaynggirr Lands as those our primary work for the report was hosted. We pay respect to all the Aboriginal and Torres Strait Islander Nations and Peoples of Australia.

We pay respect to their Elders past, present and emerging and acknowledge these Lands were never ceded but havebeen mistreated to our collective detriment.

We acknowledge the strength and leadership of Aboriginal and Torres Strait Islander people across the nation in protecting the health and beauty of the Land we now call Australia. This leadership is based on science built over many millennia and must play a crucial role in helping us navigate an uncertain future.

Report authors are Professor Melissa Haswell and Mr Jacob Hegedus, Office of the Deputy Vice Chancellor (Indigenous Strategy and Services), University of Sydney and Emeritus Professor David Shearman, University of Adelaide.

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About the authors

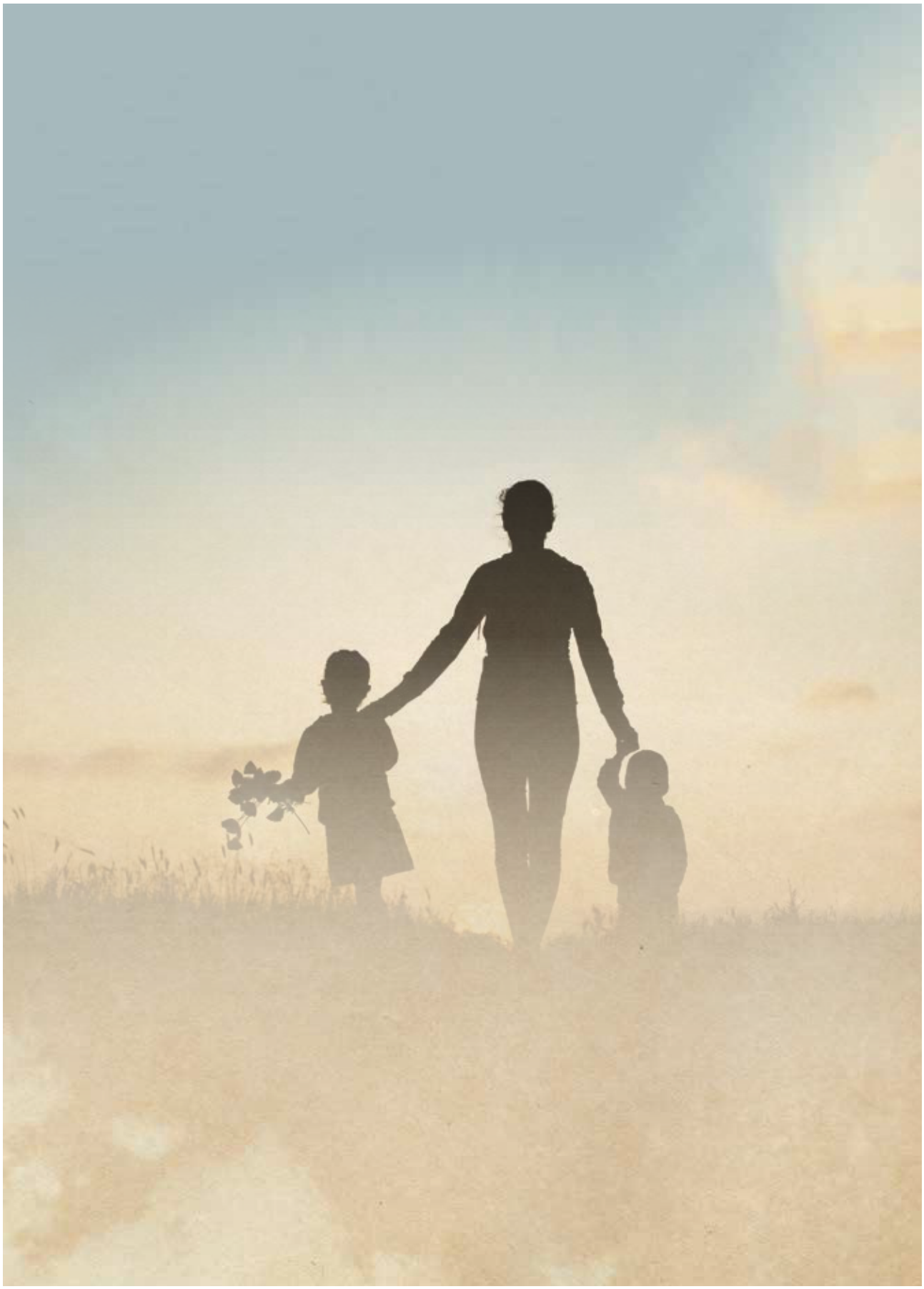
Melissa Haswell MSc PhD is Professor of Practice (Environmental Wellbeing) in the Deputy Vice Chancellor (Indigenous Strategy and Services) Portfolio and Honorary Professor in the School of Geosciences at the University of Sydney. She is also Professor and former Discipline Lead of Health, Safety and Environment in the School of Public Health at Queensland University of Technology. Melissa obtained her PhD in the Department of Pure and Applied Biology at Imperial College, University of London. She previously held academic positions at Queensland Institute of Medical Research, The University of Queensland and the University of New South Wales. She was the first appointed environmental epidemiologist at the National Research Centre for Environmental Toxicology (enTOX), a collaboration between three Brisbane universities.

Melissa has published in the fields of epidemiology, pathogenesis and control of infectious diseases, immunology, carcinogenesis, heavy metals, empowerment, mental health and social and emotional wellbeing. She teaches extensively in Indigenous health and community development, climate change, pollution and sustainability. She has applied her multidisciplinary and wholistic health and wellbeing knowledge to communicate extremely pressing planetary health issues in media articles and government assessments and parliamentary inquiries the Northern Territory, South Australia, Western Australia and NSW. Melissa strongly feels that decisions on the expansion of fossil fuel mining and extraction in Australia must be made with clear understanding of the full available evidence regarding direct and indirect impacts on human social, emotional, physical and spiritual health, as well as the stability of the climate and environmental assets upon which we all depend.

Jacob Hegedus is a proud Gumbaynggirr man from Grafton, Northern New South Wales. Jacob recently completed a Bachelor of Property Economics at the Queensland University of Technology, whilst working as a Research Assistant, studying Indigenous collaboration and integration within governance and decision making models in business. After starting his professional career in funds management at the Queensland Investment Corporation, Jacob returned to academia, starting a Master of Business Administration (Finance) at the Australian Institute of Business and commencing a role as a Research Assistant at the University of Sydney. Jacob has a strong passion for social justice and fair economic opportunity, and continues to embody these commitments every day, in all aspects of his work and study.

Professor David Shearman AM MB, ChB, PhD, FRACP, FRCPE was Professor of Medicine at The University of Adelaide from 1975–1997, and Emeritus Professor thereafter. He previously held senior positions at Edinburgh and Yale Universities. He is both medical doctor and scientist. He is the author of many books relating to climate change, its science, consequences, and democratic international and economic implications. His most cited work is *The Climate Change Challenge and the Failure of Democracy* co-authored with Joseph Wayne Smith and written for the Pell Center for International Relations and Public Policy at Salve Regina University in Rhode Island.

Emeritus Professor Shearman served on the International Panel on Climate Change for two terms on the health and scientific sections. He has been President of the Conservation Council of South Australia and, with the late Professor Tony McMichael, he founded Doctors for the Environment Australia in 2001 and was the Honorary Secretary from 2001 to 2018. He is author and co-author of several hundred scientific and medical papers, and he writes frequently for the media. He was appointed a Member of the Order of Australia (AM) in 2015 for service to medicine and to climate change.



Executive summary

The purpose of this report is to provide the Australian community and decision makers with a synthesis of the now extensive evidence demonstrating multiple direct and indirect health and wellbeing risks from oil and gas developments. It responds to a request from deeply concerned paediatricians about proposed shale gas development of the Beetaloo Basin and processing facilities at the proposed Middle Arm Precinct in Darwin Harbour.

The report identifies and discusses an extensive body of recent, peer-reviewed scientific and public health literature on five areas of extreme concern, namely:

- 1: the procedural risks posed by oil and gas operations to biodiversity, water and food security,
- 2: contributions to the climate emergency,
- 3: the vast array of potentially harmful chemicals involved,
- 4: contamination pathways into water and air and
- 5: resulting physical, social, emotional, spiritual health losses associated with extensive disruption of life near oil and gas fields and its sprawling infrastructure.

Threats to climate: Extensive research shows that oil, gas and LNG production and burning contribute substantially to extremely steep rises in atmospheric CO_2 and methane gas (86 times more potent over 20 years) and, consequently, to global heating. Queensland's coal seam gas industry has already driven a 14.1% and 27.4% rise in national fugitive and stationary emissions excluding electricity respectively, over 2005 levels. Besides comparing extremely poorly with wind and solar, substantial research and new life cycle analysis has dismissed the supposed climate advantage of gas over coal. This analysis indicated that leakage of methane more than 1% of production levels *eliminates climate benefits* over coal. Thus, the 49 new oil and gas projects planned for Australia directly conflict with our commitment to the Global Methane Pledge to reduce emissions by 30% by 2030 and other climate commitments.

Threats to water: Besides climate damage, the industry uses vast quantities of fresh water, often much greater than anticipated, posing water security threats to arid areas. Furthermore, each step of the gas production creates multiple opportunities for chemical contamination of surface and ground water. There is extensive documentation of contamination via spilling, leaking, flooding, overflows and deliberate environmental application through so-called 'beneficial uses', especially in handling the vast quantities of toxic wastewater. This wastewater contains hundreds of naturally occurring and added drilling and hydraulic fracturing chemicals. These can include heavy metals, phenols, barium, volatile organic compounds including benzene, toluene, ethylene and xylene, radioactive materials, fluoride, polyaromatic hydrocarbons, salt and many chemicals of unknown toxicity.

Threats to air quality: The review found that a vast array of chemicals are released into the air during all steps of the process, including volatile organic compounds, polyaromatic hydrocarbons, nitrogen oxides, radioactive materials, diesel fumes, hydrogen sulfide, acrolein and heavy metals. A cocktail of additional chemicals form in the atmosphere, including formaldehyde, particulate matter from aerosols and ground level ozone, which travel long distances damaging health and agriculture.

Chemical threats: Extensive research has shown that these chemicals can cause cancer, tissue damage, reproductive harms, impairment of normal human growth and development, birth defects, respiratory and cardiovascular disease and deaths. Furthermore, a poorly understood group of chemicals, endocrine disrupting chemicals, act at extremely low concentrations to interfere with the body's communication system of hormones that regulate growth, behaviour, metabolism and reproductive function.

Health and wellbeing consequences: A substantial quantity of increasingly rigorous research evidence has accumulated from studies across oil and gas basins, especially in the United States. Each gas basin is different in its geography, hydrogeology (underground rock and water systems), chemistry (different mixtures of added and naturally occurring chemicals), weather and air flow characteristics, legislative regimes and regulatory compliance, and social and cultural diversities. Despite these variations, there is a consistency across locations in finding a greater burden of health loss among those most exposed to oil and gas operations and infrastructure.

Reported health risks include increased severity of asthma in children demonstrated by elevated incidences of exacerbations requiring medical treatment, crises requiring emergency department visits and hospitalisations. Research shows higher hospitalisation and death rates due to heart attacks, heart failure, respiratory diseases and some cancers associated with oil and gas operations and/or predicted from air pollution exposure in many studies across whole populations. Higher injury and fatality rates from increased large truck traffic volumes, higher incidences of depression, anxiety, social withdrawal among young females and higher prevalences of sexually transmitted infections have been linked to the impacts of oil and gas operations on home and community life. Furthermore, multiple studies have detected interference with normal development of unborn babies. This includes higher risk of low birth weight, pre-term delivery and spontaneous abortion, severe birth defects and risk of acute lymphoblastic leukemia.

Many studies have demonstrated that these outcomes occurred after, not before, gas development commenced, while others have shown that these outcomes specifically occur downwind and/or downstream (groundwater flow) of gas operations. Most studies have controlled for a wide range of potential confounders (other explanations for the observed differences).

The report also highlights the cultural and spiritual harms reported by Aboriginal Australians in the alleged poor adherence to the right to free, prior and informed consent to these operations on their Traditional Lands. Finally, the report issues a loud warning about the risks of sexual violence that have been suffered by First Nations Americans and Canadians associated with oil and gas activities interfering with their remote communities. These risks have been completely ignored in all government assessments of potential consequences borne by Australian people.

Conclusion: This wide-ranging review including recent academic and research insights has only strengthened long-standing concerns regarding the multiple, complex risks of serious harm to human health and wellbeing associated with oil and gas development. New studies are emerging regularly, with deepening fears that reproductive consequences and increased cancer rates may be revealed in the future, with longer duration of human exposure to these multiple and unchecked potential harms. In addition to direct health risks, human health and wellbeing is threatened by the risks of contamination of air and water with a wide array of harmful chemicals, the excessive use of limited freshwater resources and substantial contributions to climate change should the proposed new developments progress. Human safety and security is also at risk.

Unfortunately, Australians are very ill informed about the research and evidence presented in this report, and only sparse health research has assessed impacts in Western Queensland where many farmers and residents struggle to cope with approximately 15,000 coal seam gas wells.

The Report concludes with an urgent plea to all Australian governments to recognise the full extent of risk that this industry brings to our nation at a time when the dangers of climate change demand rapid reduction, not expansion, of fossil fuels to preserve our future.

This wide-ranging review including recent academic and research insights has only strengthened long-standing concerns regarding the multiple, complex risks of serious harm to human health and wellbeing associated with oil and gas development.

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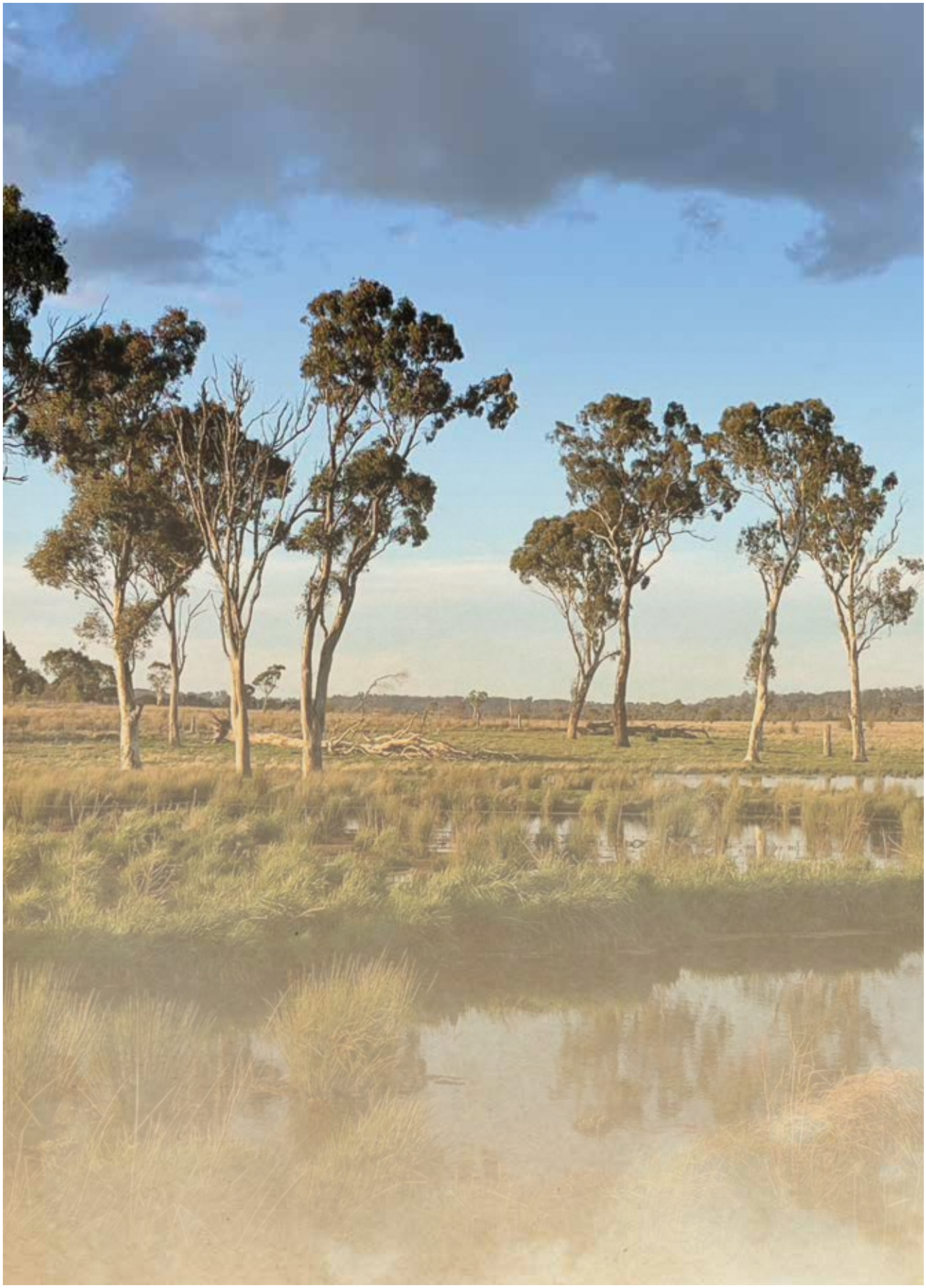

1. Overview and purpose of the report

Good health requires not merely the absence of disease, but also clean air, a safe and sufficient supply of clean water and nutritious food, a safe and stable climate and a strong and supportive social, cultural and spiritual environment. These are the foundational pillars of human health.

Human activities, particularly since the Industrial Revolution, have both enhanced and diminished our continuing access to these fundamental requirements. Major global efforts mobilised by the United Nations Millennium Development Goals brought about improvements in human health and wellbeing. However, we now recognise that achieving these economic development goals by individual nations came largely at the expense of the environment. Global efforts now being guided by the Sustainable Development Goals aim to work in harmony with national commitments to the 2015 Paris Agreement on Climate Change to achieve "Dignity, prosperity and peace on a healthy planet" by 2030.

Much of the responsibility for realising the vision of the Paris Agreement, to achieve "Dignity, prosperity and peace on a healthy planet" by 2030 lies at the feet of individual nations, who face difficult decisions to ensure a sustainable future for current and coming generations. According to the Intergovernmental Panel on Climate Change (IPCC, 2023), a major determinant of future health and prosperity is how quickly the world can move away from fossil fuels – coal, gas and oil – and embrace the remarkable economic, environmental and health opportunities offered by renewable energies.

As the late Professor Will Steffen, groundbreaking climate and planetary scientist and communicator, legacy Climate Councillor and Executive Director of the Australian National University Climate Change Institute, and author and reviewer of five Intergovernmental Panel on Climate Change Reports spanning eighteen years reminded us, "Failure is not an option: After a lost decade on climate action, the 2020s offer one last chance" (Steffen, 2021; Climate Council, 2023).

Australia is one of the world's wealthiest nations with one of the largest *per capita* global footprints and greenhouse gas emissions. Australia is also already among the world's top exporters of both coal and liquified methane gas (LNG) derived from coal seams and offshore drilling. Remarkably, Australia is rapidly moving to implement extensive plans for commencement of ***a new export industry*** using shale gas extraction, with developments in the Beetaloo Basin in the Northern Territory only the first in a series of major new gas initiatives aimed at increasing export volumes.

These expansion plans run counter to pleas from the United Nations Secretary General to cease new developments. They put Australia's commitment to net zero greenhouse gas emissions by 2050 in jeopardy and risk failure in meeting our National Determined Contribution obligations under the Paris Agreement. Moreover, expanding exports of methane to other countries, which are expected to account for the emissions resulting from this Australian product, appears to contravene the spirit of many articles of the Paris Agreement. Instead, developed countries like Australia are expected to take the lead by undertaking absolute economy-wide reduction targets [not only offsets] (Article 4); keep our fossil fuels and their potential greenhouse gases securely in the ground (Article 5) and support the efforts of developing countries to build clean, climate-resilient futures (Articles 9, 10 and 11).

The Paris Agreement also invites all citizens (non-Party stakeholders) to address and respond to climate change and "recognises the need to strengthen the knowledge, technologies and practices and efforts of local communities and Indigenous Peoples".

Our report ***"The risks of oil and gas development for human health and wellbeing: A synthesis of evidence and implications for Australia"*** is a response to that invitation. It was initiated at the request of paediatricians practicing in the Northern Territory, where national and territory governments accelerated approvals to introduce, for the first time, an export industry for unconventional gas extraction from shale deposits.

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Extensive research has indicated that gas developments, in addition to contributing to climate change, can threaten water supplies with overextraction and contamination and cause multiple health outcomes in local and regional populations. By mid-2022, more than 2000 peer-reviewed papers, reflecting rapidly expanding research efforts in the United States, have examined health-related concerns (Physicians, Scientists and Engineers for Healthy Energy, 2023). These include papers on toxic chemicals added and brought to the surface, air and water contamination, direct health and developmental impacts, climate change, community change, seismicity, infrastructure and regulation.

Because of the complexities of unconventional gas mining, and the multiple chemical, physical and social stressors involved, a full assessment of potential public health hazards must encompass all steps of the process, from community awareness of and reactions to development proposals and implementation, to site preparation and construction, materials transport, drilling, flowback and produced water collection and handling, hydraulic fracturing, gas production, storage and transport and decommissioning and monitoring of spent wells.

The broader implications of the industry for water, food and climate security stimulated a wide and vigorous response around Australia between 2012 and 2019 when proposals were raised to start or expand coal seam gas extraction in NSW, including near urban areas such as Camden, Western Sydney, Sydney Park (Saint Peters), and Sydney Water Catchment Area (Helensburgh), as well as rural locations including the Northern Rivers, the Pilliga Forest (Narrabri) and New England. South Australians also rejected shale gas fracking in Mt Gambier and Kalangadoo. With stiff community opposition, many of these plans, with the exception of the Western Queensland and the Pilliga Forest, were discontinued. Many may have thought that the struggle to stop further expansion of gas extraction across Australia was over.

Despite major sprawling development across Western Queensland, the Australian literature on health impacts of coal seam gas remains limited. In the United States, a wide array of major research teams from numerous universities have received substantial funding independent of the gas industry to grow the now considerable evidence base of concerns. In contrast, Australian research is solely focused on coal seam (not shale gas) operations and most is provided through the Gas Industry Social and Environment Research Alliance with the Commonwealth Science and Industry Research Organisation (CSIRO, 2023). According to their website, this has culminated in a health study design framework and a 69 page final synthesis report focusing on chemicals, lights, noise and dust (Keywood et al., 2018; Huddlestone-Holmes and Dunne, 2023). The latter identified 25 chemicals used in coal seam gas extraction which warrant further investigation and other studies are in progress.

This report builds on our previous work (Haswell and Shearman, 2019) to provide a comprehensive source of information to assist people, especially those working to inform decision-makers about how individuals, communities and their environmental assets may be impacted by unconventional oil and gas developments. It aims to help Australians to be aware of and gain access to the large body of evidence of the multiple direct and indirect physical human health impacts of the mature and diverse shale gas industry in the United States, where it co-exists with a solid public health and environmental research community.

This new report is issued in response to a health emergency, not only about climate change, but also about the overall impacts of an industry that state, territory and federal governments in Australia are again fast-

tracking with approvals and direct funding. State-wide pushes to expand unconventional gas production in Queensland, New South Wales, West Australia and the Northern Territory are undeterred by knowledge about widespread harmful impacts experienced in the United States.

This report also urges leaders to pay attention to the extensive foundation of evidence, including new evidence since earlier inquiries, which documents the actual experiences of climate, environmental, social and physical health losses due to the now enormous gas industry in the United States. As new published information on health losses emerges regularly, the full extent of these harms is still unknown.

Every day in the United States, an estimated two billion tons of fracking chemicals and water are forced under high pressure into shale deposits, over an enormous land footprint. Water containing both introduced and naturally occurring chemicals is then brought to the surface for treatment, dispersion into the environment for 'beneficial' purposes or reinjection into the ground. In that country, an estimated 17.6 million people live within a mile of an oil or gas well that has been hydraulically fractured – a number that would have been unthinkable just 20 years ago as the developments got underway. The resulting cost of air pollution impacts alone to the American community was an estimated US$77 billion in health care costs in 2016, including 410,000 additional episodes of asthma treatment for children, and 7500 deaths (Buonocore et al., 2023). Very few Australians are aware of this data – and even fewer understand what it could mean for our health and wellbeing should the industry progress.

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In summary, this Report is based on extensive review and synthesis of the literature on and actual experience of the impacts of the shale gas industry in other countries, especially the United States. The large body of research reviewed reflects studies across multiple states in the US, with greatly varying policies, regulations, population distributions and chemical makeup of both naturally occurring and deliberately introduced chemicals. While specific variations in exposures and impacts no doubt occur across these settings, there is substantial consistency in detecting evidence that harms can and do affect people, their communities and their water, air and climate.

We urge readers to recognise that we can only truly understand the wide array of potential impacts of such a complex and sprawling industry by learning from careful research-based assessments using quantitative and qualitative inquiry with communities at risk. While some circumstances will be very different between Australia and the US, and within different sites in Australia, this is clearly an industry that brings many complex chemical, psychosocial, environmental, cultural and climate stressors. Rigorous Health Impact Assessment informed by extensive science, lived experience and the voices of people who would be directly and/or indirectly affected, helps us to understand that ***all*** of these stressors impact synergistically to threaten health. This is a

much more powerful way to predict health losses people may experience. Only with this information can we make wise decisions about what kinds of industries we need to invite and grow in our country to help us meet future challenges.

We urge leaders and decision makers to take notice of the evidence and fully comprehend the risks and documented harms involved at a time of unprecedented environmental instability. We urge full attention, resources and human capacity to be directed towards the safest and healthiest future – the science makes it clear that this can only be secured by winding down fossil fuel developments and responsibly embracing new clean energy opportunities.

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2. Background information on the processes and risks in unconventional oil and gas extraction

This section provides a brief overview of the multiple steps involved in unconventional oil and gas exploration, extraction, transportation and processing, and highlights risks and problems that can and have arisen. This section focuses largely on the processes of shale oil and gas production, with less reference to coal seam gas production. This is because, in contrast to coal seam gas, Australia has had very little experience in shale gas extraction as a major export industry and many in the community are largely unaware of the differences. Furthermore there is a wealth of peer-reviewed published information from many research teams examining the risks and consequences experienced in diverse circumstances and regulatory regimes across the United States. The information is important for Australia to learn from in its own decision-making about the industry. Attention in this section is on land and water use change and potential risks to water and food security and biodiversity; while further sections examine contributions to climate change (Section 3), loss of air and water quality (Section 4) and risks to physical, psychosocial, First Nations' justice and women's and children's safety (Section 5).

This section first describes broad differences between conventional and unconventional methods for gas and oil extraction. We then briefly describe the major steps involved and identify some of the known risks and hazards that accompany each step. We draw attention to the very large quantities of water used in the hydraulic fracturing process and cite an important paper which revealed alarming, unexpected upward trends in water usage per well and wastewater production, particularly in arid areas of the United States. Associated water, food and biodiversity security concerns have yet to be fully investigated but are clearly of extreme relevance in the context of the already stressed water supply in parts of Australia with a prominent agricultural industry and an extreme biodiversity crisis.

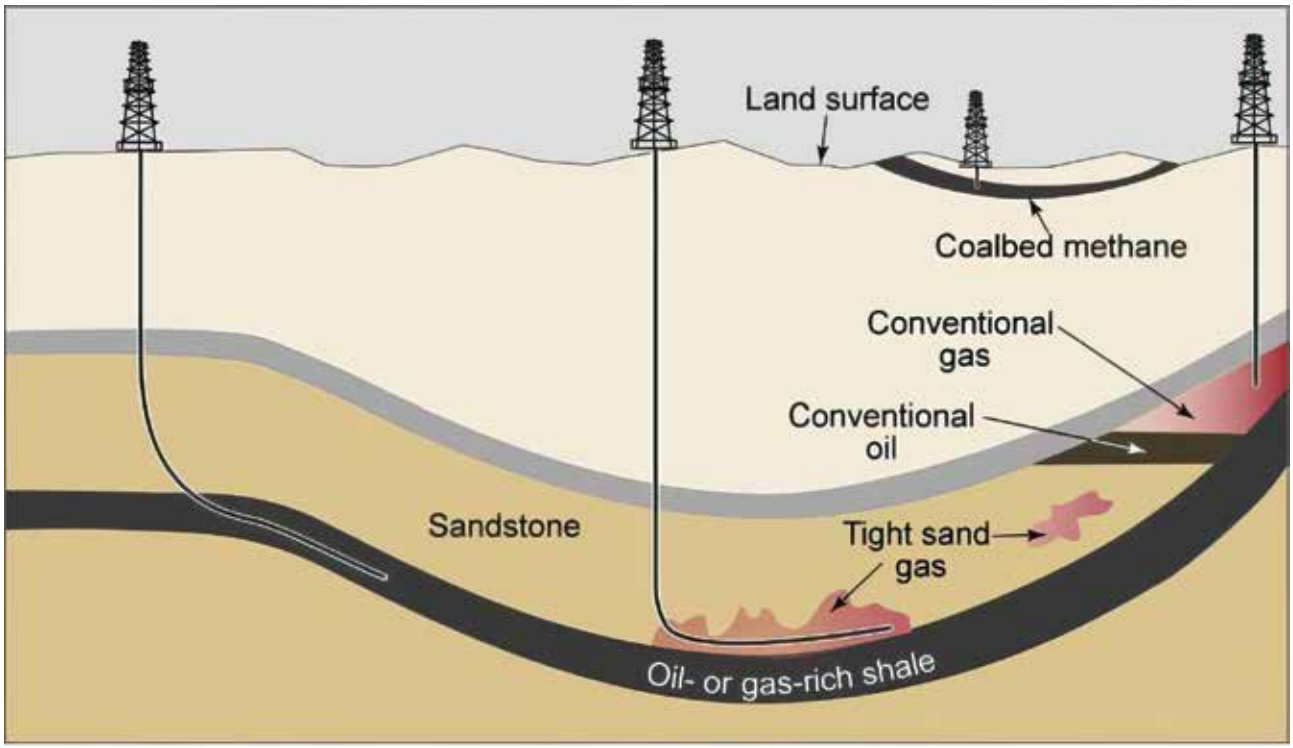
What is unconventional gas and oil and how is it different from conventional?

Easily accessible, concentrated land-based 'conventional' deposits of methane gas (also referred to as 'natural' gas, 'fossil' gas or coalbed methane) have met domestic needs in Australia for decades at costs well below the international market price. However, these conventional reserves are increasingly depleted, not only in Australia, but also globally. Hence, 'unconventional' techniques that harvest gas that is distributed underground over widespread areas at commercially viable cost have been developed and have proliferated across the United States, in Queensland and in other parts of the world.

Unconventional oil and gas operations refer to the site preparation, drilling, extraction, transportation and processing of methane gas that is held tightly in shallow deposits of coal (coal seam gas or coalbed methane), sandstone and limestone (tight gas) and deep shale deposits (shale gas). For export purposes, Australian gas is turned into a liquid (liquefied natural gas [LNG]) and shipped to trading partners. The extraction of coal seam, tight and shale gas often requires invasive techniques, such as removal of fluid from the coal seam (dewatering) and horizontal or deviated drilling and hydraulic fracturing (Figure 2.1). All unconventional oil and gas extraction requires an extensive large scale industrial footprint.

Because unconventional gas is widely dispersed, the continuous drilling and hydraulic fracturing of hundreds to thousands of wells spread across entire regions are required to maintain supply and ongoing

Figure 2.1: Conventional and unconventional oil and gas reservoirs



Sources: U.S. Energy Information Administration and U.S. Geological Survey (U.S. Government Accountability Office from Washington, DC, United States, Public domain, via Wikimedia Commons)
https://commons.wikimedia.org/wiki/File:Figure_1-_Conventional_and_Unconventional_Oil_and_Gas_Reservoirs_(8080671862).jpg

Figure 2.2: Tower for drilling horizontally into the Marcellus Shale Formation for natural gas in Lycoming County, Pennsylvania, USA

Source: Ruhrfisch, CC BY-SA 3.0, via Wikimedia Commons 2009
https://commons.wikimedia.org/wiki/File:Marcellus_Shale_Gas_Drilling_Tower_1_crop.jpg

commercial viability. The need for multiple wells across large areas, plus horizontal drilling and hydraulic fracturing to release the gas, are activities that distinguish unconventional from conventional oil and gas production.

To date (2023), unconventional extraction in Australia has been largely limited to the rapidly expanding coal seam gas operations in Western Queensland and in some parts of New South Wales. The vast majority of coal seam gas produced is exported. So far minor quantities of shale gas for the domestic market only have been produced through hydraulic fracturing of shale, but that is the only experience that Australia has had with this industry thus far. However, multiple proposals for shale gas developments are now being considered in many parts of Australia, with the Beetaloo Basin in the Northern Territory recently prioritised for acceleration, along with further expansions of coal seam gas production.

Oil may also be produced from shale in a similar way to gas. Where profitable oil deposits are available, oil and gas production in the US often overlap through the same wells. The progression from unconventional gas to unconventional oil – and from conventional to unconventional oil – raises a new set of environmental concerns. As Deborah Gordon (2012) of the Carnegie Endowment for International Peace warned:

> *Many new breeds of petroleum fuels are nothing like conventional oil. Unconventional oils tend to be heavy, complex, carbon laden, and locked up deep in the earth, tightly trapped between or bound to sand, tar, and rock. Unconventional oils are nature's own carbon-capture and storage device, so when they are tapped, we risk breaking open this natural carbon-fixing system. Generally speaking: the heavier the oil, the larger the expected carbon footprint.*

These issues are also relevant to predicting fugitive methane emissions from shale gas basins, because the proportion of methane lost during the production of 'dry' gas (i.e., with almost no oil contaminants), such as the coal seam gas in the Queensland Surat Basin, tends to be lower than in basins that produce 'wet' gas containing higher levels of oil contaminants (Neininger et al., 2021; see Section 3).

The components of unconventional gas production processes and their potential negative environmental impacts are briefly described below. The information was accessed from the US Department of Labor Occupational Safety and Health Administration (OSHA) (2018). Occupational health and safety hazards and examples of incidents that have occurred in the United States are also described on the OSHA website.

Application and approval processes

Prior to any action, there is a long and, for communities, often stressful process while the government considers the development. Steps in this process include submission of proposals, review of the proposals by various state and territory agencies, granting of exploration licences, seismic testing, and exploratory drilling. Applications to proceed with full production are then submitted with voluminous Environmental Impact Statements, and assessment and final determinations are made. Sections 5.2 and 5.3 describe some of the psychosocial impacts of these preparatory steps, which can induce feelings of conflict, distress, anger, worry and fear in affected communities and Aboriginal people.

Transportation

Each stage of development brings major increases in large-truck traffic for the transport of personnel, drilling rigs and components, heavy equipment, on site vehicles, chemicals and wastewater. In addition to potential injuries and deaths among oil and gas truck drivers, the increased truck movements affect drivers from other industries, such as cattle, and pedestrians and drivers in nearby communities (described in Sections 5.1, 5.2 and 5.4).

Seismic testing, site preparation and well pad construction

The first steps in new gas exploration and production include seismic testing, the construction of roads and access tracks to the well drilling and other operational sites; the cleaning, leveling and construction of the well pad; and the digging of pits and trenches for disposing of water, drilling fluids, muds and other discharge. Seismic testing is performed to identify the optimal place to site the future wells as well as the size of the target gas or oil reservoir. These activities, including seismic testing alone, can require substantial land clearing and community disturbance with potentially major problems for farmers and habitat and ecosystem integrity. As exploratory drilling in Australia requires fewer approvals than drilling for oil and gas production, it can lead to problems with legacy and abandoned wells that may not be well documented or monitored (McCarron and Dougall, 2021). Proceeding to the next steps also requires the installation of high tensile power, telemetry and telecommunications infrastructure. All of these activities are noisy, dusty and may cause biosecurity risks for the ecosystems or agricultural industry upon which these activities and sites are often located.

As substantial numbers of fly in–fly out (FIFO) workers are required to undertake the construction, drilling and production activities, temporary accommodation quarters, often called 'man camps', are built nearby (Section 5.3; 5.4).

Drilling

Well pads can house one or more wells. A drilling rig is placed into upright position and the drill parts assembled on site. Large drills, lubricated

by special 'muds', penetrate the ground. Muds are composed of lubricant and protective agents mixed with other chemical additives. Muds with contaminants also return to the surface during drilling. Muds are reused but may be buried in onsite surface pits when no longer useable.

Multiple casings (steel pipes) are placed down into the drilled hole to line the well and contain the fluids and gas that will be placed into and drawn up from the drill hole. For shale gas, and increasingly for coal seam gas in Western Queensland, the drilling proceeds downwards to the shale, then turns horizontally (horizontal drilling) or deviates (slants) from the straight down vertical path (deviated drilling), producing tunnels along the shale or coal layer for over 3 km (Hossain and Al-Majed, 2015).

Drilling may provide a short and long-term pathway for potentially harmful chemicals, including salt, to migrate upwards and to reach local aquifers that have been drilled through (Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development, 2014). Handling and disposal of waste muds, drill cuttings and chemical additives can pose risks to groundwater and adjacent land and to the atmosphere through evaporation from waste ponds.

Old and aging wells for both conventional and unconventional gas and oil mining are susceptible to wear-out failures caused by rusting, electrolytic corrosion and dissolution of metals and concrete by acids. Breaching of well integrity can result in long-term low-level fugitive methane emissions, groundwater contamination and surface seepage and spills of toxic chemicals.

Analysis of 1144 violation notices issued from 3533 wells in Pennsylvania found 85 instances of cement and casing failures and six cases of blowouts and gas venting between 2008 and 2011 (Considine et al., 2013). Other violations, comprising nearly 90% of notices issued, included major and minor land spills, surface water contamination and site restoration.

A further review of well barrier and integrity failures of unconventional and conventional oil and gas wells estimated that about four million onshore wells had been drilled globally as of 2014 (Davies et al., 2014). The authors estimated that approximately 6.3% of shale gas wells drilled in Pennsylvania had well integrity issues, most of them were cement or casing failures. Globally, the authors found a widespread lack of well monitoring and of clearly defined responsibility for 'orphaned' wells, where the company that originally drilled the well no longer exists or transfers assets to another company. They concluded that concerns regarding well integrity and barrier maintenance for conventional gas wells apply equally to unconventional gas wells, hence suggesting that these issues are an important cause of methane leakage from wells.

Kiren et al. (2017) reviewed the literature investigating the wide array of chemical, mechanical and operational causes of well integrity failure worldwide. These authors similarly found the leading causes to be cement degradation, casing corrosion, pressure and temperature stress, and insufficient plugging and abandonment operations once a well has been decommissioned.

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Hydraulic fracturing (fracking)

Once a well has been drilled, a process called "well completion" follows. This involves placing and cementing a final production well casing into the well and then punching holes through the casing to allow for fluids and chemicals to be discharged into the shale or coal seam and for wastewater to be collected. Gas also flows up to the surface into the pipe, or through smaller tubes inserted into the pipe to speed the flow of gas to the surface.

The first step in coal seam gas production is the removal of water (dewatering) that has been in contact with the coal for millennia. This so-called "produced water" is highly saline and contains many naturally occurring chemicals, many of which are toxic to humans (see Section 4). The removal of water and gas can cause subsidence on the surface of the land, which causes significant difficulty for agricultural activity (Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development, 2014c).

Extracting oil and gas from shale and often from coal seam deposits requires hydraulic fracturing for the gas to flow sufficiently. Each well may undergo multiple applications of hydraulic fracturing. This procedure involves detonating small explosives placed along the well casing and then injecting high volumes of pressurised hydraulic fracturing fluid. The fluid contains silica sand, which keeps cracks made in the shale or coal open for gas to

Figure 2.3: Natural gas flaring

Source: Photo by Tod baker, (CC BY-SA 2.0) Retrieved from https://www.flickr.com/photos/todbaker/9148692

flow, along with many chemicals, including lubricants, biocides (to kill bacteria), gelling agents, and anticorrosive agents as described in Section 4.

Hydraulic fracturing:

- uses very large amounts of local water, reducing availability for local farmers and communities (Jiang et al., 2014);
- requires drilling at multiple sites to achieve full access to the gas-bearing strata – resulting in hundreds of wells over large land areas and compounding the risks associated with each well;
- carries the risk of seismic activity from the forceful injection and/or lubricating effect of hydraulic fracturing into geological fault lines, as has been observed in some locations (Bau and Eaton, 2016; Eaton and Schultz, 2018).

The chemicals used in hydraulic fracturing in the US and in Australia are described in Section 4. Water and food security concerns that arise from the use of large volumes of water for these processes and their application for agricultural purposes are discussed below.

Wastewater production and management

Oil and gas wells produce varying amounts of unwanted water from the strata containing the fossil fuels or from fracking itself. This water may contain chemicals, including naturally occurring radioactive materials, arsenic, mercury and volatile organic compounds – many of which are harmful to human and animal life – as well as chemicals added during drilling and extraction (see Section 4).

Recycling of wastewater, i.e. using it repeatedly in hydraulic fracturing operations, is favoured in some jurisdictions, especially where water is scarce. However, the reuse of flowback water after fracking for additional fracking results in increasingly high concentrations of hazardous chemicals in the fluids being handled, elevating risks for workers and in accidents, spills and ultimate disposal. According to Webb et al. (2014), recycling of wastewater is not common because of these increased hazards. Parker et al. (2014) also analysed multiple challenges encountered in treating and managing fracking water, which are also very expensive.

One method of wastewater disposal, namely injection back into the ground, can induce seismic activity in some locations. For example, a 900-fold increase in seismic activity was recorded in Oklahoma following the commencement of wastewater reinjection (Ellsworth, 2015; Keranen et al., 2014). Weingarten et al. (2015) confirmed that wastewater injection from oil and gas operations were the sole cause of the unprecedented increase in earthquakes, from 1–7 (1970s) to 75 to 190 (2011 to 2013) to over 650 in 2014, experienced across the central United States between 2009 and 2014. These can be reduced by reinjecting lower volumes.

Another method used is centralised wastewater treatment where wastewater is collected and transported from the well to a specific treatment facility. Those used for shale oil and gas extraction involve several steps, including separation and air and gas flotation to remove gels, dissolved gases, oil, sand, polymers and suspended solids; precipitation of metals; activated carbon filtration with aerobic degradation to remove organic compounds; and reverse osmosis to remove salts (Butkovskyi et al., 2018; Easton, 2013; Jiang et al., 2014). In Australia, coal seam gas wastewater is treated first by reverse osmosis in order to remove the large quantities of salt and other contaminants (Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development, 2014a), but organic compounds and heavy metals may remain in

the treated water. This water is then used for various 'beneficial uses'.

Other methods of dealing with wastewater include evaporation from large holding ponds, spraying onto roads or nearby paddocks, and discharging into rivers, all of which disperse residual chemicals into the local environment (Jiang et al., 2014). Section 4 also discusses the environmental and health risks arising from so-called 'beneficial uses' of untreated wastewater, such as for dust suppression, road construction and de-icing of roads in the winter. The use of wastewater for agricultural purposes, such as watering cattle, also raises concerns, with some examples described below. Some of the emerging concerns, for example regarding heavy metals and endocrine disrupting chemicals as described in Section 4, are not yet fully understood (Davies et al., 2015). Thus, proposed 'adaptive management' techniques should be viewed with scepticism and accepted only after extensive consideration of the potential complications and risks they may pose.

However, despite or perhaps partly because of the many options being used, the actual safety and sufficiency of wastewater management as practiced remains unclear. Furthermore, there is no long-term solution for the disposal of salt waste in inland areas, which when not managed well may threaten the ecological health and productivity of rivers, soil and vegetation (Davies et al., 2015). In Queensland there are very large volumes of extremely concentrated salt brine that is currently stored in large holding ponds waiting for an effective strategy for safe disposal. Among possibilities being considered is a commercial salt industry or dumping into the ocean (Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development, 2014a).

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Oil and gas processing

Crude oil and gas flowing from wells may contain toxic and equipment-damaging chemicals, such as acids, heavy metals (mercury and arsenic) and volatile organic compounds (such as benzene). These contaminants can be removed through a number of chemical and physical processes, for example by incineration (flaring), biofiltration and adsorption through acid gas treatment. These processes represent a significant expense to the industry, especially as they require constant application to multiple wells and gas infrastructure in order to be effective.

Flaring, venting and fugitive emissions

Flaring is a deliberate process used to burn excess methane in a controlled way, breaking it down from a highly explosive and potent greenhouse gas (see Section 3) into a much less potent greenhouse gas, namely CO_2, before release into the atmosphere. It is performed in order to relieve pressure and prevent explosions in gas and oil wells, pipelines and during gas processing and maintenance, sometimes lasting for several days or weeks.

Flaring that does not achieve complete combustion of methane or when the gas also contains contaminants, the process not only emits carbon dioxide, but can also release volatile organic compounds, polycyclic aromatic hydrocarbons, black carbon, heavy metals, carbon monoxide, nitric oxide, nitrogen dioxide and sulfur

dioxide. Excess methane and other volatile organic compounds are also deliberately released directly into the atmosphere through a process called venting. This is performed multiple times during the completion and production phase. These can have negative health and environmental and health consequences, contribute to climate change, acid rain and respiratory illnesses.

Methane is also released through leakage at every step and is called 'fugitive emissions'. During extraction, processing and distribution of oil or gas, accidents, normal wear and tear and improperly constructed infrastructure all permit direct loss of methane gas into the atmosphere. This includes from gas and oil wells, machinery, storage tanks, compressors and dehydrators on the well pad, during processing, from pipelines and at transmission compressor stations, during underground storage if necessary, during transfer at its destination and with the end users within households, commercial properties and industrial plants (Lafleur et al., 2016; Weller et al., 2020; Department of Climate Change, Energy, the Environment and Water, 2023).

Until recently, there have been few research-based estimates of fugitive emissions occurring from municipal pipelines delivering gas to end users. Using data from an advanced mobile methane leak detection system, Weller et al. (2020; 2021) estimated that there are over 659,000 pipeline leaks in the United States local gas distribution systems. These leaks released an estimated 0.69 (95% CI 0.25-1.23) million tonnes of methane into the atmosphere each year, which is approximately 5 times greater than reported by the US Environmental Protection Agency's greenhouse gas inventory. To our knowledge, similar research-based estimates are not available for Australia's major LNG importers, China, Japan and South Korea.

Finally, as we describe in Section 3, major and minor accidents, such as the Alysso Canyon disaster, have occurred in storage locations which have released enormous quantities of methane directly into the atmosphere. Other gases present with the methane caused a significant health emergency for people living nearby.

Other processes

There are other processes associated with unconventional oil and gas operations that also pose potential health and environmental risks. These include the extensive mining of silica sand and manufacture of hazardous chemicals used in vast quantities in hydraulic fracturing, the management of very large quantities of salt if wastewater is treated by reverse osmosis. Liquifying methane to produce liquified natural gas before shipping is extremely energy intensive (See Section 3).

Finally, the new and unproven technology of carbon capture and storage proposed to assist in reducing the greenhouse gases emitted for these extensive procedures carries an extensive environmental footprint. The IPCC's 2022 Climate Change Mitigation Report (Pathak et al., 2022) found that, globally, carbon capture and storage has been slower than anticipated to deploy, has very limited capacity to contribute to net emission reduction, supports far fewer Sustainable Development Goals and is substantially more expensive that wind, solar and battery energy system development.

All these problems have been experienced throughout the Gorgon carbon capture and storage project in Western Australia, which after six years of operation has only running at one third capacity in capturing emissions from its large-scale gas fields (Mercer, 2023). Oil and gas industry leaders insist that the technology is proven and effective, but IPCC scientists do not agree.

Serious threats associated with these operations: Water security, food security and biodiversity

Water security at risk

Each hydraulic fracturing event for shale gas production uses 5.7 to 60.6 million litres of water (American Geosciences Institute, n.d.), which can be applied many times per well across hundreds to thousands of wells in an area (Vengosh et al., 2014; Jiang et al., 2014). Kondash et al. (2018) reported that the median amount used per well in 2016 was 28 million litres in the Marcellus, 42 million litres in the Permian and 21 million litres in the Bakken regions of the United States. While wastewater that returns to the surface is sometimes reused, challenges in water reuse are discussed below.

This use of valuable freshwater raises concerns for water security in some locations. Water security is defined as having a sufficient and secure supply of water for drinking, food production and other human and ecosystem services (Entrekin et al., 2018; Rosa et al., 2018). Already many areas of the world, including in the United States and Australia, are facing significant water stress, which will worsen as climate change progresses. A global analysis reported that 31–44% of the world's known shale deposits are located in areas likely to be affected by water stress; 20% are in areas where groundwater is already depleted and 30% underlie irrigated lands (Rosa et al., 2018). These authors warned of likely competition between unconventional gas production and food and other human uses of water.

Substantial concerns have been raised by modelling conducted for the Office of Groundwater Impact Assessment on the extensive use of water by the coal seam gas industry in Queensland (Underground Water Impact Report, 2018; McCarron and Dougall, 2021). The modelling predicts future pressure drops in groups of freshwater springs and loss of 571 private and licensed stock and domestic water bores. The Office has already reported significant declines in water levels and loss of trees and ecological health of springs in areas of coal seam gas activity.

As shale gas and oil mining has expanded in the United States, the amount of water used per well to produce a unit of gas (water-use intensity) has also risen substantially (Kondash et al., 2018). This was associated with longer lateral drilling distances and greater intensity of hydraulic fracturing in 2014–2015, simultaneously with a reduction in drilling of new wells as oil and gas prices fell. High-intensity production also resulted in even more wastewater produced per well. Kondash et al. (2018) examined water usage records across four shale gas mining regions in the United States and reported increased water-use intensity (lower water efficiency) and wastewater production across all four. The increase was as high as 770% in water usage per well and 1440% in wastewater production in the Permian and Eagle Ford Basins, located in semiarid Texas and New Mexico, respectively, over a five-year period.

Sometimes, 'solutions' to problems can actually cause further problems and may not be adequately researched before implementation. For example, the siting of multiple wellheads (up to 12) on the same pad and multi-directional drilling was anticipated to reduce surface footprint. However, as demonstrated by Kondash et al. (2018) and discussed above, the wellheads may not be placed optimally to locate the 'sweet spots' of gas in each direction. This then has meant longer distance drilling, larger water requirements, greater pressures for hydraulic fracturing and greatly enlarged volumes of wastewater requiring safe

Contamination and deterioration of soils and competition for water and land use carry significant human health risks, especially considering the cumulative impacts of hundreds of wells over decades.

handling. After a decade of drilling, according to research by Jacquet et al. (2018), multi-well pads have not been widely used; a majority of pads housed only one (45.7%) or two wells (15.2%), for an average of 3.2 wells per pad in Pennsylvania and 2.2 in West Virginia.

Food security at risk

Concerns over water security are clearly directly connected to concerns for the agricultural industry and food security (Hitaj et al., 2020). These concerns are likely to apply to many areas of Australia where coal seam gas and shale gas deposits are found. Water stress is already experienced by local farmers and communities in existing developments in the Darling Downs, Queensland and Narrabri, NSW. Similarly, water availability is already a pressing challenge for farmers and communities near proposed sites for exploration and mining in the Northern Territory and Western Australia. In addition, oil and gas operations, and the mining of sand for hydraulic fracturing, damages the health of soil, through direct contamination with an array of chemicals, through soil heating, impacts on watershed, increased salinity, pH changes and nutrient availability which can reduce crop yields (Allred et al., 2015 and Moran et al., 2017).

Contamination and deterioration of soils and competition for water and land use carry significant human health risks, especially considering the cumulative impacts of hundreds of wells over decades. Haswell and Bethmont (2016) noted that the link between soil health, food safety and security and unconventional gas has received insufficient research interest even though it is a critical issue for Australian farmers. Livestock health and water rights are paramount concerns for these farmers, especially with increasing drought conditions predicted in Australia and globally (Collins et al., 2013; IPCC, 2022) and likely in 2023 with forecast El Nino conditions.

Very few studies have examined impacts on agricultural products and yields. Finkel et al. (2013) identified substantial reductions in both dairy cow numbers and milk production in areas of Pennsylvania with heavy drilling activity. Hoy et al. (2018) examined changes in agriculture associated with drilling in the Marcellus shale region compared with communities in New York where drilling was banned. They found little difference in many of the agricultural variables they examined; however, they noted an increase in average farm size, reflecting a reduction in the number of smaller farms, likely through amalgamation, and a decline in beef farms in drilling areas.

Negotiations between water and energy sectors are rife with conflicting views and complexity and increasingly so with climate change and population growth (Hussey et al., 2013). Prospects for successful coexistence of farming and gas mining are further challenged by new roads and mining infrastructure on agricultural land, heightened pollution risks, livestock disturbance, lack of attention to legislated occupational health and safety rights as gas developments operate in farmers' workplaces, landscape changes and economic uncertainties surrounding the impacts of unconventional gas mining in Australia and elsewhere (Freyman, 2014; Bamberger and Oswald, 2015; Hussey et al., 2013; Chen and Randall, 2013; Dougall, 2019; McCarron and Dougall, 2021; Bressan and Deshaies, 2023). Psychosocial impacts experienced by farmers are described in Section 5.2.

Biodiversity at risk

Biodiversity is essential for healthy ecosystems, which in turn are essential for human health. Biodiversity protects human access to clean air and water and a secure food supply. In forested areas and other ecologically sensitive sites, these activities as well as clearance for pipelines and infrastructure causes substantial tree clearing, habitat fragmentation and loss, and stress and disturbance of wildlife (Langlois et al., 2017; Black et al., 2021). Ensuing steps in the processes of gas development, including air pollution and surface water pollution, threaten aquatic ecosystems, vegetation and wildlife (Meng, 2017). There is a growing literature demonstrating how these disruptions are changing habitat choices, migration and reproductive patterns and species loss (Northrup et al., 2015; Barton et al., 2016; Juliusson & Doherty 2017).

Australia and the world are facing a global biodiversity crisis which comes with grave concerns for human health and wellbeing.

Summary

This section has provided a brief scaffold to build understanding of the multiple, complex activities involved in unconventional oil and gas operations and the risks they pose to people and the environment. While some activities are shared with conventional methods which also carry risk, two aspects set shale and coal seam gas production apart. First, to overcome the more difficult task of harvesting dispersed oil and gas over vast areas, unconventional oil and gas production requires hundreds to thousands of well pads creating a very large land footprint. Secondly, the difficulty in releasing oil and gas from shale and coal deposits often requires multiple applications of hydraulic fracturing.

This technique requires the use of many chemicals, silica sand and very large quantities of fresh water and results in large quantities of wastewater containing even more toxic chemicals returning to the surface and requiring management and disposal. The literature documents spills and accidents, well integrity failures, wastewater management challenges and methane leaks. Combined with land clearing, noise and disturbances from seismic testing, networks of roads, high power energy infrastructure, truck traffic and potential exacerbation of water scarcity in dry areas, it is not surprising to see emerging evidence of negative impacts that unconventional oil and gas operations bring to water security, food security and biodiversity, as well as to people.

These screenshots were taken of the Pilliga Forests on the Homeland of the Gomeroi People. Covering 500,000 hectares, it is the largest continuous remnant forest in the eastern side of Australia and a National Biodiversity Hotspot. In December 2022, despite an outpouring of public opposition, the NSW government approved the construction of 850 coal seam gas wells in the forest.

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3. Climate implications: Why we must keep Australia's methane (aka 'natural' gas) in the ground to secure our future

This Section provides an analysis of the substantial contribution of oil and gas production, transportation, processing and combustion on the dangerous and precarious state of our climate. We first describe the causes, the severity and the imperative of rapid action to stop producing and burning fossil fuels. We then discuss the key role that methane – the product of unconventional gas developments – is contributing to climate change.

We then identify the many reasons why methane is not a 'low-carbon fuel' and how continued production and export of gas from Australia is exacerbating climate change. We review a range of evidence that destroys some of the 'myths' about gas compared to coal and urge direct transition to much cheaper and much safer renewable energies. We also look at some of the trends in our National Greenhouse Gas reporting that show the substantial contribution of coal seam gas and LNG exports to the increases in both stationary energy (excluding electricity) and fugitive emissions since 2005.

We then focus on Australia's responsibility as a wealthy nation, with a very high per capita carbon footprint but significant potential to support the enormous global transition required to protect the health and wellbeing of current generations and the future of our children.

We are now living in a climate health emergency.

What is happening to our climate?

According to the world's most eminent scientists, Earth's climate is changing rapidly, with signals across virtually every human dimension pointing to the role of human activity in pushing towards much more dangerous planetary conditions. The resulting impacts of global warming, are now clearly playing out in front of us, with devastating impacts on livelihoods across the globe, and on global health (IPCC, 2022; 2023). There is almost universal understanding among scientists that the major human activity contributing to this change is the continuing choice to burn fossil fuels – coal, oil and gas – to power our lives.

The Sixth Intergovernmental Panel on Climate Change (IPCC) Final Synthesis Report, released in March 2023 (IPCC, 2023), and, the Impacts, Adaptation and Vulnerability Report released in March 2022 (IPCC, 2022), clearly articulate the urgency for change and the consequences of failing to change:

> *Human activities, principally through emissions of greenhouse gases, have unequivocally caused global warming…. Global greenhouse gas emissions have continued to increase, with unequal historical and ongoing contributions arising from unsustainable energy use, land*

use and land-use change, lifestyles and patterns of consumption and production across regions, between and within countries, and among individuals (high confidence).

Human-caused climate change is already affecting many weather and climate extremes in every region across the globe. This has led to widespread adverse impacts and related losses and damages to nature and people (high confidence). Vulnerable communities who have historically contributed the least to current climate change are disproportionately affected (high confidence).

Risks and projected adverse impacts and related losses and damages from climate change escalate with every increment of global warming (very high confidence). Climatic and non-climatic risks will increasingly interact, creating compound and cascading risks that are more complex and difficult to manage (high confidence).

Some future changes are unavoidable and/or irreversible but can be limited by deep, rapid and sustained global greenhouse gas emissions reduction. The likelihood of abrupt and/or irreversible changes increases with higher global warming levels. Similarly, the probability of low-likelihood outcomes associated with potentially very large adverse impacts increases with higher global warming levels (high confidence).

The Sixth Assessment reported that because of the greenhouse gases already emitted, even if fossil fuel use ceased today, we will witness increasing harms to the Earth's physical and ecological systems, and consequently to human health and wellbeing, until 2030. The modelling indicates humanity can still limit harms to that level with strong and committed global decarbonisation from 2030 onwards, limiting warming as close as possible to a 1.5°C increase above pre-industrial temperatures (IPCC 2022; 2023).

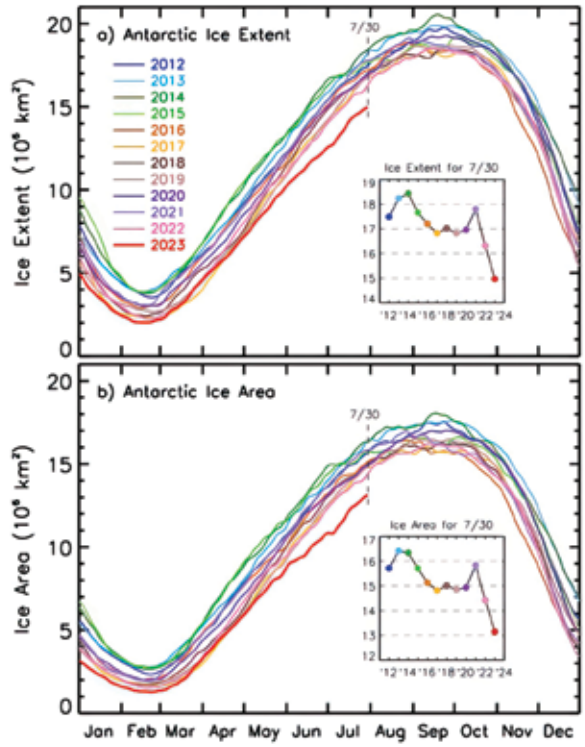
However, if global action now is not sufficient, we will see rapidly escalating changes well beyond what we have already experienced. As noted above, the likelihood of catastrophic (abrupt and irreversible) global impacts will increase with steady deterioration of planetary conditions. Current global policies are leading to a 2.7°C rise, which is beyond catastrophic (IPCC, 2023). According to The Lancet Countdown on health and climate change, under conditions of catastrophic climate change it will no longer be a question of whether we can adapt, but one of fighting for survival, as 'hothouse' Earth no longer provides the basic necessities, such as safe, clean and sufficient food, water and air (Costello et al., 2023).

Australia is highly sensitive to climate change, as we have already witnessed the beginning of this deterioration in recent unprecedented bushfires, heatwaves and floods. In 2023, we are moving from wet and cooler La Nina conditions into heat and drought extremes of El Nino conditions. For seven days in a row, July 2023 temperatures were above all previous global records. These are now impacting on all aspects of human life, with an estimated 61,672 excess deaths among Europeans during the 2022 heat waves (Ballester et al., 2023). Simultaneously, the loss of sea ice in the Antarctic in 2023 (see red line in figure below) has also been unprecedented, potentially bringing forward inundation of Australian coastal cities and islands. These observations in the first seven months of 2023 alone, combined with those gathered over decades, confirm what many climate scientists (including the late Professor Will Steffen) have already pointed out – that our earth systems are now approaching tipping points from which there will be no return (Steffen et al., 2021).

Figure 3.1 is taken directly from the National Aeronautics and Space Agency (July 29, 2023) "Seasonal cycle of Southern Hemisphere sea ice extents (a) and areas (b). given as daily averages, for the years 2012 through 2023.

The vertical line represents the last data point plotted Seasonal cycle of Southern Hemisphere sea ice extents (a) and areas (b). given as daily averages, for the years 2012 through 2023. The vertical line represents the last data point plotted [July 26]" (Comiso et al., 2023).

Figure 3.1: Seasonal cycles



Source: National Aeronautics Space Agency
https://earth.gsfc.nasa.gov/cryo/data/current-state-sea-ice-cover

Role of fossil fuels, focusing on methane

Fossil fuels – coal, oil and methane gas –are the source of 80% of all greenhouse gas emissions from human activity, driving both global warming and indoor and outdoor air pollution. Greenhouse gases (carbon dioxide, methane and nitrous oxide) and other pollutants (particulate matter, ground level ozone, oxides of nitrogen and other gases) are released into the atmosphere from mining/ extraction, processing, transport and combustion (IPCC, 2013; 2018; 2022).

Methane, commonly called 'natural gas', is the product of hundreds of millions of years of carbon removed from the atmosphere into the shells of sea creatures, into plants through photosynthesis and onto rocks. Vast quantities of carbon were safely stored in layers of shale formed where oceans once were, in coal deposits fossilised from ancient vegetation and forests and in some types of rock. In the last 30 years, humans have brought massive quantities of carbon to the surface through coal mining and oil and gas extraction. The three types of gas extraction reflect the places where carbon was stored and methane formed, being shale gas (3–5 kilometres below the surface), coal seam gas, (held in place along the surface of coal by natural water) and tight gas (in rock deposits) (see Section 2).

When coal, oil and gas are burned for heat and energy, most of the carbon is released into the atmosphere as carbon dioxide. However, methane that escapes into the atmosphere without being burned, as it does during coal mining and oil and gas extraction, transportation and processing, will remain in the atmosphere for 12–20 years and is very potent in trapping energy from the sun.

Essentially then, global warming has largely resulted from the reintroduction of this naturally-stored carbon back into the atmosphere as carbon dioxide and methane as a result of human activities. The rate of change in atmospheric chemistry from mining, extraction and burning is orders of magnitude faster than any non-human process (for example volcanic activity). Hence within decades, human activity has increased the concentration of CO_2 from 280ppm to 420ppm (National Oceanic and Atmospheric Administration, 2022).

Concerningly, as human activities have caused some planetary warming, other natural processes of carbon sequestration are also starting to break down. Some examples include release of methane previously trapped

under Arctic ice, warmer oceans releasing CO_2 rather than absorbing it, loss of reflective polar sea ice increasing the absorption of heat into land and water, and carbon released from unprecedented forest fires in drought-stricken forests. In turn the loss of forest means that less carbon is being taken out of the atmosphere through photosynthesis by trees and vegetation. These are examples of the 'positive feedback' that occurs when a human-induced change triggers changes in the natural world that then amplify the damage.

Potency and rise in atmospheric methane

Methane is the second largest contributor, after carbon dioxide, to global warming. Methane is the most important of the 'short-lived climate pollutants', a group of very potent greenhouse gases that also includes other gases emitted during gas production operations, such as black carbon (derived from gas flaring), ground level ozone (described in Section 4) and oxides of nitrogen.

The IPCC Sixth Assessment Report on Impacts, Adaptation and Vulnerability (IPCC, 2022) emphasises the dual requirements for rapid reductions in CO_2 and in short-lived climate pollutants (most importantly methane) in order to limit global warming. Methane, even if comparatively short-lived, traps 86 times as much heat energy, warming the atmosphere much more rapidly than equivalent levels of CO_2 over 20 years.

Methane now accounts for an estimated 45% (IPCC, 2023) of the increase in the trapping of heat in the atmosphere (causing global warming). Atmospheric levels of methane have increased steadily and substantially since 2008. In October 2021, the World Meteorological Organisation (WMO) reported the biggest annual increase in methane concentration since the start of systematic measurement in 1983. At that point, methane levels were 2.62 times higher than pre-industrial levels.

Contribution of oil and gas production to methane levels

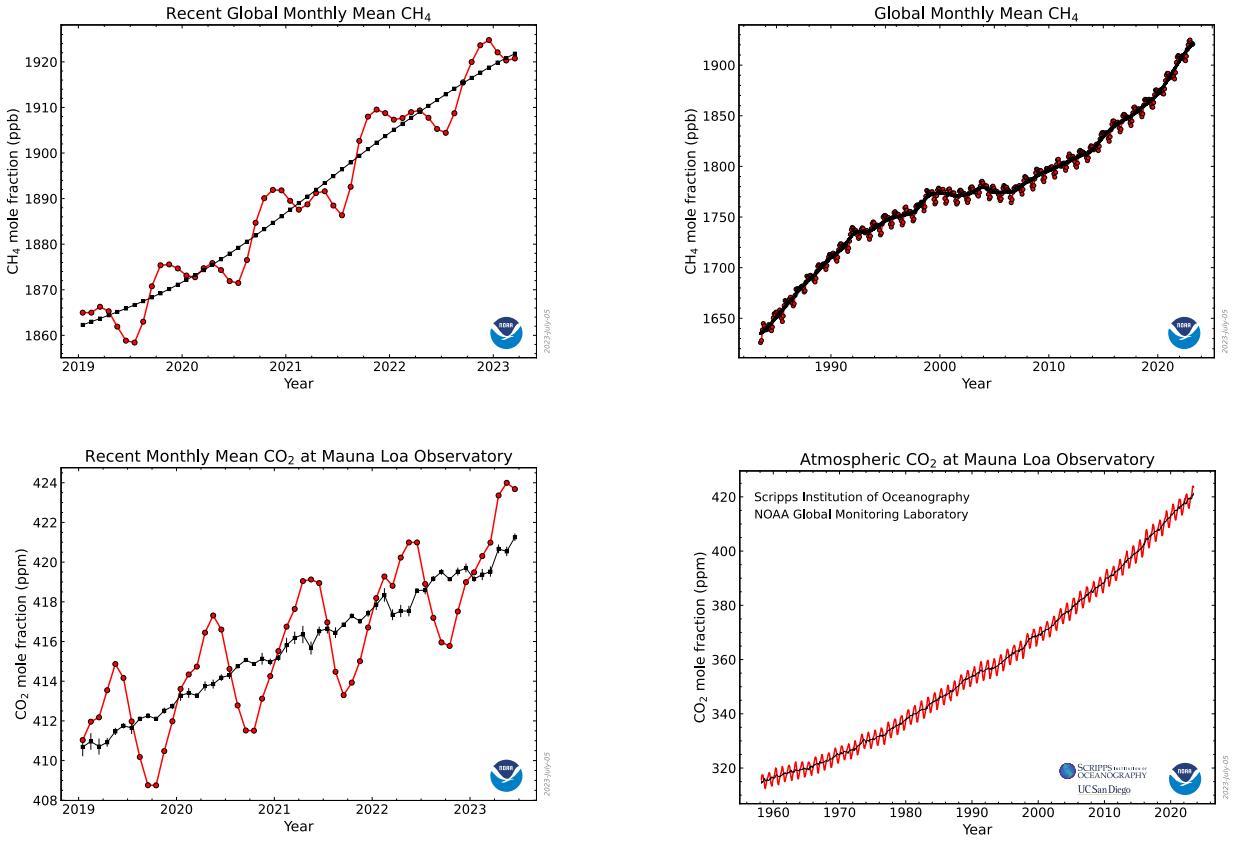
The International Energy Agency's plan (2021) to achieve global energy decarbonisation argues that there is no need for new fossil fuel developments. The UN Secretary General has urged all nations to cooperate as global citizens to stop fossil fuel expansion and to assist developing nations which do not have the resources to move quickly enough in their transition to renewable energies without external support.

Despite this clear warning, however, exploration and exploitation of fossil fuel resources continue unabated and/or are expanding, both globally and in Australia (see Section A1). In 2023, there are many reasons to be seriously concerned about the climate change implications of continued reliance on and expansion of gas production for energy purposes. Unfortunately, early claims that using unconventional gas for energy is a bridge or 'transition' to lower greenhouse gas emissions are not justified. When the entire life cycle of gas production, transportation and combustion is taken into consideration, fugitive (leaking) methane emissions (not combusted to form CO_2 before release into the atmosphere) means that the claimed climate 'advantage' of gas over coal is greatly diminished at best and more potent than coal at worst (Shearer et al., 2014; Staddon and Depledge, 2015; Voiland, 2016; IEA, 2017; Smillie et al., 2022; Gordon et al., 2023).

It is now clear that the impacts of gas emissions have been significantly underestimated, and its climate benefits over coal overestimated, for many reasons. Some of these are discussed below.

Methane's oversized short-term impact on warming compared to carbon dioxide (i.e., the fact that a molecule of methane traps approximately 86 times more energy than a molecule of carbon dioxide) over 20 years (Voiland, 2016; NASA, 2016; IPCC, 2023) is

Figure 3.2: Recent global monthly mean CH_4 and CO_2 readings



Source: CH_4 – NOAA Global Monitoring Laboratory: https://gml.noaa.gov/ccgg/trends_ch4/#:~:text=Global%20CH4%20Monthly%20Means,Last%20updated%3A%20Jul%2005%2C%202023
CO_2– NOAA Global Monitoring Laboratory: https://gml.noaa.gov/ccgg/trends/

far more important than the frequently used 100-year average potency of 28 times that of CO_2. As we approach potential tipping points, near term impacts (occurring within 10 to 20 years) have become extremely important. However, some modelling, including that used in the Australia's National Greenhouse Gas accounting, continues to use the 100-year figure for estimating CO_2 equivalents of fugitive methane.

Fugitive emissions account for higher proportions of the extracted gas escapes than were initially expected (Howarth, 2014; Gordon et al., 2023). Leaks occur for reasons of well-casing failures, or leaky pipes and infrastructure or, possibly, fracking-induced channels for gas flow from underground to surface. Extensive modelling by Gordon et al. (2023) indicated that leakage over 0.2% of the total methane production volume before combustion calls into question the benefit of 'natural' gas over coal as an energy source.

The most comprehensive study of methane emissions from coal seam gas production in the Surat Basin in Queensland indicated that 0.4% of production volume is lost as fugitive emissions (Neininger et al., 2021). This estimate is 2 to 3 times higher that of previous estimations in the Surat Basin which did not account for a range of factors, but similar to levels found for other 'dry gas' fields (gas without contamination with oil) in the US and The Netherlands. Although this is within the low range compared to unconventional gas produced in other regions of the world, it calls into question the significance of its advantage over coal based on Gordon et al. (2023).

Importantly Shearer et al. (2014) pointed out that switching from coal to renewable energies, rather than to gas, completely avoids those concerns since the much larger known net gain in life cycle emissions reduction with wind and solar energy does not depend on methane leakage rates.

When methane is exported (the vast majority of gas produced in Australia is exported), it is transported by pipeline propelled by compressor stations to processing stations. This infrastructure and processes may emit both methane and other air pollutants which are immediately harmful (Buonocore et al., 2023). For shipment, the gas is then liquified at -160°C, producing liquefied natural gas (LNG), which is extremely energy intensive.

While proposed oil and gas developments may pledge to use solar or wind energy to drive these processes and help reduce their carbon footprint, this would need to be carefully assessed to ensure that these developments do not divert Australia's already over-stretched renewable energy transition skills and resources away from developments designed to benefit households, services and businesses (Knight, 2023).

Once the oil and gas is exported by ship (which is also fossil energy intensive), the LNG is then reverted back to methane gas and placed into supply networks in our export partner nations, currently China, Japan and South Korea. As in Australia, methane may leak from these networks and in households before the point of combustion.

In addition to its direct effect on global heating, methane can also be converted into the highly potent greenhouse gas, tropospheric (ground level) ozone, which also damages human health and agricultural production (see Section 4). Being highly reactive in the atmosphere, methane also enhances stratospheric water vapour and influences aerosols and the lifetimes of extremely potent greenhouse gases, the hydrochlorofluorocarbons and hydrofluorocarbons (IPCC 2013, O'Connor et al., 2021; Szopa et al., 2021).

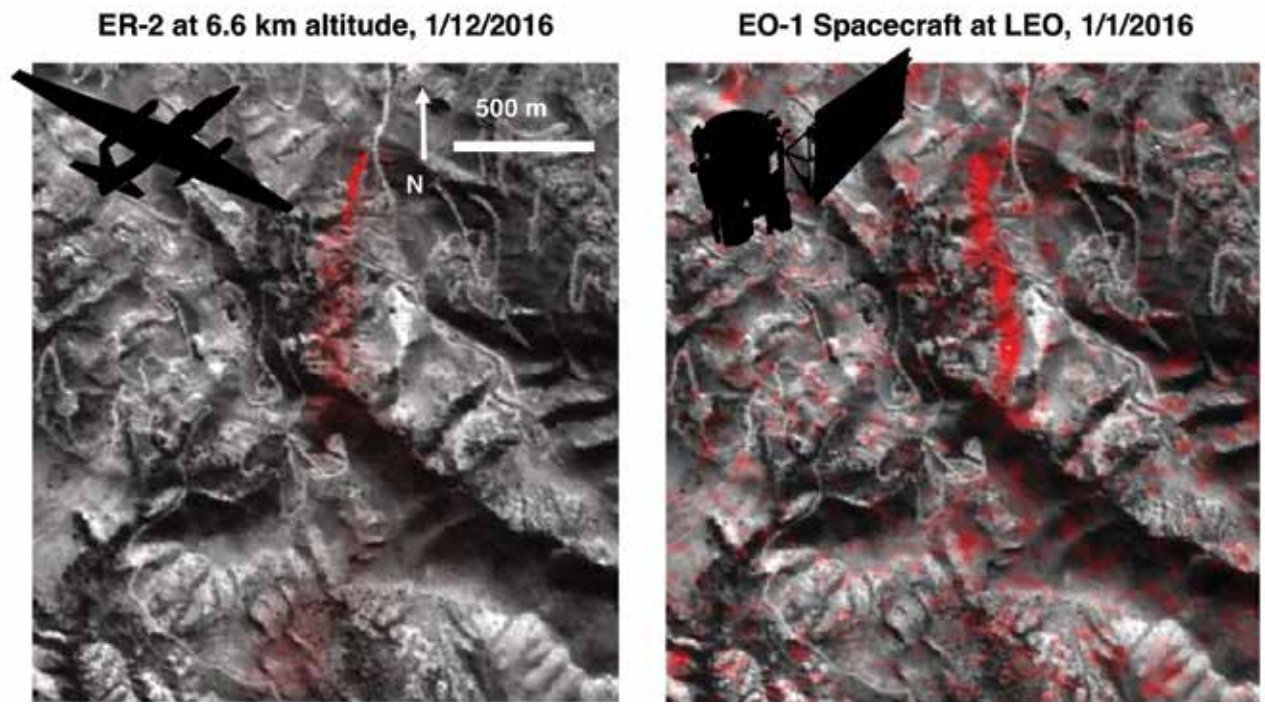
Modelling suggests that abundant supply of natural gas in the United States has competed against, rather than bridged to, renewable energies and delayed urgent transitions to a decarbonized energy system to limit global warming (Shearer et al., 2014; McJeon et al., 2014; Staddon and Depledge, 2015). Similarly, Smillie et al. (2022) found in modelling the international market effects of increasing LNG exports from the US that "the increased supply of lower cost gas will not only drive fuel switching from coal but also lower energy prices leading to increased energy consumption overall." Estimates of purported gains from the switch from gas to coal were substantially reduced by these market forces.

Despite extensive research, claims that gas is a 'low carbon' fuel persist in media, advertising and government discussions, obstructing honest and open discussion about the best ways to avoid climate catastrophe.

Methods of large-scale carbon capture and offsets to 'make up for' emissions from continued fossil fuel expansion are not proven to do so. While methane capture from existing oil and gas production activities around the world is highly desirable (United Nations Environment Programme/Climate and Clean Air Coalition, 2022), this does not mean that new oil and gas developments are acceptable. The United Nations urges technology and funding to reduce emissions from current installations that are adding to increased methane levels in the atmosphere, not to produce more gas.

Accidents involving well blowouts and leakage from methane storage sites, as exemplified by the 2016 Aliso Canyon disaster (Figure 3.3), have happened, with staggering impacts, and may occur at similar sites in the future (Conley et al., 2016).

Figure 3.3. NASA photograph showing for the first time a single point methane leak at Aliso Canyon in June 2016, three days after a major accident which led to the release of an estimated 97,100 metric tons of methane. Left hand side is from aircraft at 6.6 kilometer height, right hand side is a satellite image.



Source: NASA/JPL-Caltech/GSFC; https://photojournal.jpl.nasa.gov/figures/PIA20716_fig1.jpg

Finally, because the world's nations have failed to stabilise and sharply reduce greenhouse gas emissions over the last decade, there is insufficient time left for a slow and gradual transition towards decarbonisation of the energy supply. Hence even if a switch to gas did provide a significant reduction in CO_2 emissions as claimed, this reduction would not be sufficient to avoid exceeding the 1.5 or 2° C carbon budget (IPCC, 2018).

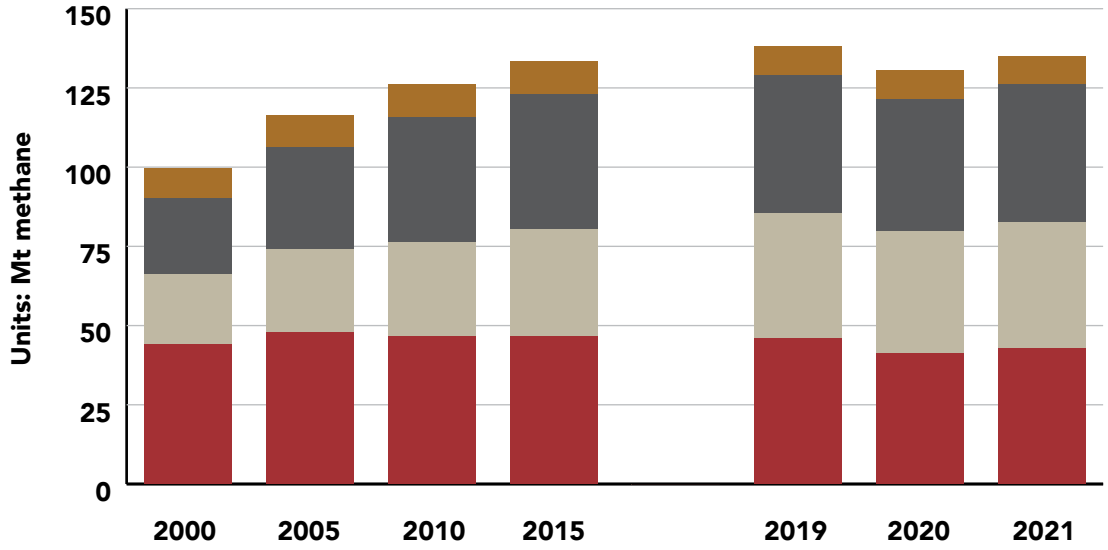
Worden and colleagues (2017) estimated that oil and gas production is responsible for between 48% and 75% of the total methane emissions from all human activities, i.e. 12 to 19 of the total 25 million tonnes released each year.

The Global Methane Assessment 2030 Baseline Report (United Nations Environment Programme/Climate and Clean Air Coalition (2022) presents the results of extensive modelling and states that:

> *Without serious reduction efforts, global baseline methane emissions will continue increasing through 2030. By 2030, methane emissions are projected to increase by between 20–50 million tonnes per year above current levels… Emissions in the fossil fuel sector are expected to increase over the decade to 10 million tonnes per year by 2030 (ranging between 4 and 23 million tonnes) within the oil and gas sector (especially gas).*

To draw attention to and monitor the alarming increase in atmospheric methane, the International Energy Agency (2022) developed Methane Tracker 2021 to improve the accuracy of measurement of methane emissions from energy activities. This work shows that emissions from gas increased between 2015 and 2019 and remained steady from 2019 to 2021. Little change was observed during the COVID-19 pandemic.

Figure 3.4: Global methane emissions from the energy sector over time 2000–2021



Source: International Energy Agency (2022)
https://www.iea.org/reports/global-methane-tracker-2022/overview

Australia's role and responsibility as a wealthy country and leading gas exporter

As discussed above, science has provided unequivocal evidence of the severity, the causes and the consequences of further inaction. Action must be taken immediately to protect future generations.

The Lancet Commission on Climate Change and Health describes the impacts of increasing atmospheric greenhouse gas concentrations on human health and wellbeing as the greatest health threat of the 21st century (Woodward et al., 2014; Watts et al., 2017). The majority of the loss of health, life, livelihood and property from climate change to date has been borne by the developing world, which has contributed least, but suffered the most, from climate change, mostly driven by developed countries directly and indirectly through export of their fossil fuels. This same concept is even more evident within countries (Chancel et al., 2023). The wealthiest 10% of the global population, including low, middle and high income countries, is responsible for 48% of total emissions, experiences the least relative losses and have the greatest capacity to finance global action on climate change if they chose to.

The greatest injustices, however, will be borne by children born today and all future generations if we fail to act now. They will bear the greatest suffering from catastrophic climate change, having had no choice or voice in its progression and left with few resources to deal with it.

As Australia is one of the world's wealthiest nations with one of the largest *per capita* greenhouse gas footprints, the changes Australia must undertake cannot be clearer – and are already outlined in international agreements

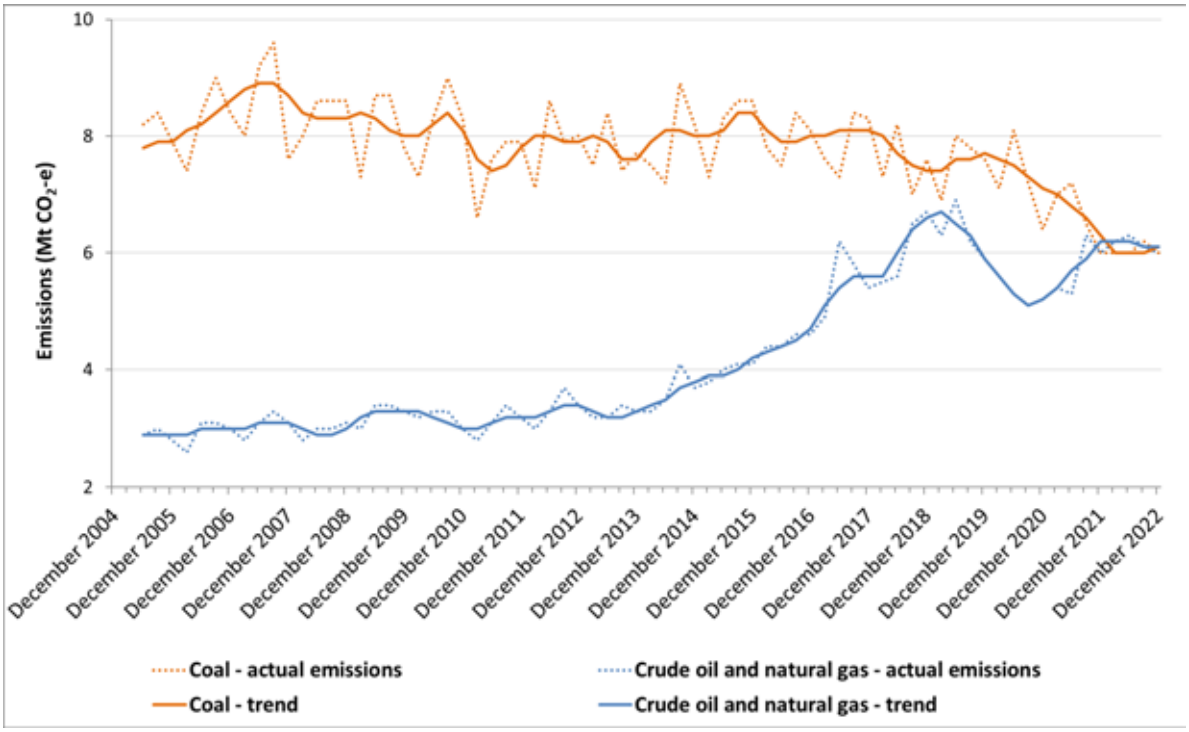
we have committed to, particularly the Paris Agreement and recently the Global Methane Pledge, which Australia signed in October 2022.

The Paris Agreement emerged from the COP21 United Nations Framework Convention on Climate Change (UNFCCC) in 2015 with commitments from 175 countries to take responsibility for reducing greenhouse gas emissions and assist in limiting global warming to 2 °C, and preferably to 1.5 °C. To date, Australia has reportedly been heavily criticised by international governments and health leaders for its lack of commitment and action (Smith, 2021; Beggs et al., 2022).

Domestically, Australia has demonstrated its commitments to reduce domestic electricity emissions through the Australian Energy Market Operator's 2022 Integrated System Plan (AEMO, 2022). This Plan operationalises its Step Change scenario through a 30-year electricity market roadmap. The map forecasts the nearly complete phaseout of coal and existing gas generators by 2040, with an ongoing but minor role for 'peaking gas' in exceptional circumstances. These models play close attention to the cost and stability of the transition process, and market adjustments required to achieve net zero. The Quarterly Update of Australia's National Greenhouse Gas Inventory demonstrates this progress with electricity emissions decreasing 21.4% between June 2005 and December 2022 due to domestic renewable energy penetration (Department of Climate Change, Energy, the Environment and Water, 2023).

In sharp contrast, Australia's rapid increase in LNG exports since 2015 are singled out as the main driver of a 27.4% increase in stationary energy (excluding electricity) emissions from direct burning of fuel in heating and industrial processes, such as liquifying gas for export. Similarly, a 14.1% increase in fugitive emissions since June 2005 is attributed to the extraction, production, processing and transportation of natural gas and oil, including leakage, evaporation and storage losses, flaring and venting of carbon dioxide, methane and nitrous oxide.

Figure 3.5: Fugitive emissions, actual and trend, by sub-sector, by quarter December 2004 to December 2022



Source: Department of Climate Change, Energy, the Environment and Water

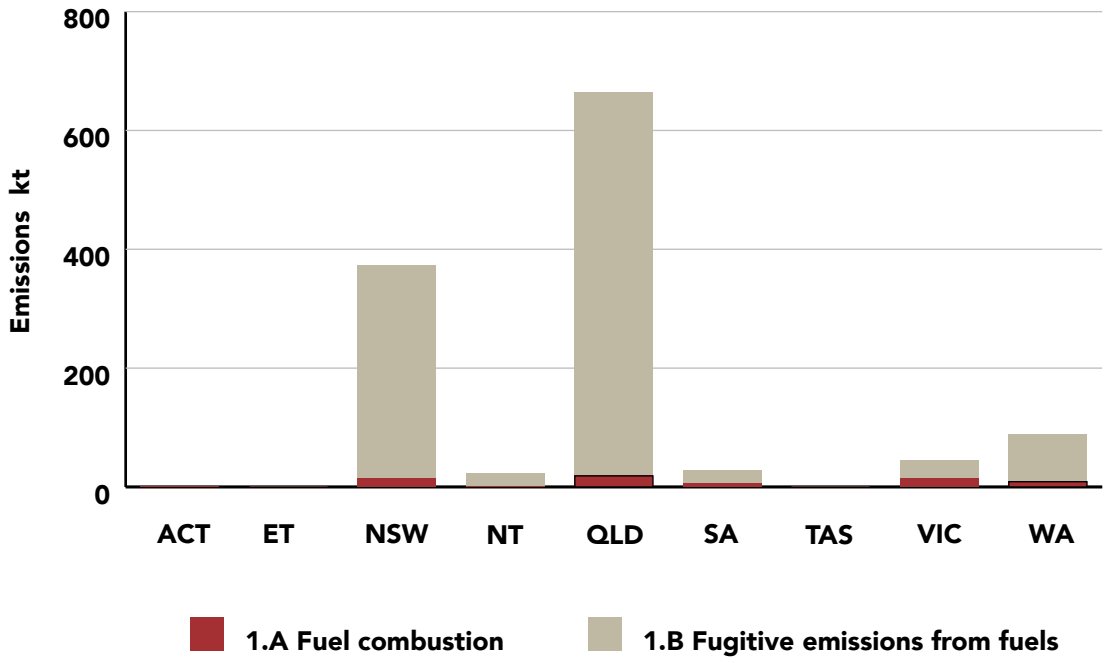
These increases in fugitive emissions from gas fields are clearly evident in Queensland, where emissions from fuels far exceed those of other states and territories.

In October 2022, the Hon Chris Bowen MP, Minister for Climate Change and Energy, signed the Global Methane Pledge which commits countries to reduce global methane emissions across all sectors by at least 30% below 2020 levels by 2030 (Australian Government, 2022). While this is positive news, it is challenging to see how this could possibly be achieved, given the above emissions trends from existing gas production, let alone with the enormous expansions being planned.

Australia is fast-tracking extensive plans to increase gas production, including the commencement of a major new shale gas export industry (Office of the Chief Economist, 2022). With 49 new gas initiatives and 69 new coal mines planned as of 2022, plus the accelerated development of the Beetaloo Basin in the Northern Territory (hailed as Australia's equivalent to the Marcellus Shale plan, the largest US Basin), it is hard to understand how major rises in emissions will be avoided. Estimates of carbon emissions from these 118 new initiatives have been estimated at 4.8 billion tons of greenhouse gases (CO_2-equivalents) by 2030 (Denniss, 2023). Suggestions that carbon capture and storage will be able to solve this problem are not consistent with research (Grubert and Sawyer, 2022).

Furthermore, these developments are operating without taking responsibility for Scope 3 emissions – that is, those that occur in the countries importing the product. Expanded

Figure 3.6: State and territory reported emissions of methane gas from fuel combustion and fugitive emissions from fuels in 2020



Source: https://greenhouseaccounts.climatechange.gov.au
NB some data was either not available or was confidnetial (eg ACT and TAS)
ET: External Territories

export volumes of methane to other countries, who are expected to account for the emissions resulting from this Australian product, appears to contravene the spirit of many articles of the Paris Agreement (United Nations Climate Change, n.d.), for example:

- Developed countries should take the lead by undertaking absolute economy-wide reduction targets [not only offsets] (Article 4);
- Parties should conserve and enhance as appropriate, sinks and reservoirs of greenhouse gases [for example, keep methane secure within shale and coal seams] (Article 5);
- Voluntary cooperation among Parties is encouraged to promote more ambitious targets, contribute to the mitigation of GHG emissions and support sustainable development (Article 6);
- Developed countries have obligations to support the efforts of developing country parties to build clean, climate-resilient futures, while encouraging voluntary contributions to other Parties (Articles 9, 10 and 11).

Summary

In summary, this Section has highlighted the difficult reality that all scientific assessments of our planet indicate that we are clearly living in the onset of a planetary health emergency of previously unseen proportions. We explored the current and perilous state of the Earth's climate, highlighting how the mining/extraction and combustion of coal, oil and gas have returned vast amounts of carbon previously stored safety underground and under ice by natural processes into the atmosphere and oceans. This has already had major consequences on the health of people and the environment we depend on, including extraordinary extremes experienced in the first seven months of 2023. The Sixth Intergovernmental Panel on Climate Change reports clearly warn us of the rapidly closing window to stop emitting greenhouse gases, especially CO_2 and methane from fossil fuels, to avoid catastrophic impacts that will be suffered by current and especially future generations.

We then demonstrated the particular importance of methane – the product of unconventional gas operations – in driving rapid global heating that requires immediate and effective attention. We presented multiple lines of research evidence which discredits the suggestion that gas is safer for the climate than coal. We observed, in Queensland in particular, how the rapid expansion of coal seam gas mining and liquefied natural gas production has increased both stationary energy (excluding electricity) and fugitive emissions since 2005. We ask, how in the world is our current government going to honour our Methane Pledge to reduce methane emissions by 30% given the additional burden of emissions from enormous oil and gas development projects in the planning pipeline.

Beyond the critically important Methane Pledge, we also highlight the crucial responsibility, accepted by Australia like all signatory nations to the Paris Agreement, to do better, not worse, in helping the world to achieve the necessary decarbonisation to avoid catastrophic consequences. Approving and progressing oil and gas developments on a scale unprecedented in Australia is unconscionable.

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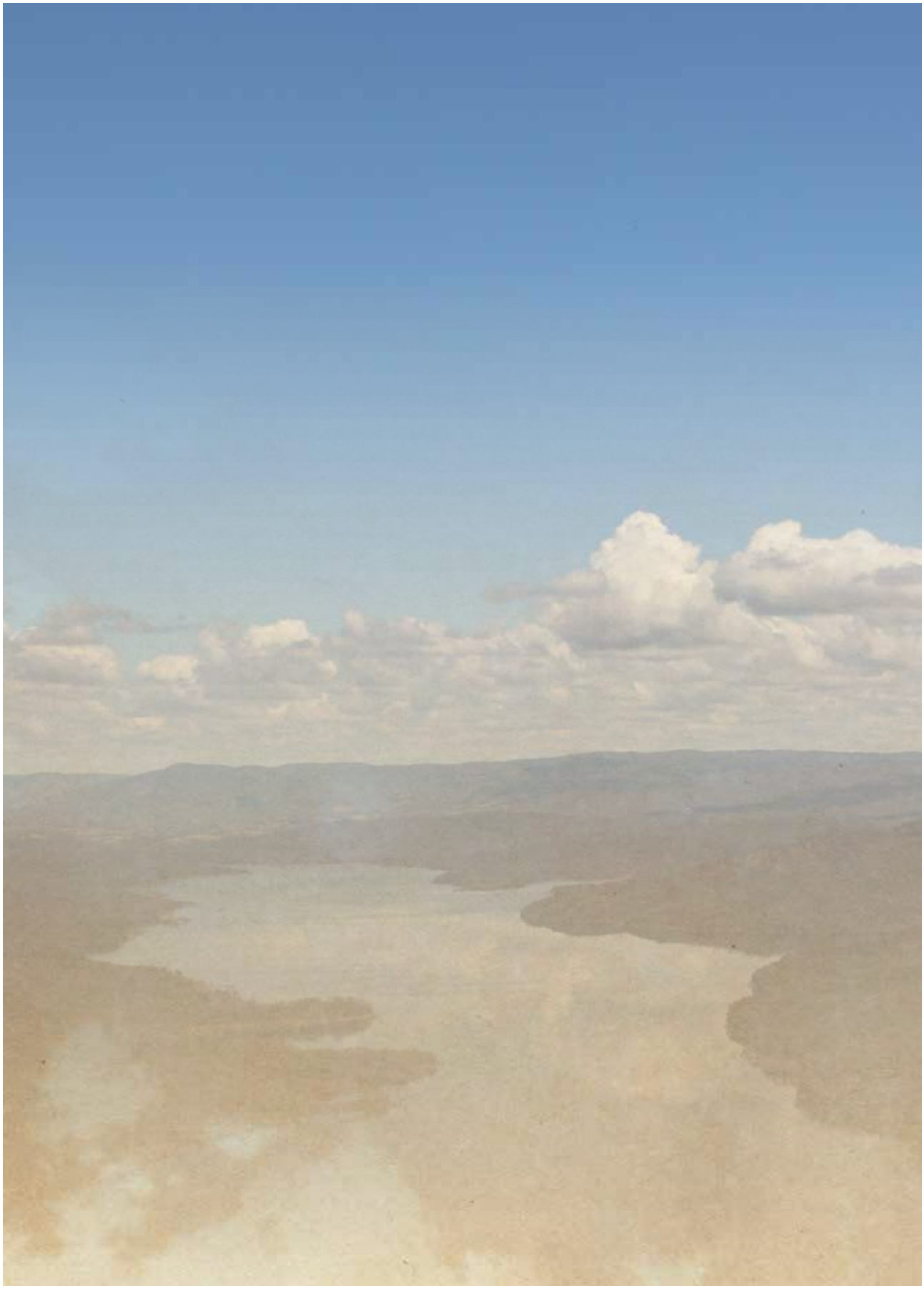


4. Water and air quality implications: Migration routes and chemicals of concern

This Section describes some of the key evidence to date of the many pathways of exposure and the many introduced and naturally occurring chemicals resulting from the unconventional gas industry that are known to be potentially harmful to humans and the environment. Section 3 provides examples of contamination incidents that have been reported in the United States so frequently that regulatory agencies and researchers have not been able to keep up with investigation of even the most significant events.

The evidence presented in this Section was extracted from a title and abstract scan of 527 publications identified through the comprehensive research database Scopus using key words 'unconventional gas' and 'health'. In addition, 204 peer reviewed publications (as of July 2023) examining flowback and produced wastewater, and 75 on chemicals and additives identified through the Repository of Oil and Gas Energy Research (ROGER), were title screened for their relevance to health and reviewed. From this search, over 50 papers were read, have been analysed and are cited in this section.

Potential exposure pathways

Research on, and assessment of, health concerns associated with unconventional gas mining have mainly focused on the wide range of chemical additives and materials that are required for the procedure. The role of the large number of naturally occurring chemicals that are mixed with added chemicals and brought to the surface within the large quantities of wastewater generated at the various stages is more complex and less understood, but even more relevant to the assessment of human health risks (Colborn et al., 2011; Elliot et al., 2017; Vidic et al., 2013; Maloney et al., 2017, 2018).

As discussed in Section 3, there is now greater awareness of the numerous pathways by which harmful chemicals, gases and salt can migrate into shallow aquifers and other drinking water supplies through leaking wells and subsurface flows. Spills, leaking wastewater from holding pond liners, flooding and overflow of ponds during heavy rain and other accidents and disposal of inadequately treated wastewater onto the ground or into creeks and other water bodies all threaten surface water and surrounding soil

… there is now greater awareness of the numerous pathways by which harmful chemicals, gases and salt can migrate into shallow aquifers and other drinking water supplies through leaking wells and subsurface flows

(Vengosh et al., 2014; Maloney et al., 2017; 2018; Carey et al., 2009; Rossi et al., 2023). The salinity of spilled fluids can dissolve toxic chemicals, such as uranium, within the soil and contaminate aquifers and surface waters, as was observed in Narrabri, NSW (Carey et al., 2009).

Maloney et al. (2017) examined 6422 reported spills across four states in the US from 2008 to 2014. They found that wastewater, crude oil, drilling waste, and hydraulic fracturing fluid were most often spilled in volumes ranging from 100 to 10,000 litres. More recently, Rossi et al. (2023) found widespread underreporting of the location of spills, lack of follow-up testing of groundwater for contamination and underestimation of spill volumes among 1029 produced water spill incidents in 2018–2020 in the official California database.

The deliberate practice of using untreated produced wastewater and sludge from oil and gas wells for maintenance and de-icing of roads and as a dust suppressant to reduce harmful particulate matter (PM10) exposure was legalised in 13 states in the USA. Recent research has demonstrated that wastewater is not only inferior as a dust suppressant (Stallworth et al., 2021), it raises many concerns about harm to the environment and human health. Tasker et al. (2018) identified radium, strontium, barium, inorganic salts and organic matter contaminants in oil and gas wastewaters applied to roads in Pennsylvania, where an estimated 130 million litres were applied annually from 2008 to 2014. They conclude that this deliberate practice released 200 times more of the known radioactive carcinogen radium into the environment than reported spills:

> *In Pennsylvania, we found that radioactivity associated with radium released to the environment via road spreading exceeds the radioactivity of radium released by spill events* [200 times more] *or wastewater treatment plants [four times more]. The spreading of O&G wastewaters on roads could be a significant contributor of inorganic and organic micropollutants to the environment and has been largely ignored in environmental studies on O&G development.*
>
> (Tasker et al., 2018, p 7089).

A growing number of studies provide evidence suggesting that pressure changes due to dewatering, multiple hydraulic fracturing and/or reinjection of fluids into wells and through natural and induced cracks in the strata can, and have, led to drinking water contamination, including from abandoned wells (Warner et al., 2012; Jackson et al., 2013; Kharak et al., 2013; Kassotis et al., 2014; Lefebvre, 2017; Stanish et al., 2021; Perra et al., 2022; Jellicoe et al., 2022; Warner et al., 2012). These studies add weight to concerns long expressed by geohydrologists and imply that even in the absence of errors and infrastructure failures, contamination of water can occur through the 'normal' or 'usual' processes of hydraulic fracturing and wastewater disposal and is therefore not preventable.

In Queensland, Navi et al. (2014) discussed similar possible contamination pathways into surface waters associated with the handling of vast quantities of coal seam gas wastewater, as well as in some practices currently in use for 'beneficial purposes', including irrigation of crops, livestock watering, dust suppression, aquaculture and a trial injection of treated coal seam gas water into drinking water aquifers. The authors raised potential concerns regarding salt accumulation, crop productivity, reduced permeability of soil, lower nutrient availability due to excess sodium and bioaccumulation of heavy metals, as well as additional concerns regarding the safety of farmers applying this water through inhalation of contaminated aerosols. They also questioned the use of coal seam gas water for cattle and for aquaculture, given the possibility of contaminants entering the meat or fish and being transferred to humans upon consumption.

Chemicals also reach the atmosphere from flaring (Figure 4.1), venting, holding tanks, ponds, compressor stations and other infrastructure. While initially most public health concern focused on risks to water, the US

Figure 4.1: Decommissioned coal seam gas well, Pilliga Forest

Credit: Lock the Gate Alliance

experience to date indicates that health risks associated with air pollution are at least as serious for human health as water contamination (Finkel and Hays, 2013; Brown et al., 2014). This includes gases, such as methane and co-occurring volatile organic compounds that escape through the gas extraction process and from faulty and leaky wells. Harmful airborne chemicals may escape directly from wells during production and volatilise (evaporate) from contaminated water into the air.

Residents living near gas wells and infrastructure and industry workers may be exposed to airborne pollutants directly, e.g. through diesel exhaust from extensive truck movements, drilling, compressors and other machinery used in the process, flaring and from gases from the coal seam or shale deposits released during well completion and other phases (Petron et al., 2012; Adgate et al., 2014; Field et al., 2014). Besides toxic gases directly emitted during these processes, it is important to recognise secondary atmospheric pollutants that form when two or more reactive chemicals come together in the atmosphere in the presence of sunlight and heat.

Humans can also be exposed when airborne chemicals return through rainfall on waterways and livestock pastures to contaminate soil and bodies of water and potentially be transferred to livestock and fish.

Wastewater from both coal seams and shale strata is mildly to extremely saline. Treatment by reverse osmosis or other disposal methods produces enormous quantities of salt, creating a serious environmental hazard for both ecologically significant areas and agricultural regions through impacts on soil fertility (Khan and Kordek, 2014; Davies et al., 2015). Saline leakage from water handling processes can also mobilise naturally occurring chemicals in soil, such as arsenic and uranium, transporting them into groundwater aquifers. One such incident caused by a leak in a wastewater holding pond liner in Pilliga Forest CSG operations has been reported (Carey et al., 2014).

A significant occupational health concern for unconventional oil and gas workers is excessive exposure to silica – large quantities of 'frac sand' required for hydraulic fracturing (OSHA, 2012; Esswein et al., 2013). Mining of this sand

also causes substantial ecological damage. An extensive study of the effects of inhaling hydraulic fracturing sand dust suggested that while the pulmonary effects may be less severe than those of crystalline silica, the frac sand was more toxic to other organ systems besides the lungs (Investigative Team, 2020).

In Australia, gas companies are expected to abide by the *Environment Protection and Biodiversity Conservation Act 1999*, as well as state and national regulations and Codes of Practice in the handling and transport of dangerous goods. They are also expected to have emergency preparedness plans and reporting procedures in place in the event of an accident or leak. Section 2 examines some of the limitations of these regulations.

Chemicals of concern in hydraulic fracturing fluids and wastewater from shale oil and gas extraction

Hundreds of chemicals of concern are purposely added to or occur naturally in water that has been in contact with gas-containing material (that is, shale, coal or granite) for millions of years underground (Colborn et al., 2011; Elliot et al., 2017; Vidic et al., 2013; Davies et al., 2015). Shale gas chemicals have been most intensely studied. Findings are presented from some of the key research examining the presence of these chemicals and their potential effects on exposed humans, including neurological and neurodevelopmental harms, harms to the reproductive and other organ systems, radioactivity and carcinogenicity and endocrine disruption.

Naturally occurring chemicals, chemicals in drilling muds and those emitted from machinery and diesel combustion engines pose a risk in gas extraction without hydraulic fracturing (conventional gas extraction). Unconventional gas extraction carries these risks, plus the many additional chemicals specifically used in the hydraulic fracturing procedure. These include surfactants, acids, bactericides, glycol and many substances not revealed under "commercial in confidence" agreements.

A systematic review by Antial et al. (2022) identified potential hazardous chemicals in drilling muds, lubricants, additives, drill cuttings and naturally occurring chemicals in vast quantities of wastewater. The 109 reviewed papers showed evidence of the presence of heavy metals such as cadmium, chromium, arsenic and lead, as well as toxic elements such as barium, radium and strontium in the wastewater. Furthermore, volatile organic compounds (VOCs) such as benzene, toluene, ethylene and xylene, and poly-aromatic hydrocarbons were frequently present. These chemicals can have multiple health effects, including birth defects, cancer, cardiovascular and respiratory disease. The authors recommended handling these materials with extreme caution.

Elliott et al. (2017b) examined the carcinogenicity data on a total of 1177 chemicals in fracking fluids and wastewater (US EPA) and 143 chemicals identified in scientific papers published before 2016 on air pollutants. They found that over 80% of these chemicals had not been evaluated for carcinogenicity. The 119 chemicals that had been evaluated included 49 water and 20 air pollutants that were possible, probable or known carcinogens, and 20 that were associated with leukemia/lymphoma, including benzene, 1,3 butadiene, cadmium, diesel exhaust and polyaromatic hydrocarbons (PAHs).

A systematic assessment of the carcinogenicity of 1,173 chemicals present in hydraulic fracturing fluid alone (1,039), wastewater alone (97) or both (37) was performed by Xu et al. (2019). Information was not available for 989 (84.3%) of the chemicals in two prominent databases. Only 104 had been evaluated by the International Agency for Research on

Cancer, and 48 were found to be definitely (14), probably (7), or possibly (27) carcinogenic. The Carcinogenic Potency Database identified 66 that were potentially carcinogenic in animal models. The authors concluded that exposure to these chemicals, especially in flowback water, may increase cancer risk.

PAHs, heavy metals, naturally-occurring radioactive materials (NORMs) and a wide array of known and unknown chemicals used in drilling and hydraulic fracturing fluid have the potential to damage the health of workers and community residents who may be exposed through contact with water that has been contaminated during the handling of the large quantities of chemicals and wastewater involved (Esswein et al., 2014). Radioactive materials, such as uranium, thorium, radium and their decay products, can be found in unconventional gas wastewater and are concentrated and brought to the surface during extraction and waste disposal (US EPA, 2018). If these technologically enhanced naturally occurring radioactive materials, or TENORMS, are present at sufficient levels, workers and nearby residents may be at risk of exposure through air and water (Esswein et al., 2014; Geltman and LeClair, 2018; US Environmental Protection Agency, 2023).

Volatile organic compounds, including BTEX (benzene, toluene, ethylene and xylene), which occur naturally in shale, can contaminate groundwater and enter the atmosphere from the flowback wastewater after fracking and during flaring of excess gas. Benzene contamination of groundwater was a frequent consequence of 77 surface spills that were reported in a 12-month period in a Colorado county with intense shale gas mining activity (Gross et al., 2013).

Elliott et al. (2017a) looked at the reproductive and developmental toxicity of 1021 chemicals identified in fracturing fluid, wastewater or both. Information on toxicity was lacking for 781 (76%). Among the 240 that had been evaluated, 103 were known to have the potential for reproductive toxicity and 95 for developmental

Volatile organic compounds, including BTEX which occur naturally in shale, can contaminate groundwater and enter the atmosphere from the flowback wastewater after fracking and during flaring of excess gas.

toxicity. Webb et al. (2018) reported numerous neurodevelopmental and neurological effects of many chemicals associated with gas operations, focussing particularly on risks to children. Some of these developmental impacts are likely to be mediated by endocrine disrupting chemicals.

Evidence of endocrine-disrupting activity in surface and groundwater in areas with unconventional gas mining raises significant concern (Kassotis et al., 2014; 2016a; 2016b; 2016c; 2018a; 2018b; 2019a; 2019b; 2020; He et al.; 2018) because these chemicals can interfere with endocrine function at very low concentrations, sometimes without overt signs or symptoms. Because of their complexity and the lack of fundamental understanding in Australia, these chemicals are discussed in further depth on pages 42–46.

To our knowledge, independent research on the safety of chemicals that would be used in proposed new shale gas exploration and production in Western Australia, South Australia and the Northern Territory is lacking, with no peer-reviewed publications available. By contrast, American researchers have published at least 75 peer-reviewed papers on chemicals/additives applied in gas extraction, many of which raise concerns about their potential health impacts (Repository for Oil and Gas Energy Research, 9 July 2023).

In an August 2018 stakeholder update, the Australian Industrial Chemicals Introduction Scheme, formally the National Industrial Chemicals Notification and Assessment Scheme (NICNAS), announced its intention to invite CSG companies to:

> *apply to protect a chemical's identity as confidential business information (CBI). If approved, we [NICNAS] will mask its identity by using a generic chemical name. These will be known as AICIS approved chemical names (AACNs) once the reforms come into effect.*

It is not clear how constituents used for shale gas operations protected under 'trade secret' legislation in the United States might be handled in Australia. Most importantly it remains unclear how this may impact access by medical practitioners to information needed for medical treatment of patients who may have been exposed to those chemicals through operations in Australia. It is also unclear how the many new chemicals that may be used in shale gas extraction will be assessed, especially if there is no information from the United States on those used and brought to surface in wastewater.

Chemicals used and produced in coal seam gas extraction in Australia

As most of the research on chemicals has examined shale gas production, fewer studies have characterised constituents of wastewater produced during gas extraction from coal seams, the predominant unconventional gas extraction method in Australia to date (Khan and Kordek, 2014). Untreated produced water contains high levels of sodium and bicarbonate, often with suspended solids, iron, silica and barium (Khan and Kordek, 2014). Heavy metals, boron, fluoride, organic compounds and ammonia may also be present (Volk et al., 2011).

The most significant work thus far on coal seam gas (CSG) has been done by NICNAS and the Commonwealth Science and Industrial Research Organisation (CSIRO), with fourteen

NICNAS and CSIRO found that 44 of the 113 chemicals examined were potentially harmful to workers in the event of exposure during an industrial accident.

reports on the risks to human health and environment of exposures to 113 chemicals used in drilling and hydraulic fracturing for CSG in Australia (NICNAS and CSIRO, n.d.). NICNAS and CSIRO (n.d.) found that 44 of the 113 chemicals examined were potentially harmful to workers in the event of exposure during an industrial accident. Twelve were found to have the potential to harm workers during mixing and dilution of highly concentrated chemicals if adequate protection methods were not used. With regard to public health, NICNAS identified 40 chemicals used in CSG mining that had the potential to harm the community should people become exposed by swimming in or drinking water contaminated by spills during transport or leakage from wastewater ponds.

CSIRO also commissioned laboratory-based leaching experiments using samples from various sources of coal exposed to conditions roughly simulating those of hydraulic fracturing (Apte et al., 2017). Findings for a range of potentially hazardous metals, radioactive materials and organic compounding existing in the coal leachate were then compared where possible with existing water quality benchmarks for aquatic ecosystems and stock watering systems used in Australia. The authors highlighted the following inorganic chemicals released from the coal samples out of a total of 60 identified as priorities for further investigation: aluminium, arsenic, beryllium, boron, cadmium, chromium, cobalt, copper, gallium, lead, manganese, nickel, selenium, silver, thallium, uranium, vanadium and zinc. The organic coal contaminants retrieved included phenols, cresols and low molecular weight total recoverable hydrocarbons. An additional

14 organic chemicals, including alkanes, alcohols, aldehydes and polycyclic aromatic hydrocarbons, were also present, but their origin was unclear (Apte et al., 2017).

Concentrations of radionuclides, namely radium, thorium and uranium, were deemed below concern. However, the authors pointed out that these materials could become concentrated during certain procedures, such as getting trapped in crust formations in pipework, on filters and on reverse osmosis membranes used in water treatment (Apte et al., 2017).

Concentrations of many additional chemicals found in the coal leachate, such as barium, could not be assessed due to a lack of available guidelines or regulations for drinking water or aquatic water systems (Apte et al., 2017). The authors called for additional research to extend these findings to actual hydraulic fracturing activities within CSG mining.

It is important to acknowledge the limitations of this work. For example, only chemical additives (not naturally occurring chemicals present in wastewater) used in CSG mining (not including additives used in shale and tight gas mining) that were identified voluntarily by the industry (not mandated disclosure) were studied. Furthermore, the assessment focused solely on the (surface) above-ground handling of the chemicals, limiting information on other environmentally mediated exposures to workers and communities.

Navi et al. (2014) identified a wide range of potentially hazardous naturally occurring substances in water drawn from coal seams that have been reported in the global literature, including salts, barium, fluoride, boron, arsenic, lead, cadmium, chromium and organic compounds including phenols, biphenyls and PAHs. Many of these compounds have been reported in CSG water withdrawn in Queensland, in some cases in substantially higher concentrations than Australian Drinking Water guidelines.

Air emissions with potential direct health impacts

Human exposure to air pollutants is difficult to measure for a number of reasons: monitoring methods and stations are often not designed for or located in places suited for the most accurate capture of the human exposure; the dispersal of pollutants is affected by wind and weather conditions; there are extreme fluctuations of released pollutants over time related to industry activities; there are differences in housing quality that promote or impede the intrusion of ambient air pollution; and human activities, such as children playing and adults exercising outdoors, have varying impacts on the inhalation rate and depth of breathing (Brown et al., 2014).

Nevertheless, harmful chemicals in air are as concerning as those in contaminated water as a source of potential harm to communities near gas and oil operations These exposures come from drilling operations and diesel-powered machinery and trucks as well as from wastewater handling, especially when the wastewater is stored in open air ponds and holding tanks.

For detailed analysis, readers may consult the extensive review of hazardous air pollutants associated with oil and gas development done by Garcia-Gonzales et al. (2019). Their review identified stage-specific pollutants that had been reported in the literature and underlined the importance of the production phase, as opposed to the hydraulic fracturing stage as expected, in contributing to air pollution. This is because of its long duration, the larger number of pollutants and the occurrence of episodes of very high emissions. The review named BTEX chemicals, formaldehydes and acetaldehyde, hydrogen sulfide and acrolein as the chemicals likely to be of greatest concern in airborne emissions (Garcia-Gonzales et al., 2019).

Other research on air pollution linked to gas extraction has examined volatile organic

compounds (like benzene), polyaromatic hydrocarbons, heavy metals, radioactive materials, fine particulate matter (PM2.5), endocrine disrupting chemicals and secondary organic aerosols and ground level (trophospheric) ozone (Lloyd-Smith & Senjen 2011; Fann et al., 2018; Helmig, 2020, Li et al., 2020). These chemicals can affect the respiratory, endocrine, nervous and cardiovascular systems and some, notably benzene and radioactive chemicals, can cause cancer (Colborn et al., 2011; ATSDR 2007; McKenzie et al., 2012).

The combination of chemicals in the produced wastewater (flowback) that become volatile varies according to the fracking fluid additives used and those naturally occurring in the coal seam or shale. Details of chemicals present in these fluids may not be known or are difficult to access from companies. Many have not been assessed for toxicity to humans or the environment (Colborn et al., 2011; McCarron & King 2014).

Pollack and colleagues (2021) found that oil and gas operations contributed significantly to benzene, ethane and hexane levels, with concentrations in production regions often far exceeding those in major urban areas.

A study by Li et al. (2020) added weight to concerns about radioactive particles emitted during unconventional, but not conventional, gas mining, with raised concentrations of airborne radioactive particles detected as far as 20 km downwind of operations. These particles have been linked to increased blood pressure and inflammatory markers and decreased lung function.

Diesel engines and trucks carrying chemicals and waste emit particulate matter, nitrogen oxides, diesel fumes and volatile organic compounds, many of which are known or suspected carcinogens.

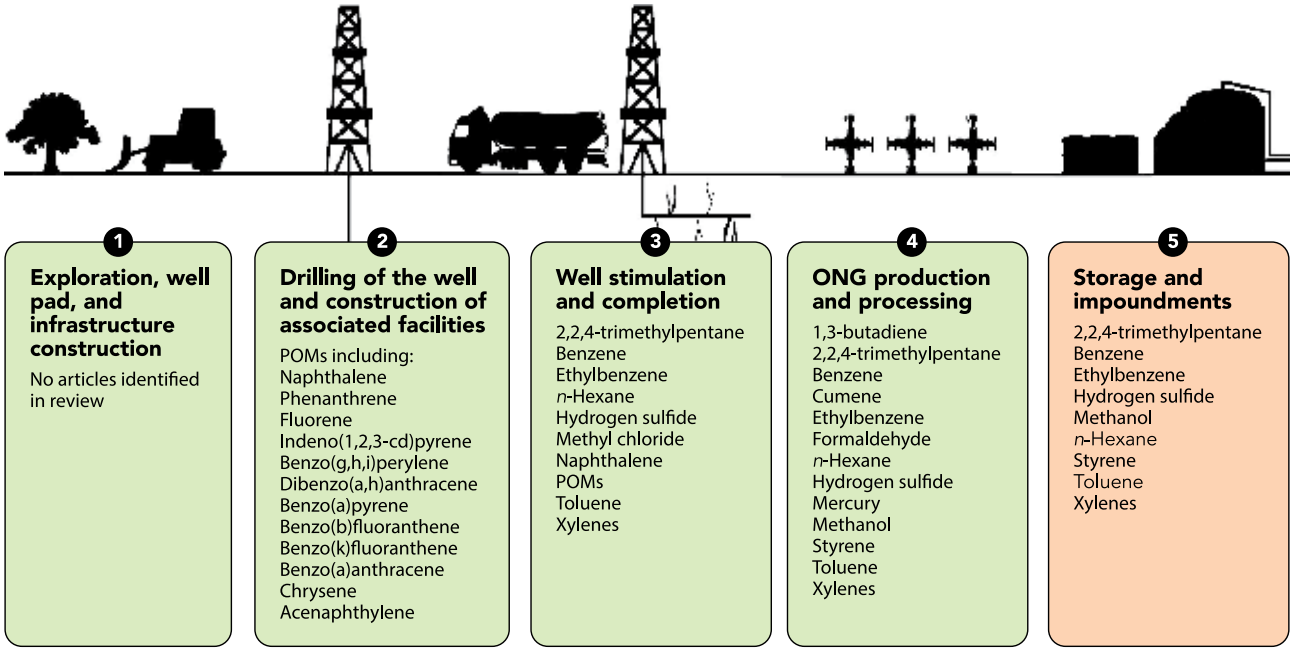
Chemicals of particular concern: Endocrine disrupting chemicals in air and water

As described above, there are many opportunities for harmful chemicals to move from the extraction site to the surrounding environment through air and water. The wide array of endocrine disrupting chemicals (EDCs) and the amount of EDC activity that reaches the environment deserve much more attention than they have yet received in Australia. Despite the rapidly growing literature in the United States on these chemicals, as well as recent experiences across Australia with one family of EDCs, namely PFAS, they have rarely even been mentioned in risk assessments and documents guiding decision-making on gas production expansion in the country, and few Australians understand the threat of these chemicals to human health.

The endocrine system, together with the nervous system, regulates and coordinates communication between cells, organs and systems. This extremely important and delicate role in human bodily function is achieved through the secretion of a complex array of hormones. Hormones direct the development, reproductive functions, metabolism and normal functioning of the body.

EDCs are defined as individual or mixtures of chemicals that can interfere with any aspect of the ways in which hormones – these major messengers produced by the endocrine system – act in the body (Di Pietro et al., 2023). They act by interfering with the attachment of hormones to receptors on cells, by blocking the signals that hormones stimulate within cells for normal functioning, by interfering with signals for cells to stop growing and/or by preventing the production, breakdown or movement of hormones around the body (Di Pietro et al., 2023). Furthermore, and particularly worryingly, EDCs can also alter the

Figure 4.2: Hazardous air pollutant (HAP) compounds collected through primary measurements and recategorized. Abbreviations: ONG, oil and natural gas; POMs, polycyclic organic matter



Source: Garcia-Gonzales et al., 2019

folding of DNA, preventing the expression of genes and the production of required proteins at the right time. This means that some of the damage caused by EDCs before or soon after birth (ie damage to the foetus from the mother's bloodstream or when breast feeding) can be expressed in adult life and transmitted to the next generation without further exposure (Nagel et al., 2020).

By interfering with hormones, EDCs have the capacity to cause a wide array of health and developmental problems. While this field of research is in its infancy, studies have already linked exposure to EDCs to numerous serious health disorders (discussed below).

Three further characteristics of EDCs make them especially relevant in recognising the risk of environmental contamination and hence human exposure:

- EDCs can have profound impacts on health at very low concentrations – much lower than some other types of toxic chemicals;
- EDCs are rarely tested for, as the testing is costly and highly technical, often requiring sophisticated assays; and
- EDCs are highly persistent in the environment and are often called "Forever Chemicals" because once present, they remain as a continuing source of harm.

Finally, strategies to prevent contamination and to reduce the risk of exposure are difficult to implement, because highly specialized research is required to link impacts of EDCs to their source.

However, there is now evidence that emissions from oil and gas mining operations have a real potential to expose humans, livestock and wildlife to a wide range of chemicals with endocrine disrupting activity through contamination of both air and water. Balise et al. (2016) reviewed 45 peer-reviewed publications that examine links between conventional gas extraction processes and the presence and potential impacts of endocrine-disrupting activity. They found moderate

evidence of an increased risk of preterm birth, miscarriage, birth defects, decreased semen quality, and prostate cancer that could result from disruption of the oestrogen, androgen, and progesterone receptors by chemicals associated with (mostly conventional) oil and gas production. The researchers postulated that unconventional gas mining likely poses more potential risks to reproductive health than conventional gas operations given the many endocrine-disrupting chemicals involved in the hydraulic fracturing process. Bolden and colleagues (2018) reviewed 48 air quality studies associated with shale gas production and identified 106 chemicals with endocrine disruption potential, including estrogenic and androgenic activity and alteration of steroid formation.

Multiple studies by Kassotis and colleagues (2014; 2016a; 2016b; 2016c; 2018a; 2018b; 2019a; 2019b; 2020; He et al., 2018) have revealed the presence (by chemical analysis) and bioactivity (ie activity tested on living cell cultures) of wastewater and in ground and surface water in areas with moderate and high drilling activity. The quantities detected are known to be capable of causing harm to aquatic organisms. Further effects of early life exposure to these chemicals found in experimental models have included interference with mammary gland development (Sapoukey et al., 2018), reproductive function (Balise et al., 2019), immune system functioning and anti-viral immune responses (Boule et al., 2018; Robert et al., 2019).

A very recent study by Breitmeyer et al. (2023) examined potential sources of 33 per- and poly-fluorinated alkyl substances (PFAS), a well-known family of endocrine disrupting chemicals, in surface waters in Pennsylvania. PFAS chemicals are thought to be highly disruptive at very low exposure levels and very persistent, and they are now widespread in human beings globally from many sources. They are the target of substantial and expensive clean-up operations across the USA and in Australia at airports and military installations. Breitmeyer et al. (2023) found elevated levels of PFAS (8.42 ng/s/km^2) in surface water associated with combined sewage outflows (mixed municipal sewage and oil and gas wastewater) in the seven sites sampled in areas with a high density of oil and gas wells (median 1548 wells, compared to a median of 10 wells across the whole sample). The authors noted that PFAS chemicals are effective in enhancing the recovery of petroleum hydrocarbons (oil), and thus petroleum recovery operations may have been a source of the PFAS found in the combined sewage outflows into surrounding streams.

Although there is no expectation that PFAS would be used in Australian shale gas production, there are many endocrine disrupting chemicals of concern that are likely to be in the gas wastewater produced that may pose risks to people, livestock and ecological systems in future developments. In contrast to the significant body of literature summarised above on shale gas, we are aware of only one study exploring endocrine disruption activity associated with gas operations in Australia, and very little is known about EDC activities in coal seam gas wastewater (Bain and Kumar, 2018).

Ground level ozone impacts on regional health

The toxic air pollutant ground level ozone is not directly emitted from oil and gas mining operations, but forms from mixtures of pollutants emitted during unconventional gas operations, especially in the presence of sunlight and heat. While some other chemicals, such as volatile organic compounds, remain relatively localised, ground level ozone and fine particulate matter travel large distances and can harm wildlife, agriculture (livestock and plant production) and people in affected regions. The damage caused by ozone to the agricultural industry, and therefore food security, has long been recognised and scientifically modelled (Adams

et al., 1989). New methods for examining the impacts of rising ozone levels simultaneously with rising CO_2 concentrations are improving the prediction of combined damage to crop yields (Tai et al., 2021).

Helmig et al. (2020) conducted an extensive analysis of air quality data in relation to oil and natural gas operations in Colorado. They synthesised evidence from 50 studies demonstrating that oil and gas operations contribute significantly to levels of volatile organic compounds (VOCs) and ozone production in the atmosphere forming from VOCs, methane and particulate matter. Ozone, unlike VOCs, is transported in the atmosphere away from the site of gas extraction operations; daytime peak ozone levels were often found to be tens of kilometres away. Given the significant harms associated with unsafe levels of ozone, the authors concluded that:

> *These downwind air quality impacts from O&NG industries should be a strong consideration in the design of monitoring networks and decision-making on regulating existing and new O&NG development in the region.*
>
> (Helmig et al., 2020, p. 25).

The study also found that levels of ozone pollution from oil and gas operations were sufficiently high to significantly damage ecosystems and agricultural productivity in the region and argued that these losses should be quantified and farmers compensated accordingly (Helmig et al., 2020). Globally, economic damage to staple crops due to ozone is estimated at US$14–26 billion per year; hence efforts to lower ozone formation by reducing methane and nitrogen oxide emissions is also an urgent food security challenge (Emberson, 2020).

An in-depth study by Pozzer et al. (2020) examined the specific contribution of oil and gas operations to summer and winter ozone levels, the number of days exceeding safe ozone levels, and the estimated number of excess premature deaths due to exposure across the United States. The authors estimated that the ozone footprint from oil and gas operations is likely to have caused 320 (95% CI 298–344) excess premature deaths per year in the United States (Pozzer et al., 2020). Adding similar estimates of premature deaths linked to fine particulate matter emitted from oil and gas operations (Fann et al., 2018) indicates the industry causes over 600 premature deaths per year.

Finally, Francoeur et al. (2021) used an improved fuel-based oil and gas industry technique to demonstrate that emissions of methane, non-methane volatile organic compounds and oxides of nitrogen from oil and gas basins are two to three times higher than previous estimates. These chemicals are precursors of both ground level ozone and formaldehyde.

As described in Section 5.1, Buonocore et al. (2023) more fully modelled the likely health impacts and health costs of air pollutants associated with oil and gas operations in the United States. This work estimated that three main pollutants, nitrogen oxides, ground level ozone and PM2.5, resulted in 410 000 asthma exacerbations, 2200 new cases of childhood asthma and 7500 excess deaths in the year 2016. Associated health costs were estimated at US$77 billion. The industry has since expanded significantly, likely further increasing the annual costs to people and the economy.

… three main pollutants, nitrogen oxides, ground level ozone and PM2.5, resulted in [approximately] 410 000 asthma exacerbations, 2200 new cases of childhood asthma and 7500 excess deaths in the year 2016. Associated health costs were estimated at US$77 billion.

This work clarifies once again the substantial, underestimated contribution of natural gas production (from fugitive methane released and from the formation of ozone; both are very potent greenhouse gases) to the seemingly relentless progression of global warming as well as to human disease and death in the United States.

Summary

This Section has reviewed research that has been undertaken to understand the very large number and cumulative quantities of both introduced and naturally occurring harmful chemicals involved in unconventional gas production, transportation and processing. We present evidence indicating the many ways that these chemicals can and have entered into the broader environment via air and water through both accidental and deliberate actions and potentially through underground migration processes stimulated by oil and gas operations. The combination of some of these chemicals and their resulting by-products can also accumulate and persistent indefinitely in the environment or be taken up and concentrated by plants and animals and ultimately enter the food chain, as discussed in Section 2.

We also described studies which have identified that these complex mixtures can include many chemicals that:

- **have the potential to cause cancer (carcinogens);**
- **directly damage tissue and organs in the body;**
- **interfere with the reproductive system;**
- **interfere with normal human development, including those capable of causing birth defects and impairing neurodevelopment (teratogens and neurodevelopmental toxins); and**
- **may interfere with metabolism through disruption of the endocrine system (endocrine disrupting chemicals).**

Particularly concerning among these chemicals is ground level ozone, which is formed in the atmosphere from chemicals released during gas production activities and, together with fine particulate matter (PM2.5), travels long distances, putting regional human health, agricultural production and wildlife health at risk. Ozone damages the respiratory system and is also a highly potent greenhouse gas.

Also concerning is evidence of endocrine disrupting chemicals found in wastewater and in ground and surface waters associated with unconventional oil and gas drilling activity. These are harmful to both human and aquatic organisations. Due to the extremely low concentrations required to cause significant health impairments, there is an urgent need to protect both people and the environment from any exposure to these chemicals.

If exposed, foetuses (through their pregnant mother's bloodstream), infants (through inhalation, drinking and through their mother's breastmilk), children, elderly people and people with chronic illnesses are often the most at risk of harm from these chemicals. The reasons for this vulnerability are complex and include increased exposure due to age-specific behaviours, sensitivity associated with developmental stages especially in utero and the additional stress put on already impaired organs and systems due to age or disease.

Section 5 presents evidence from research that has examined the potential risks and impacts on human health and wellbeing that have been associated with oil and gas developments.

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5. Effects on health and wellbeing: Physical, social, emotional, cultural and spiritual

This section examines the existing evidence of direct impacts of oil and gas production operations on people across four key areas of health and wellbeing:

- **5.1 Physical health risks and impacts on adults and children;**
- **5.2 Social and emotional impacts on individuals, families and communities;**
- **5.3 Additional concerns and losses faced by Aboriginal people;**
- **5.4 Risk of sexual violence, especially against women and children in remote areas.**

Sections 5.1 and 5.2 are consolidated evidence from the now large body of peer-reviewed publications; Sections 5.3 and 5.4, by necessity, also include some "grey" literature from major government inquiries and other reputable sources. Very few peer-reviewed studies or formal research has been done in the latter two areas, and much more is needed to arrive at a comprehensive understanding of the specific risks and impacts on the safety, wellbeing and spiritual health of Aboriginal people associated with unconventional gas and oil developments. Evidence to date indicates that it would be severe.

5.1 Health risks and impacts associated with the unconventional gas industry

The research evidence presented so far paints a clear picture of multiple potential risks and measurable outcomes of exposure to complex mixtures of air- and water-borne chemicals that accompany unconventional gas operations. Before turning to the influence of social, emotional, cultural and spiritual factors, we describe here in more detail the evidence linking unconventional gas developments to symptoms, illnesses, hospitalisations, interference with foetal development and deaths across many regions in the United States with diverse geological, chemical and regulatory conditions. Where available, peer reviewed health studies associated with coal seam gas developments in Australia are included, but these are significantly limited to date.

Methodology notes

This is a comprehensive review, not a systematic review, of relevant publications with an inclusive scope. It builds upon the continuous monitoring and communication of the literature on health and wellbeing risks associated with oil and gas developments since 2011 by authors Haswell and Shearman. The papers for this Section include previous publications accessed frequently over 12 years. Added to this are papers identified from the database Scopus using terms

*unconventional gas AND *health as well as those obtained from the Repository of Oil and Gas Energy Research (Physicians, Scientists and Engineers for Healthy Energy) over the period 2019 to 2023. Snowballing of reference lists within papers was also conducted to gain more specific understanding of information raised in the text of the publications.

The methodologies leading to each individual studies' findings are not reported to increase ease of understanding among non-specialists. However, as with most highly complex topics in environmental epidemiology, there has been a steady increase in the rigour and sensitivity of studies that has continuously built upon previous studies, reinforcing the finding of a wide array of negative impacts on health and wellbeing. Further discussion about the strengths and limitations of the body of work is provided in Section 6.

Studies assessing health risks and impacts

A large number of studies have now reported health effects among children and adults living in proximity to oil and gas operations that may result from both chemical exposures and chronic distress. These include (see Table 5.1 pp 56–59 for further detail):

- Symptoms and markers of disease: migraine headaches, chronic nasal and sinus irritation, fatigue, nausea, skin rashes, eye irritation, nosebleeds, asthma exacerbation requiring medication changes and cardiovascular disease indicators (McCarron, 2013; Rabinowicz et al., 2015, Rasmussen et al., 2016; Tustin et al., 2017, McKenzie et al., 2019; Blinn et al., 2020; Weisner et al., 2023).
- Higher hospitalisation rates among adults for heart disease, including heart attacks and heart failure; for respiratory and neurological disorders; for those with existing asthma conditions (emergency department visits, inpatient stays); and for some childhood cancers and immune deficiency disorders (Rasmussen et al., 2016; Jemielita et al., 2015; Werner et al., 2017; Whitworth et al., 2018; McCarron, 2018; McKenzie et al., 2017; McAlexander et al., 2020; Blinn et al., 2020; Denham et al., 2021; Blundell and Kokoza, 2022; Buonocore et al., 2023).
- Asthma exacerbations and hospitalisations among children (Willis et al., 2018; 2020; Bushong et al., 2020; Buonocore et al., 2023).
- Increased deaths and reduced life expectancy from cardiovascular and respiratory diseases and some cancers (Denham et al., 2021) and from all causes (Apergis et al., 2021; Li et al., 2022; Buonocore et al., 2023).
- More frequent traffic and pedestrian injuries and fatalities (Retzer et al., 2013; Graham et al., 2015; Blair et al 2018; Xu and Xu, 2020).

The following findings relating to psychological and social stressors are discussed in Section 5.3:

- Higher incidence of mental health conditions: depression and anxiety (Casey et al., 2016; 2018; 2019; Akers et al., 2022) and new onset of internalising disorders (anxiety, depression, social withdrawal, fatigue) among adolescent females seeking treatment in Pennsylvania (Gorski-Steiner et al., 2022).
- Increased incidence of sexually transmitted infections such as chlamydia and gonorrhoea, resulting from changes in sexual behaviour that can be associated with an influx of mobile workers in depressed areas (Mabey and Mayaud, 1997; Komarek and Cseh, 2017; Deziel et al., 2018).

Some examples of each health outcome investigated are briefly described to facilitate understanding of the nature of this complex research.

Symptoms linked to potential chemical exposures

Many studies have linked closeness to gas extraction operations with self-assessed symptoms at the community level. For example, Rabinowitz et al. (2015) found significantly higher prevalence of self-reported respiratory (39% vs 18%) and skin (19% vs 3%) conditions among people living within 1 km of shale gas wells in Pennsylvania compared to those living more than 2 km away. People living near unconventional gas wells worldwide, including near coal seam gas wells in the community of Tara in the Darling Downs of Queensland, have reported similar symptoms, as well as headaches, nosebleeds, numbness and tingling sensations (McCarron 2013; McCarron and King, 2014).

Weisner et al. (2023) examined a Colorado county where extensive gas production rapidly commenced following the development of a large, multi-well unconventional oil and gas site. The county adopted a variety of best practice management policies to try to mitigate negative environmental impacts on the relatively wealthy and healthy population. Despite these interventions, such as closed loop feedback systems designed to reduce emissions of volatile organic compounds, extensive air quality monitoring detected frequent significant emissions of these chemicals during pre-production operations (Weisner et al., 2023). Sound barriers were also found to be ineffective at reducing noise levels. A survey of nearly 4000 households in the area identified higher frequencies of upper respiratory, lower respiratory, gastrointestinal and acute symptoms among respondents living within 1.6 km of the extraction site compared to respondents living more than 2 miles away. Frequent symptoms included nosebleeds, nausea, vomiting and shortness of breath, consistent with known responses to exposure to volatile organic compounds.

Studies assessing health risks and impacts

Symptoms and markers of disease: migraine headaches, chronic nasal and sinus irritation, fatigue, nausea, skin rashes, eye irritation, nosebleeds, and asthma worsening requiring medication changes and cardiovascular disease indicators

Hospitalisations for heart disease including acute heart attacks and heart failure, respiratory and neurological disorders and for those with existing asthma conditions (emergency department visits, inpatient stays) and for some cancers and immune related diseases

Asthma exacerbation and hospitalisations among children

Increased deaths and reduced life expectancy from cancers, cardiovascular and respiratory disease and all causes

More frequent traffic and pedestrian injuries and fatalities

Mental health conditions: depression and anxiety and new onset of internalising disorders (anxiety, depression, social withdrawal, fatigue) among adolescent females

Sexually transmitted infections increased incidence rates of chlamydia and gonorrhoea infections which are associated with changes in sexual behaviour that can be associated with mobile workers coming in to depressed areas

Table 5.1 Cardiovascular, cardiovascular and respiratory (combined) and respiratory health effects

Author and Illness Studied	Location and Year	Methodology	Sampling Size and Age Range	Main Findings and Health Outcomes	
Denham, Willis, Croft, Liu, & Hill, 2021 Acute myocardial infarction (AMI)	2005 to 2014 Pennsylvania and New York counties that overlay the Marcellus Shale	Observational longitudinal study: analysing the relationship between age- and sex-specific county-level acute myocardial infarction (AMI) hospitalization and mortality rates and three unconventional natural gas development drilling measures.	N = 2840 county-year-quarters 45+ years	Cumulative unconventional natural gas development is associated with increased AMI hospitalization rates among middle-aged men, older men and older women as well as with increased AMI mortality among middle-aged men. Heart attack hospitalizations increased 1.4–2.8%, depending on age and sex. Heart attack mortality increased 5.4% in middle-aged men.	CARDIOVASCULAR
McAlexander et al., 2020 Heart failure	2008 to 2015 Pennsylvania	Case-control study: evaluating associations between unconventional natural gas development activity and hospitalization among heart failure (HF) patients, stratified by both ejection fraction (EF) status (reduced [HFrEF], preserved [HFpEF], not classifiable) and HF severity.	9,054 (5,839 cases and 3,215 controls) mean age 71.1 ± 12.7 years	Three of 4 phases of UNGD activity were associated with increased hospitalization for heart failure in a large sample of patients with HF in an area of active UNGD, with similar findings by HFrEF versus HFpEF status. Older patients with HF seem particularly vulnerable to adverse health impacts from UNGD activity. Associations of most UNGD metrics with hospitalization were stronger among those with more severe heart failure at baseline.	
McKenzie et al., 2019 Cardiovascular disease indicators including: augmentation index, systolic and diastolic BP, Interleukin-1β, Interleukin-6, Interleukin-8, and Tumor Necrosis Factor-α	October 2015 to May 2016 Northeastern Colorado	A cross-sectional study: evaluating associations between indicators of CVD and the intensity of O&G development and production activity within 16 km (10 miles) of a participant's home.	97 adults (28 male and 69 non-prepregnant female) ≥ 18 years	Evidence supported an association between the intensity of O&G activity and several indicators of cardiovascular disease. The results support associations between O&G activity and augmentation index, SBP, DBP, IL-1β, and TNF-α. Our study was not able to elucidate possible mechanisms or environmental stressors, such as air pollution and noise.	
Apergis, Mustafa, & Dastidar, 2021 Mortality rates, cancer, cardiac, respiratory	1998 to 2017 Oklahoma	The analysis estimates the long-run relationship between the health profile and its determinants using the Common Correlated Effects (CCE) method. The empirical setup allows for cross-sectional dependence and accounts for both observed and unobserved heterogeneity.	Not applicable 37 to 55 years old	UNGD activities have negative effects on human health-related outcomes across all counties in Oklahoma. Specifically, an increase in the number of (unconventional) wells has a positive impact on mortality rates, and incidences of cancer, cardiac, and respiratory diseases in communities in close spatial proximity, and a negative impact on life expectancy.	CARDIOVASCULAR and RESPIRATORY

Author and Illness Studied	Location and Year	Methodology	Sampling Size and Age Range	Main Findings and Health Outcomes	
Blinn, Utz, Greiner, & Brown, 2020 Sore throat headache, difficulty speaking itchy or burning eyes, stress, shortness of breath, anxiety, fatigue, sinus infection	2012 to 2017 Southwest Pennsylvania	A novel approach to comparing estimates of exposure was taken. Generalized linear modelling was used to ascertain the relationship between symptom counts and estimated UOGD exposure, while Threshold Indicator Taxa Analysis (TITAN) was used to identify associations between individual symptoms and estimated UOGD exposure. Authors used three estimates of exposure: cumulative well density (CWD), inverse distance weighting (IDW) of wells, and annual emission concentrations (AEC) from wells within 5 km of respondents' homes. Taking well emissions reported to the Pennsylvania Department of Environmental Protection, an air dispersion and screening model was used to estimate an emissions concentration at residences.	104 ≥ 18 years old median age of 57	Results suggested that living in proximity to oil and gas wells may be associated with more frequent and more complex health symptoms. However authors suggested that more complex analyses of symptoms was needed.	CARDIOVASCULAR and RESPIRATORY
Buonocore et al., 2023 Premature deaths, asthma, respiratory, heart attacks	2016 United States	Authors assessed air quality and human health impacts associated with ozone, fine particulate matter, and nitrogen dioxide from the oil and gas sector in the US in 2016.We Authors used an integrated geospatial model framework that links emissions inventories from O&G production to changes in air quality and health in exposed populations.	Whole population, United States	Estimated that air pollution in 2016 from the oil and gas sector in the US resulted in 410000 asthma exacerbations, 2200 new cases of childhood asthma and 7500 excess deaths, with $77 billion in total health impacts. NO_2 was the highest contributor to health impacts (37%) followed by ozone (35%), and then PM2.5 (28%). • Asthma exacerbations: 410,000 cases • Childhood asthma: 2,200 new cases • Asthma hospitalizations: 53 cases • Asthma Emergency department visits: 530 • Heart attacks: 270 cases.	
Jemielita et al., 2015 All cause hospitalizations for cardiovascular, respiratory and others	2007 to 2011 Pennsylvania	An ecological study: Zip-specific inpatient counts from 2007–2011 were used. The study assessed the link between inpatient rates, well count per zip code, and well density (quantiles) using fixed-effects Poisson models for overall and 25 medical categories.	92,805 hospitalisations. Age median 43.4 to 45.9	Hydraulic fracturing as determined by well number or density had a significant association with cardiology inpatient prevalence rates, while well density had a significant association with neurology inpatient prevalence rates.	

Author and Illness Studied	Location and Year	Methodology	Sampling Size and Age Range	Main Findings and Health Outcomes	
Li et al., 2022 All-cause mortality	2001 to 2015 All major US unconventional exploration regions	For each beneficiary's ZIP code of residence and year in the cohort, we calculated a proximity-based and a downwind-based pollutant exposure. Authors analysed the data using two methods: a Cox proportional hazards model and a difference-in-differences design which shows changes occurred after commencement of drilling and controls for many potential confounding variables.	15,198,496 The study relied on a nationwide cohort of over 15 million Medicare beneficiaries. Medicare beneficiaries; >95% over age 65	Evidence of a statistically significant higher mortality risk associated with living in proximity to and downwind of unconventional oil and gas wells. Results suggest that primary air pollutants sourced from unconventional oil and gas exploration can be a major exposure pathway with adverse health effects in the elderly.	CARDIOVASCULAR and RESPIRATORY
McCarron, 2018 Cardiovascular and respiratory	2007 to 2014 Darling Downs, Queensland, Australia	Ecological study of regional hospitalization data was compared before commencement of a coal seam gas industry in the region and after commencement, in association with the air pollutant inventory.	Admissions of patients for both cardiovascular and respiratory diseases.	Increased cardiopulmonary hospitalisations are coincident with the rise in pollutants known to cause such symptoms.	
Werner et al., 2017 All cause, disease of blood, circulatory and respiratory, perinatal, congenital	1995 to 2011 Queensland, Australia	This study analyzed hospitalization rates in relation to coal seam gas development in Queensland Admissions were linked to coal seam gas well numbers, indicating development intensity. Time series models estimate hospitalization rate changes during "low", "medium", "high", and "intense" activity versus a "very low" activity period.	238,457 0 to 65+	Hospitalisation rates for "Blood/immune" conditions generally increased for both sexes. Female and male hospitalisation rates for "Circulatory" conditions decreased with increasing coal seam gas activity. Hospitalisation rates were generally low for reproductive and birth outcomes; no clear associations were observed.	
Blundell & Kokoza, 2022 Respiratory-related hospital visitation	2007 to 2015 North Dakota	Authors assessed the impact of flared natural gas on respiratory health by using quasi-random variation in upwind flaring generated by the interaction of wind patterns and natural gas processing capacity. Specifically, they construct a novel dataset to estimate the causal effect of increased upwind flaring on the monthly respiratory-related hospital visitation rate by using the number of upwind wells that are connected to a capacity-constrained natural gas processing facility as an instrument for monthly upwind flaring.	180,000 <1 to ≥65	A 1% increase in the amount of flared natural gas in North Dakota would increase the respiratory-related hospital visitation rate by 0.73%. More than 32,000 total respiratory-related hospital visits for the 30-mile range alone.	RESPIRATORY

Author and Illness Studied	Location and Year	Methodology	Sampling Size and Age Range	Main Findings and Health Outcomes
Bushong, McKeon, Regina Boland, & Field, 2022 Asthma hospitalization admission rates	2001 to 2014 Pennsylvania	Authors constructed regression models to investigate the association between UNGD and asthma hospitalization admission rates (HAR), using HAR as a proxy for severe asthma exacerbation.	N/A N/A	Models were robust enough to confirm an expected association of asthma hospitalization admission rates with urban areas, PM2.5, income, and racial disparities using public data only. N/A
Rasmussen et al., 2016 Asthma exacerbations	2005 to 2012 Pennsylvania	A nested case-control study comparing asthma patients with exacerbations to asthma patients without exacerbations.	35,508 5 to 90 years old	Residential UNGD activity metrics were statistically associated with increased odds of mild, moderate, and severe asthma exacerbations.
Tustin et al., 2017 Chronic rhinosinusitis (nasal and sinus) Migraine headache Fatigue	2014 Pennsylvania	A cross-sectional study: Authors used residential addresses and information about Pennsylvania unconventional gas wells to create UNGD activity metrics for four time-varying well development phases. They evaluated the associations between UNGD activity and CRS, migraine headache, and fatigue symptoms.	7,785 ≥ 18 years old 55.3 ± 16.1 (mean ± sd)	UNGD was associated with Chronic rhinosinusitis, migraine headache, and fatigue symptoms in a large population-based survey. Associations were stronger in patients with two or more outcomes. 11.7 % (909) reported that they have received medical assistance.
Weisner et al., 2023 Upper respiratory, lower respiratory, mental health, neurological, gastrointestinal symptoms	2020 to 2021 Broomfield, Colorado	Cross-sectional: To assess whether residents near multi-well UOGD sites (within 1 mile) reported more health symptoms than those further away (> 2 miles), we used linear regression to test links between UOGD distance and summed Likert scores for health symptoms.	427 18 to ≥75	Results indicate that people living within 1 mile of multi-well unconventional oil and natural gas sites more frequently report upper respiratory and acute (e.g., nosebleeds, nausea, shortness of breath) symptoms than people living more than 2 miles from the sites. N/A
Willis, Hystad, Denham, & Hill, 2020 Asthma hospitalizations	2000 to 2010 Texas	Authors examined associations between natural gas development and paediatric asthma hospitalizations, where our primary outcome is 0 vs ≥1 hospitalization. They used quarterly production reports to assess additional drilling-specific exposures at the zip code-level including drilling type, production and gas flaring.	24,333 (not exposed to NGD) + 48,589 (patients exposed to at least one NGD site) 1 to 17 years old	Conventional drilling, compared with no drilling, is associated with odds ratios up to 1.23 [95% confidence interval (CI): 1.13, 1.34], whereas unconventional drilling is associated with odds ratios up to 1.59 (95% CI: 1.46, 1.73). Increasing production volumes are associated with increased paediatric asthma hospitalizations in an exposure-response relationship, whereas associations with flaring volumes are inconsistent.

RESPIRATORY

No community-level health studies based on closeness to specific gas operations have been done in Australia, but there have been two limited, single-time-point studies. One undertaken by Queensland Health (2013) with low community participation and few reports of physical symptoms at a one-day clinic, did not identify any links between air emission data and symptoms. In contrast, many community members reported a range of signs and symptoms potentially related to gas production activities in a house-to-house survey conducted by local General Practitioner, Dr Geralyn McCarron (2013). While their results on the prevalence of physical symptoms were conflicting, the findings of both studies support Queensland Health's statement that:

> *the available data were insufficient to properly characterise any cumulative impacts on air quality in the region, particularly given the anticipated growth of the industry. It is necessary to assess those impacts according to health-based standards which are relevant to long-term exposure.*
>
> (Queensland Health, 2013, p. 18).

Macey et al. (2014) examined the timing of the relationship between poor air quality and the presence of symptoms in four US states with substantial oil and gas production. Community members were trained to use air sampling devices to obtain samples of the air they were breathing at times when they felt normal, and at other times when they felt sick or sensed pollution from the nearby gas operations by taste or smell. This novel method enabled the community to identify numerous excursions above federal guidelines that were particularly frequent for toxins in the air they were breathing, notably formaldehyde, 1,3-butadiene, hydrogen sulphide, mixed xylenes and n-hexane. Strikingly, these excessive readings had not been detected and/or reported in routine air quality monitoring, raising questions about the sensitivity of existing data to enable issuance of alerts for the protection of health. Indeed, atmospheric research in a variety of circumstances has revealed significant underestimations of emissions of methane and other hydrocarbons based on ground level measurements and modelled predictions (Pétron et al., 2012; Brown et al., 2014; NASA, 2014).

Public health studies on unconventional gas operations continue to advance in depth, reach and rigour, and each year brings enhanced understanding (see reviews by Werner et al., 2015; Saunders et al., 2018; Hays and Shonkoff, 2016; Haswell and Bethmont, 2016; Deziel et al., 2020). These studies collectively strive to address the challenges involved in measuring complex exposures and risks, assessing impacts and responding to new knowledge.

Studies using chemical risk assessment to predict disease outcomes

Bunch et al. (2014) evaluated potential air pollution impacts associated with shale gas operations in the Barnett Shale region of the United States using routine measurements of a range of volatile organic compounds in over 7500 assessments. They concluded that there was no evidence that any of the assessed compounds posed significant risks to human health. In contrast, assessments of toxic air emissions in Colorado conducted by McKenzie et al. (2012) suggested that people living within 0.8 km of shale gas wells experienced a significantly increased risk of sub-acute non-cancer hazards associated with trimethylbenzenes, xylenes and aliphatic hydrocarbons at levels capable of causing neurological, haematological and respiratory health impacts. This study also suggested a higher cancer risk due to benzene levels among those living closest to the gas wells.

Heart disease

In the same study mentioned above, McCarron (2018) also found a simultaneous rise in hospitalisations for acute circulatory conditions (133%) amid substantial company-

reported emissions of multiple chemicals associated with coal seam gas production in Queensland, many of which are known to promote acute cardiovascular events.

McKenzie et al. (2019) observed significant positive associations between the intensity of gas development and production near place of residence in Colorado and markers/predictors of cardiovascular disease, including stiffness of the arteries, elevated systolic and diastolic blood pressure and the presence of inflammatory markers in the blood. Comparing rates of acute myocardial infarctions (heart attacks) and deaths between areas of New York State (where fracking is banned) and Pennsylvania (where it has continued), Denham et al. (2021) quantified significant increases in hospitalisations among middle-aged men and women linked to gas extraction intensity in Pennsylvania. These increases were not observed in New York counties across the state border. For every 100 wells added per square mile, there was a 5% increase in heart attack deaths among resident males aged 45 to 50. Hospitalisations of patients with severe heart failure increased between two- and four-fold at every stage of gas production from pad development, drilling, fracking and production, and to a lesser extent during the production phase for patients with less severe disease in Pennsylvania (McAlexander et al., 2020).

Respiratory disorders

A number of hospitalisation studies have also reported increases in other respiratory conditions among adults living in proximity to oil and gas operations (Apergis et al., 2021). More detailed information has emerged showing strong links with asthma exacerbations and hospitalisations among children. Modelling exposures to airborne chemicals known to be linked to asthma exacerbation and emitted at all stages of oil and gas operations, Buonocore et al. (2023) estimated that 410,000 additional episodes occurred, mostly among American children and 1500 respiratory hospitalisations in 2016 (more details below).

Children living in areas where shale gas mining activities were introduced (by zip code) experienced a 25% increase in hospitalisations due to asthma (OR 1.25 (1.07-1.47)) within 3 months after activity commencement (Willis et al., 2018). Children living in comparable areas without drilling activity did not experience a change in asthma hospitalisations.

Willis et al. (2020) also observed a 59% (confidence interval 46-73%) increase in the likelihood of hospitalisation for asthma among children living in zip codes in Texas with intense unconventional gas extraction activities compared to those with no drilling activities. The increase occurred after, not before, commencement of drilling and was positively correlated with production volumes but not with flaring intensity. Similar findings were reported by Bushong et al (2022) in Pennsylvania, with higher asthma hospitalisation rates associated with higher gas well density.

McCarron (2018) reported a 142% rise in acute respiratory conditions between 2007 and 2014 in the Darling Downs, Queensland, which now has extensive production of coal seam gas (coalbed methane). Hospitalisations, largely constant between 2007 and 2009, climbed steeply from 2010 onwards, simultaneously with sharp rises in gas production and accompanying atmospheric emissions of nitrogen oxides, volatile organic compounds, PM2.5 and PM10, formaldehyde and sulphur dioxides reported by the gas companies and

A number of hospitalisation studies have also reported increases in other respiratory conditions among adults living in proximity to oil and gas operations

published in the National Pollutant Inventory. These data signal the urgent need to further investigate and address co-occurring increases in hospitalisations and pollution emissions (McCarron, 2018).

All-cause mortality and reduced life expectancy

Three landmark studies have been completed in the last three years providing evidence of higher all-cause mortality and reduced life expectancy associated with living in areas with greater exposure to oil and gas developments.

In Oklahoma, Apergis et al. (2021) found that a 1% increase in the number of hydraulically fractured wells is associated with a 4.2% reduction in life expectancy among residents of exposed communities, reflecting positive associations between proximity of residence to wells and deaths due to cancer, cardiovascular disease and respiratory disorders.

Li et al. (2022) investigated the all-cause death rate among 15,198,496 Medicare beneficiaries over age 65 who had lived at least 2 years over a 15-year period (2001 to 2015) in all gas development regions of the United States, for a total of 136,215,059 person-years. They also obtained records of the location, construction dates and production records of over 2.5 million oil and gas wells. They then assessed the intensity of exposure to gas wells (low, medium-low, medium-high and high) of the individuals and whether they lived in postcodes upwind or downwind of wells. Using difference-in-differences methodology (controlling for time before and after gas production activities) and controlling for timing to the onset of illnesses and socioeconomic variables, the study demonstrated a highly statistically significant, linear (dose-dependent) increase in mortality according to intensity of exposure. Furthermore, the increase was observed more strongly among those living downwind, compared to upwind, of gas developments. The increased mortality among those living upwind was suggested to result from surface or groundwater contaminants; increased traffic, noise, light pollution and lifestyle disruption; and/or shifts in wind direction. The higher mortality rates among those living downwind of wells were suggested to be the result of greater exposure to air pollutants emitted by the wells in addition to the exposures experienced by those living upwind.

Three landmark studies have been completed in the last three years providing evidence of higher all-cause mortality and reduced life expectancy associated with living in areas with greater exposure to oil and gas developments.

Buonocore et al. (2023) applied advanced methodologies to previous estimates of the total health burden of air pollution from the oil and gas industry in the United States in 2016 (Fann et al., 2018). The study used national emissions inventories of PM2.5, oxides of nitrogen, VOCs, ammonia and sulfur dioxide from stages and components of oil and gas processes, including exploration, well pad development, drilling rigs, production, compressor stations, flaring, venting, processing, pipeline transportation and service stations. Highly sophisticated air pollution modelling (CMAQ) was used to model the impacts of these emissions across the continental United States. Census data and hospitalisation, morbidity and mortality data from the Centers for Disease Control and from research publications were used to model health impacts and the contributions of oil and gas emissions relative to other emission sources from natural and human causes. The authors also estimated the costs of health care and the social cost of greenhouse gases based on impacts of climate change on health.

The modelling produced from this extensive national dataset revealed that oil and gas emissions were likely to have caused 7,500 premature deaths, 410,000 asthma exacerbations, 2200 new cases of asthma, 1500 respiratory hospitalisations, 530 asthma emergency department visits, 53 hospitalisations for asthma and 270 heart attacks in 2016. The monetary losses due to oil and gas operations in 2016 from premature deaths and morbidity were estimated at US$77 billion (equivalent to $103 billion in Australian dollars in 2016).

Most of the study limitations identified by the authors were more likely to result in underestimation rather than overestimation of health losses, including, for example, underreporting of levels of non-methane volatile organic compounds and of the number of compressor stations emitting these gases and incomplete inclusion of important air pollutants. In addition, the costs due to mental health issues and productivity losses were not able to be included in the modelling analysis and would likely add substantially to the estimated figures.

Mortality associated with truck traffic

Oil and gas developments in the US have been linked to significant increases in truck movements and in fatal truck-on-car traffic accidents, especially at the hydraulic fracturing stage of extraction (Retzer et al., 2013; Graham et al., 2015; Blair et al., 2017; Xu and Xu, 2020). Using highly sensitive and specific methods to analyse data from North Dakota, Xu and Xu (2020) found that each hydraulic fracturing event on a well was associated with 6,790 one-way truck trips hauling wastewater to disposal sites and an 8% increase in fatal crashes compared to times when hydraulic fracturing had not taken place. Although the rate of traffic accidents per trip in the area did not change, the authors attributed the increase in deaths to the higher volume of truck movements and the higher front end and heavier body structure of trucks associated with servicing the hydraulic fracturing industry.

Oil and gas developments in the US have been linked to significant increases in truck movements and in fatal truck-on-car traffic accidents, especially at the hydraulic fracturing stage of extraction

Graham et al. (2015) proposed that higher levels of road surface degradation known to result from heavy vehicle traffic may also contribute to more accidents and road deaths. The cost of these additional road fatalities was estimated to be US$197 million per year, which greatly exceeded the revenue received by the state from the industry over several years (Xu and Xu, 2020). The higher accident rate also led to increased costs for vehicle insurance in the region.

It should be noted that rates of hospitalisation and death due to transport injuries are already far more common in outer regional (354 hospitalisations and 13 deaths per 100,000 population per year), remote (465 and 19) and very remote (482 and 25) areas of Australia where gas developments are planned, compared to urban (205 and 2.8) and inner regional (313 and 8.8) areas (AIHW, 2023). Furthermore, the risk of being killed is nearly three times higher for Aboriginal and Torres Strait Islander people than non-Indigenous people (Henley and Harrison, 2019; AIHW, 2023).

Evidence of impacts on foetuses and infants associated with their mothers' exposures to oil and gas during pregnancy

Since 2013, there has been an increasing focus on the likely vulnerability of foetuses to environmental hazards experienced by their mothers during gestation. Foetuses are uniquely sensitive to damage, developmental errors and altered hormonal signalling that may be caused by inappropriate chemical exposures in the uterine environment, and the outcomes can be severe. There is a growing understanding of the potential negative impacts of various exposures of the mother during pregnancy on birth outcomes; for example, air pollution (PM2.5) may influence birth weight and preterm births, and chemical exposures (teratogens) through the mother's bloodstream may cause birth defects.

Both pregnancy outcomes and infant and child wellbeing are highly sensitive to psychosocial and community stressors, including mental health stresses on parents, noise, heavy traffic, negative emotions expressed by caregivers, witnessing aggression and conflict (discussed in Section 5.3), and, potentially, fear of pollution.

Therefore, it is not unexpected that negative birth outcomes have been found to be more frequent in pregnancies spent in proximity to gas wells and, very recently, in areas with gas flaring. Several studies have documented lower birth weights and higher incidences of small-for-gestational-age and preterm births associated with mothers' exposure to gas operations in both the US and Canada (Hill, 2018; Whitworth et al.,2017; Caron-Beaudoin et al, 2021; Cairncross et al., 2022). Some of these studies are described below.

Measured pre-natal risks associated with maternal exposures to gas operations

Three conditions of pregnancy that can affect birth outcomes have been shown more frequently in pregnant women living closer to active gas well, namely antenatal depression and anxiety (Casey et al., 2016; 2018; 2019; Akers et al., 2022), hypertension (5% increase) and pre-eclampsia (26% increase) (Willis et al., 2022).

Negative birth outcomes include:

- Reduced average birth weight and small for gestational age (Stacy et al., 2015; Currie et al., 2017; Hill, 2018; Deziel et al., 2020; Hill and Ma, 2020; Tran et al., 2020; Willis et al., 2020; Caron-Beaudoin et al., 2021; Cairncross et al., 2022);
- Higher incidence of low-birthweight babies (Currie et al., 2017; Hill, 2018; Hill and Ma, 2020);
- Higher frequency of pre-term and extreme pre-term deliveries and spontaneous abortions (Casey et al., 2016; Hill et al., 2018; Whitworth et al., 2018; Cushing et al., 2020; Deziel et al., 2020; Hill and Ma, 2020; Gonzales et al., 2020; Caron-Beaudoin et al., 2021);
- Birth defects, including congenital heart valve defects, anencephaly, spina bifida and gastroschisis (McKenzie et al., 2014; Janitz et al., 2019; Tang et al., 2021; Cairncross et al., 2022; Willis et al., 2023; Gaughan et al., 2023; Han et al., 2023);
- Higher incidence of blood cancers, especially acute lymphoblastic leukemia (Werner et al., 2016; 2018; McKenzie et al., 2017; Clark et al., 2022).

All these outcomes can be caused by chemical exposures of mothers during pregnancy and can have lasting impacts on future health. Preterm birth is associated with infant mortality and long-term health problems, and lower birthweight, even within the normal range above 2.5 kilograms, is associated with a higher risk of type 2 diabetes and cardiovascular and renal disease (Barker, 2006).

Confirming previous studies suggesting an association between birth weight and exposure to unconventional gas mining

mentioned above, Currie et al. (2017) found a 25% increased risk of low-birthweight infants among mothers living within 1 km of a hydraulically fractured well, and smaller but detectable elevated risks at 2 and 3 km distance. Using these findings, it was estimated that 29,000 infants born in the United States each year were at increased risk of low birth weight, which carries significant implications for their subsequent health.

Detailed studies by Hill (2018) using difference-in-differences methodology controlled for a wide range of relevant maternal and geographical characteristics when examining birth weight outcomes of infants of mothers living within and beyond 2.5 km of one or more shale gas wells in Pennsylvania. This work showed a 7% increase in the frequency of low birth weights, a 5 g reduction in average full-term birthweight and a 3% increase in preterm births for each well located closer than 2.5 km. This affect was only observed for residence near active wells during pregnancy.

Further work has indicated that unconventional gas mining is also associated with increased risk and severity of preterm birth, especially when exposures to oil and gas extraction activity occurs in the first trimester of pregnancy (Whitworth et al., 2018). Similarly, Gonzales et al. (2020) found an 8-14% increase in the odds of delivering at less than 31 weeks associated with high exposure to well sites among Hispanic and Black women.

Cushing et al. (2020) specifically examined the association between gas flaring and birth outcomes, identifying increased odds of pre-term birth (OR 1.50; 95% CI 1.23-1.83) and shorter gestation (OR -1.9; 95% CI -2.8 to -0.9) among Hispanic women living in places with high levels of nightly flaring compared to those without such exposure. No trend was observed for non-Hispanic white women. The authors suggested that the greater vulnerability of Hispanic women to these circumstances may have been related to higher stress levels, a phenomenon that has been observed with exposures to other air pollutants, such as PM2.5 (Westergaard et al., 2017).

Higher incidence of severe birth defects

A regional study of 124,832 infants in Colorado reported positive links between the incidence of congenital heart defects (and possibly of neurotubular defects) and increasing number of shale gas wells within 10 miles (16 km) of residence in the infant's birth year (McKenzie et al., 2014). Low birth weight, in contrast, was negatively correlated with numbers of wells in this study.

More recently, Tang and colleagues (2021) found significantly (up to three times) higher frequency of infants born with anencephaly (missing large parts of the brain and skull structure), spina bifida (defective spinal cord), gastroschisis (where intestines are located outside the body at birth), and aortic valve and pulmonary valve defects (narrowed or blocked) when the mother lived near gas wells during pregnancy. In Canada, Cairncross et al (2022) examined 34,873 pregnancies in rural Alberta. After controlling for multiple variables, they found a 31% increase in major congenital abnormalities and a 12% increase in small-for-gestational-age babies among those whose mothers lived within 10 km of a hydraulically fractured well. Note that this study suggests the presence of an effect at a substantially farther distance from gas operations than previously recognised. Willis et al. (2023) examined 86,315 congenital anomalies among 2.2 million births in

… it was estimated that 29,000 infants born in the United States each year were at increased risk of low birth weight, which carries significant implications for their subsequent health.

Texas. Interestingly, they found that the increased odds of any anomaly associated with gestational residence within 5 km of unconventional gas wells (OR 1.20; 95% CI 1.17–1.23) and a produced water holding site (OR 1.17; 95% CI 1.14–1.20) were greater than for oil wells (OR 1.08; 95% CI 1.04–1.12).

In 2023, Gaughan et al. added substantial weight to these studies with a detailed analysis of 965,236 live birth records in Ohio. These researchers found a 13% increase in the presence of any birth defect (CI 0.98–1.30 95%), a 57% increase in neural tube defects (CI 1.12–2.19 95%), a 99% increase in defects to the limbs (CI 1.18–3.35 95%) and a 93% increase in spina bifida (CI 1.25–2.98 95%) associated with living within 10 km of an active oil and gas well. Han et al. (2023) identified increases in some heart defects and total birth defects associated with annual gas production in several counties across Texas.

Increased incidence of and hospitalisations for blood cancers and asthma

Higher rates of childhood hematologic cancers among children living close to oil and gas developments compared to those in areas without such developments have been observed in shale gas producing regions in the United States (McKenzie et al; 2017). Similarly, Werner et al. (2016) reported higher hospitalisation rates for children with cancer (9% higher; 95% CI 2–16%) and blood/immune diseases (14% higher; 95% CI 2–27%) in the coal seam gas mining areas of the Darling Downs, Queensland, compared to a rural agricultural area without coal or coal seam gas mining. Age-specific comparisons of hospitalisation rates revealed that living within areas with coal seam gas production activity was associated with significant increases in hospitalisations for respiratory diseases among very young (0 to 4 years) and 10- to 14-year-old children (ranging from 7 to 11% higher) and a 467% increase in blood/immune diseases among 5- to 9-year olds, when compared with children in areas without coal seam gas mining (Werner et al., 2018).

Two additional studies examined whether children growing up near unconventional gas wells are experiencing greater incidences of cancers, including acute lymphoblastic leukemia (McKenzie et al., 2017; Clark et al., 2022). This severe disease causes painful and frightening symptoms, and treatment requires hospitalisation and extensive chemotherapy over a long time period. In Colorado, McKenzie et al. (2017) reported a 4.3-fold (95% CI 1.1–16) increased odds of having lived within 16.1 km of 33 or more active gas and oil wells among 5- to 24-year-olds with acute lymphoblastic leukemia compared to controls with other types of cancer.

Consistent findings were reported in Pennsylvania by Clark et al. (2022). Also using a registry-based case control design, this research revealed a 2.35-fold (95% CI 0.93–5.95) increase in the odds of developing the disease among children aged 2 to 7 whose mothers had lived within 2 km of at least one gas well during the period from three months before their conception to their birth, compared to age-matched children without any cancer. Furthermore, this work used a measure called a "[ground]water-pathway specific metric" linked to the home address. The results supported the hypothesis that chemicals contaminating the groundwater are involved in the disease pathway.

Studies of longer-term impacts, such as the likelihood of developing adult cancers and chronic diseases, are limited to date because not enough time has elapsed since the beginning of potential widespread exposure to gas activities for these diseases to arise. Remarkably, it has taken just over two decades of unconventional gas development in the United States for more than 17.6 million Americans to be located within a mile of at least one oil or gas well.

Summary

Taken together, many studies reviewed here have identified significantly higher frequencies of health and developmental problems associated with living close to unconventional gas wells and other production activities that are potential sources of exposure to damaging chemicals (Werner et al., 2015; Dezeil et al., 2020). Some have provided evidence of causation via polluted water, and some have modelled already known effects of known pollutants emitted via the air. Others have identified known hazards that we don't yet have research methods to understand and quantify.

As a body of research, this evidence provides a compelling case for direct harms of the oil and gas industry across the lifespan on individuals – from foetal development, to infancy and childhood, to young and pregnant women to adulthood and elderhood. Pre-birth and childhood impacts, and impacts on mothers, fathers and extended family members, can have whole of life consequences. The complex diversity of chemicals and modes, timing and patterns of possible exposures and the added influence of varying social, emotional, economic and spiritual stressors would be expected to produce a diversity of findings and outcomes across studies. With Australia's substantially smaller pool of public health researchers and resources, it is difficult to imagine research of this scale and magnitude to be possible to reveal how communities are impacted should a major American-style industry be established here.

This section highlighted the three outstanding studies that have substantially increased our understanding of all-cause mortality (7500 premature deaths) and the enormous health losses and economic costs (AUS$103 billion dollars per year) associated with air pollutant emissions from a mature oil and gas industry (Li et al., 2022; Apergis et al., 2021; Buonocore et al., 2023). While morbidity and mortality are higher in heavily developed oil and gas regions, the analysis also demonstrated the spread of ozone, PM2.5 and oxides of nitrogen from these regions to others, including into neighbouring states. Another critical factor not included is morbidity due to deteriorating mental health, which has been less extensively studied.

There are more critical health impacts that have not yet been included in large modelling studies so those so far are underestimations. These include morbidity and decreased productivity to the loss of psychosocial wellbeing and mental health, which has not been as extensively studied but described in the next section. Furthermore, the contribution of oil and gas developments and the leakage and combustion of their products to the acceleration of climate change has vast health implications.

The strengths and challenges of this body of literature, along with other studies reviewed in this Report, are discussed in Section 6.

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5.2 Global and local psychological, social and mental health impacts

Mental health is of enormous importance to Australia's national wellbeing. Climate change and fossil fuel projects, including gas and oil developments, impact on mental health causing decreases to productivity and overall health. In this section we outline the major losses we currently face from poor psychosocial wellbeing and mental health within the overall health burden and loss of productivity of Australia. The rising importance and mixed emotions that arise from climate anxiety are briefly identified, not only due to fear of the consequences of climate change but also due to the moral injury caused by governments that are still rapidly expanding oil and gas developments despite pleas from the world's people to stop.

The section then looks specifically at the plethora of psychological, social stresses and losses experienced by people and communities living in the midst of the oil and gas industry. Brief descriptions of the local and regional impacts of the pre-development, the brief boom and the production phases involved in oil and gas expansions are provided from research studies. This is followed by an overview of studies that have measured associations between oil and gas developments and mental health in the community, in adults and in one study with adolescents.

This is the first of three Sections that focus on the losses experienced among those impacted directly and indirectly from oil and gas development of social, emotional, cultural and spiritual wellbeing. It is important to note that impacts described are ***additive and compounding*** – that is, these stresses are occurring in addition to the risks of chemical exposures through air, water and food, of loss of ecological values, water quality and security, and of unabated climate change progression.

These stressors and resulting poor mental health most likely contribute significantly to illnesses, such as asthma exacerbations, respiratory and cardiovascular emergencies and impairment of infants' healthy start to life. The stress of dealing with these health crises feeds directly back onto the mental health burden carried by the family.

Section 5.3 examines further burdens borne by Aboriginal people from expansive oil and gas development and Section 5.4 highlights the serious known risks to safety of women and children from major FIFO development.

Burden of mental ill health in Australia

Loss of personal, family and community wellbeing and poor mental health makes an enormous impact on the health of the Australian population, both directly and indirectly. An estimated one in five Australians (20%) experienced anxiety, depression and/or substance use disorders in 2020/21 (Australian National Mental Health and Well-being Survey, ABS, 2022). Together, the health burden of dealing with a mental illness (for example anxiety, depression and substance abuse) and musculoskeletal disorders (back pain) contributed almost equally to 48% of Australia's total (non-fatal) health burden in 2018 (AIHW, 2021). Furthermore, the leading cause of death among 15–24 year olds and 25–44 year olds between 2019 and 2021 was suicide, which is at least twice as frequent among young Aboriginal and Torres Strait Islander Australians than among non-Indigenous young people (AIHW, 2023). Suicide was also fifth leading cause of death among children aged 5 to 14 years.

The Productivity Commission (2020) estimated the total economic cost of mental ill health and suicides in Australia at $200 to $220 billion per year, with direct costs of $16 billion for mental healthcare and support services and $39 billion in productivity losses due to reduced employment opportunities, absenteeism and

presenteeism. Rural and remote areas are particularly underserviced, for example less than 2% of Northern Territorians outside Darwin and Alice Springs and 3% of people living in rural and remote areas of Queensland accessed mental health services in 2016. Suicide rates between 2013 and 2017 tended to be higher in remote areas (twice the national average). Beyond these figures, there is an additional largely unquantified burden from loss of psychosocial wellbeing which is not measured, either because it does not meet mental illness criteria, no services are available or the person does not access help.

Climate anxiety among Australian youth: Oil and gas development as a moral injury

Of particular importance to this discussion, but largely ignored so far in national studies, is the growing evidence of climate anxiety with emotions of worry, fear, anger, grief, despair, guilt and shame that often impact on their daily lives (Wu et al., 2020; Hickman et al., 2021). These feelings are especially prevalent among children and young people, who may struggle to see their future in a climate changed world.

The results of a survey answered by over 3,000 Victorians and 700 Victoria healthcare professionals (Sustainability Victoria, 2020) reported that:

> *The health impacts of climate change are more front-of-mind for young people and this demographic is potentially at higher risk of developing climate change-related mental health conditions. Around half of young Victorians report extreme feelings of frustration, fear, sadness and outrage. Also of note is that four out of five healthcare professionals (79 per cent) report feeling "overwhelmed" when thinking about the future impacts of climate change.*

A similar survey by Mission Australia found that 67% of Australian youth are concerned about climate change, with 26% feeling very or extremely concerned (Gao et al., 2023). This 26% also experienced substantially more concern about their ability to cope with stress, lower personal wellbeing and mental health conditions, compared with their peers who were less concerned about climate change.

Many young people feel a deep sense of betrayal from government inaction and failure to take the necessary urgent steps to protect their future (Hickman et al., 2021). In Australia, this is best demonstrated by continued plans to expand, rather than contract, fossil fuel developments when scientists globally (IPCC, 2021) and the UN Secretary General António Guterres are calling for rapid cessation of new fossil fuel projects at a time of climate crisis:

> [This is] *code red for humanity… greenhouse gas emissions from fossil-fuel burning and deforestation are choking our planet and putting billions of people at immediate risk, and many of the changes are becoming irreversible.*

In the British Medical Journal, Rao and Powell (2021) state:

> *For the eco-anxious, more concerning than even this apocalyptic news is the extraordinary level of indifference and banality with which the climate crisis is treated by many others, including those in positions of influence.*

Hickman et al. (2021) calls such actions 'moral injury' – akin to stoking a fire in a burning house – and a critical contributor to the high prevalence of climate anxiety identified in their global survey:

> *By endangering and harming fundamental human needs, the climate crisis is also a human rights issue. Legal bodies recognise an intersection between human rights, climate change, and climate anxiety. Subjecting young people to climate anxiety and moral injury can be regarded as cruel, inhuman, degrading, or even torturous.*

Local and regional psychosocial stressors from oil and gas developments

Beyond the inter-generational mental health impacts of continuing expansion of new fossil fuel developments, there is also a wide spectrum of local and regional impacts of gas developments on psychosocial and mental health, including and especially of children and young people. While not as extensively examined as direct physical health impacts, there are many avenues, in addition to climate anxiety discussed above, through which both immediate and distant exposure to the unconventional gas industry has been linked to increased stress, feelings of disempowerment and negative impacts on mental health and wellbeing (Adgate et al., 2014; Hossain et al., 2013; Ferrar et al., 2013; Powers et al., 2014; Kriesky, 2012; Morgan et al., 2016; NSW Parliament, 2012; Sangaramoorthy et al., 2017; Lai et al., 2017; Fisher et al., 2018; Hirsch et al., 2018). Very little work has explored experiences and impacts of these developments on young people.

Australian studies predominantly relate to coal seam gas extraction in the Western Downs of Queensland, while US studies relate to shale gas developments; both settings mostly impacting farmers and previously small and relatively quiet communities. Importantly, there is a significant further literature that examines sociological change, power imbalance, social license and attitudes to gas developments in the US and Australia that is not included in this review. This information builds theoretical understanding of the trends discussed below.

Three phases of gas development

To assist in understanding these impacts, the characteristic events and impacts that occur during the three phases of oil and gas developments are described. Shared features across the whole experience are then discussed in the next subsection.

The experience of communities affected by gas developments is often described as three phases, prior to and preparation for development, the construction or boom phase and the post-boom phase, a typical pattern for resource extraction undertaken in non-urban areas.

Prior to commencement, impacts on individuals and communities may include distress, anxiety, fear of the unknown and social disharmony due to disagreements that split the community into those who support the industry and those who oppose it (Moffatt and Baker, 2013; Hirsch et al., 2018). This has been observed in many communities in New South Wales, including places where gas developments did not progress (the Northern Rivers, Gloucester, Helensburg, Medowie) and in Narrabri and the Pilliga Forest where it has progressed despite substantial community opposition. Feelings often intensify as seismic surveys and exploration begins, noise increases and social hazards associated with disruptions to the local social fabric become apparent and communities come to realise the extent of change ahead.

Box 5.2.1 provides an insider perspective from a rural psychiatrist, Dr Steve Robinson, on how intense the impacts of the threat of a gas development and commencement of exploration wells were in an otherwise close-knit rural community. Multiple chronic mental health risks can be identified in his account, namely anxiety, uncertainty, confusion, secrecy, division, conflict, property damage, loss of peace and quiet, noise, loss of place, loss of identity as a community, loss of financial security and assets, loss of dreams and aspirations, insecurity, poor employment outlook, strangers and fear. His submission to a Senate Select Committee Inquiry on Unconventional Gas Mining (Parliament of Australia, 2016) also emphasises how the additional distress leads to recurrences of mental illnesses among the most vulnerable in the population, including depression and anxiety. Dr Robinson also highlighted some new cases of depression among those who had not

been previously affected, particularly associated with "stresses that continue for a very long time, involving a powerful opponent and having no apparent solution promote feelings of helplessness and hopelessness". In addition, he observed occurrences of "angry outbursts, single episodes of antisocial behaviour and interpersonal disharmony" and highlighted the tremendous sense of injustice felt by residents.

BOX 5.2.1: CASE STUDY:
A rural psychiatrist/resident perspective

An excerpt from a submission to the NSW Parliamentary Enquiry on Coal Seam Gas by retired psychiatrist, Dr. Steve Robinson, describes an insider's experience with his own community in the Hunter Valley when the CSG exploration began.

> ***Exploration is when the psychological stresses are first noticed in the community. Exploration maps are placed in the local newspaper but they are difficult to decipher and individual landholders are not notified. This uncertainty starts to generate community anxiety. Some individual landholders are approached and offers are made mostly for access but with agreements that include confidentiality clauses. Individuals don't know if they are being treated fairly.***
>
> ***The community starts to divide between the few who see it as an opportunity for an additional income and the larger number who hear the risks and see little in the way of benefits. The local council has a sharp pro-mining versus anti-mining divide leading to a spill of one mayor. The letters page in the local newspaper has amply echoed this divide for the past 5 years.***
>
> ***Seismic surveys come and go with some damage to paddocks, heavy vehicle traffic ruining country roads, and noise. Drilling occurs with the same complications. The town takes on a different look with mining vehicles being prominent and drilling teams from interstate coming and going. The visual impact is slowly increasing.***
>
> ***A few properties are purchased for good prices, other houses close-by cannot be sold and their value drops. Lifetime plans are put on hold or cancelled. Property development in the area declines as a result of the general uncertainty. Rental property is more expensive. The tourism industry is threatened and wealthy prospective city retirees look to other beautiful areas not impacted by mining. The gas company employs very few locals.***
>
> ***Exploration wells are fracked to optimize the flow and the wells are flared for months. There is no explanation of the risks and precautions taken in these fracking and flaring operations. There is no publicity given to any air or water testing. There have been at least two separate unpredicted explosions locally due to gas migration known to the community from just a dozen exploration wells and even more dramatic events elsewhere from gas mining. This results in understandable anxiety about safety risks. [This community is in] this first phase has taken 5 years so far and production has yet to commence.***

https://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Gasmining/Gasmining/Submissions

Aboriginal communities may feel disempowered and voiceless when they have not been afforded the right to prior, free and informed consent and to prepare themselves to witness industrialisation of their Lands, more truck movements, and people coming onto their Country (Jumbunna Institute for Indigenous Education and Research, n.d.). Section 5.3 explores this further.

Once decisions are made, the construction (or boom) stage begins. In the 'boom' phase, tight-knit communities can feel inundated with strangers coming in, taking the new jobs, disrupting housing affordability and availability and burdening health and other services (Hossain et al., 2013; Hirsch et al., 2018; McTaggart et al., 2018; Carrington and Periera, 2011). Crime and intimate partner abuse may also increase (Carrington et al., 2011; Lockie, 2011; Bartik et al., 2017; James and Smith, 2017; Ruddell et al., 2014). Several studies have linked the male domination of the mining industry to the promotion of patriarchal culture which marginalises and isolates women and enhances their vulnerability to subordination and abuse (Sharma and Rees, 2007).

Such impacts are detrimental to the social cohesion and for some, the moral character, of the community (Moffatt and Baker, 2013; Sangaramoorthy et al., 2017; Lai et al., 2017; James and Smith, 2017; Fisher et al., 2018; McTaggart et al., 2018). Attempting to deal with conflict, loss of social cohesion and added stress burden of these changes has been associated with increase substance abuse and domestic violence (Measham et al., 2016). Increases in domestic violence and adult substance abuse are adverse childhood experiences with strong evidence of links to poorer long-term mental health and functional outcomes (Mathews et al., 2023).

Several authors have identified increased incidence rates of sexually transmitted infections, chlamydia and gonorrhoea, which they attribute to changes in sexual behaviour that can be associated with mobile workers coming in to depressed areas (Mabey and Mayaud, 1997; Komarek and Cseh, 2017; Deziel et al., 2018). While this may reflect partnering and consensual or commercial sexual relations, it could also be influenced by increased risks of sexual violence and disempowerment of women associated with the large influx of men into oil and gas development regions as discussed in Section 5.4.

The New South Wales Parliament Legislative Council Inquiry into Coal Seam Gas (2012) found widespread concern about coal seam gas developments in rural, urban and indigenous communities. Submissions from the public described concerns about poor behaviour by coal seam gas companies and contractors, the pace of development and fear of loss of land and livelihood.

In the post-construction phase, jobs may decline and housing demand drops. Production, gas and oil transport through pipelines with compressor stations every 50 to 100 kilometres and, as local processing continues, with drilling and fracking, with its 24-hour lights, flaring, noise, privacy invasion, odours, tree clearing and truck movements –all cause some people to feel a deep sense of loss of control, loss of place, anger, powerless and loss of peace and a feeling of being trapped and unable to escape (Lai et al., 2017; Sangaramoorthy et al., 2017; Hirsch et al., 2018). This phase may continue for years as a long-term feature of the industry's constant and visible impact on the community, for some a constant reminder of what they have lost (Willow, 2014; Eaton and Kinchy, 2016; Richard and Slagley, 2019).

The literature on employment in mature (post-boom) communities in shale gas regions of the United States shows mixed results. Some studies observe no measurable impact on employment, while others report modest gains (Jacquet et al., 2018; Hoy et

al., 2018). Notably, an in-depth comparison of employment between counties in Pennsylvania with substantial drilling of the Marcellus shale and New York State which banned shale gas development, analysis observed an increase in employment in construction and resource sector, but an equivalent decrease in employment in the manufacturing sector after, but not before drilling began. Thus, there was no statistically significant net change in employment linked to the gas operations over 12 years (Cosgrove et al., 2015). While Komarek (2016), reported an early increase in total employment and wages of 7% and 11% in the Marcellus drilling region, this lasted for three years and then declined markedly.

There are a host of additional studies demonstrating sociological and economic impacts of mining on communities. Hajkowicz et al. (2011) compared selected quality of life indicators including socio-economic factors, communications, housing, education, employment and life expectancy of 71 local government areas with national indicators. Their study found that mining towns scored higher on these indicators, however, they did not suggest that their study demonstrated a causal relationship. They also pointed out they did not consider indicators related to health, family life, sense of community or the impact of FIFO – Fly In Fly Out work on aspects such as alcohol and drug misuse, and family violence and breakdowns. These impacts on whole communities have been described as 'collective trauma' (Perry, 2012, Hirsh et al, 2018). Conversely, the conditions of FIFO work, stress on relationships and the feeling of being an outsider also has negative consequences on oil and gas workers' mental health (Hirsch et al., 2018).

A few questions included in a survey by Australia's Commonwealth Scientific and Industrial Research Organisation of 390 residents across five communities impacted by coal seam gas extraction in Queensland may have reflected those critical aspects of community wellbeing (Walton, McCrea and Leonard, 2016). The key question among many asked was how they felt their community was coping with the industry and found that nearly half (48.5%) felt their community was 'only just coping', 'not coping' or 'resisting' the industry. While 51.5% felt their community was adapting, just 11.4% of this group saw the change as 'into something different but better' (Walton et al., 2014). Similar findings were revealed when the survey was repeated in 2016; 51% reporting 'only just coping' or worse.

Specific changes highlighted by the authors were the significant drop in community attitudes towards 'employment and business opportunities' that dropped as economic activity declined within the two year interval, 2014–2016. While personal safety, community wellbeing and community spirit, cohesion and trust scored highest in both surveys, communities repeatedly scored environmental management, planning and leadership, being informed, having a voice and trust in the coal seam gas companies and state government scored lowest in both surveys.

Within the same Queensland region, Marcos-Martinez et al. (2019) observed a 7% increase in household income associated with coal seam gas development compared to areas without development. However, they observed no difference in employment levels between the areas and no evidence of the so-called 'indirect employment multiplier effect' even in the early phase of coal seam gas development.

Overall, while the 'boom' phase may appear to bring some positive social change to residents seeking employment opportunities, impacts on residents are uneven and most feel uncertainty in how communities will cope with the post-construction phase (Rifkin 2015; Walton et al., 2014).

Solastalgia, loss of place and disempowerment

Disturbance of place attachment as a result of the sprawling industrial footprint of unconventional gas development may contribute to the condition of solastalgia – an intense longing for lost environmental qualities of a place that previously had deep meaning to one's sense of identity and continuity of past, present and future possibility. This mental health vulnerability comes from Glenn Albrecht (2005) who named and described the concept of 'solastalgia' after examining the impact of open cut coalmines in the Hunter Valley. Albrecht defined 'solastalgia' as:

> *the pain experienced when there is recognition that the place where one resides and that one loves is under immediate assault … a form of homesickness one gets when one is still at 'home'.*

Solastalgia as a specific and important form of wellbeing loss has received increasing attention in the literature (Lai et al., 2017; Sangaramoorthy et al., 2017; Huth et al., 2017) and was recognised in Queensland Health's small project in coal seam gas regions in 2013.

Working with residents impacted by open-cut coal mines in the Hunter region of NSW, Connor, Albrecht, Higginbotham, Freeman, Smith and others (2004) established the critical importance of sense of place and belonging, and the reality of deep distress and sense of powerlessness that results from the loss of place. The team developed the Environmental Distress Scale (Higginbotham et al., 2007) to help measure levels of distress.

The work of this team also identified the critical importance of promoting recovery from solastalgia through taking protective and restorative environmental action. This approach, which includes exercising the right to protest against environmental damage has also been endorsed by many researchers as a method of coping with climate anxiety and distress from environmental damage available to young people, parents and all citizens (Hickman et al., 2016; Ogunbode et al., 2022).

Using the Environmental Distress Scale developed by Higginbotham et al (2006), Elser and colleagues (2020) reported significant concerns among a sample of West Texas residents about foul-smelling air, heavy vehicles, noise, vibrations, loss of cultural heritage and environmental damage affecting future generations. Nearly 50% of respondents report symptoms of solastalgia – worries about polluted air, water and scenery (Elser et al., 2020).

An ethnographic analysis of the impact of the oil and gas industry in Bradford, Pennsylvania by Simona Perry (2012) of Rensselaer Polytechnic Institute revealed the profound loss felt by the community as captured in a focus group with community members:

> *They expressed the feeling that the shale gas industry had forever altered the connections they had with their family histories, childhood memories, their lands, their neighbors and communities, the past, and the present. These sentiments were expressed by everyone interviewed regardless of their opinions about whether the shale gas developments were having an overall positive or negative impact in the county. As one landowner put it, "That's why we're feeling this death-feeling because change is a-coming. It's like you want to hold onto it and you know it's not going to be there…. one participant noted, "the dread I feel in the pit of my stomach" in slowly realizing as they talked about the photographs they had taken and what was most important to them—their land, their water, their farm, their children's health—that those things could so easily be destroyed forever, and made the comment, "It feels like we're losing our love. The things we love the most may be taken away. That's what we're all saying with this.*

Disempowerment, vulnerability (loss of safety) and deep loss is also a dominant theme through this literature. Willow (2014) provides a powerful analysis of the consistency of these feelings shared between First Nations Canadian Anishinaabe peoples who suffered massive deforestation and mercury contamination of their land and waters, Yonngom people living downstream from the environmentally disastrous Ok Tedi mine in New Guinea and White middle-class people who became anti-fracking activists in Ohio felt devastated by the immense change brought by shale gas development. The author states:

> *For Ohioans who oppose shale energy development, landscapes that until recently provided the promise of sustenance, stability, renewal, and relaxation have, in the face of apparently uncontrollable and unknowable environmental changes, been replaced by landscapes of disempowerment and vulnerability.*
>
> (Willow, 2014).

Reflecting on a protest in Mexico saying 'we are all Indigenous', the author states:

> *When they evoke the analogy of the miner's canary— the caged bird that alerts coal miners to the presence of poisonous gasses—Native North American scholars convey a similar message: While indigenous people may be among the first to suffer, the devastating results of environmental degradation are certain to spread.*
>
> (Weaver 2010; as cited in Willow, 2014).

Another qualitative study was conducted with rural people in Saskatchewan and Pennsylvania who remain quiet and elect not to take action against the unwelcome changes brought by gas developments (Eaton and Kinchy, 2016). Residents of both locations raised many grievances, but many struggled with the notion that 'progress' requires social, environmental and health sacrifices. They felt that they had to accept the negative impacts that upset them as part of perceived benefits to their region, and hence felt they had no right to protest. Others felt powerless against the dominance of the industry, while others vented through individual action, such as voicing complaints to show their anger and opposition. However, those residents felt unable to unite and seek greater control over their situations through collective coordinated action.

Solastalgia … the pain experienced when there is recognition that the place where one resides and that one loves is under immediate assault … a form of homesickness one gets when one is still at 'home'.

The author recorded a quotation from an elderly multi-generational landowner in Pennsylvania:

> *It's changed from being a rural area to being a semi-industrial area. Especially when you are on the roads….I just [feel] like, wow, they've – they've taken this over, this is no longer ours. …This is not ours anymore.*

Urging more emphasis on listening to communities which do not openly protect against the industry, the authors concluded:

> *At times our interviewees expressed profound feelings of powerlessness, seeing their mere selves as structurally ineffective against the corporate oil and gas industry, and the distant and bureaucratic power of the state.*

Antecedents and associations with clinically diagnosed mental health disorders

Thus, substantial evidence has identified that all phases of gas development can bring disempowerment and loss to community residents. This includes those with initial high hopes disappointed by a lack of perceived long-term opportunities, those who unsuccessfully resisted the industry and those impacted by the loss of loved ecological qualities of their environment. These feelings of disempowerment and solastalgia, especially when constantly reminded of the changes brought by the industry, may in turn exacerbate the risk of clinical depression and anxiety and suicidal ideation (Moffatt and Baker 2013; Morgan et al., 2016; Hirsch et al., 2018).

Malin (2020) analysed 75 in depth interviews with people living in areas of intensive gas production in Colorado. She reported that the ***industrialisation of communities caused people chronic stress, negative mental health outcomes and depression***. Many people spoke in depth about the stress of uncertainty regarding risks and impacts on their health [as verified by research], feelings of powerlessness in the face of extensive environmental change and lack of trust in government regulations and monitoring.

In southern Queensland, 239 landholders, community and service representatives from 12 communities attending workshops discussed their lived experience with psychosocial, health service, housing and financial stressors and negative mental health impacts with coal and coal seam gas extraction (Hossain et al., 2013). Most alarming was a sense of disempowerment, isolation and pessimism. Participants urged greater protection of mental health and increased psychological services.

The suicide of an Australian farmer in 2015 who, according to a family statement (Bender family, 2015), resisted pressure and experienced the consequences of unconventional gas operations and underground coal gasification on his farmland for over 10 years adds gravity to the findings of these studies. This death stimulated the abovementioned national Senate Select Committee Inquiry on Unconventional Gas Mining (Parliament of Australia, 2016; Box 5.2.1) but, after an interim report, the Inquiry was suspended due to the 2016 Australian election and the Inquiry was not completed.

The Australian Office of the Chief Economist (2015) expressed concerns about the stress and anxiety experienced by farmers who are forced to accommodate coal seam gas operations on their land and workplace. Augmenting the Edinburgh Farming Distress Inventory to include stressors linked to CSG mining, Morgan et al. (2016) confirmed these concerns. Their work found that a significant proportion of farmers surveyed had many concerns, not only about the direct impact of CSG operations on their farming business (on farm concerns), but also larger worries about deteriorating community values, threats to their health and the future of their children (off-farm concerns). These worries contributed significantly to overall stress burdens and odds of experiencing depression and anxiety, especially among farmers directly affected by mining activities.

…industrialisation of communities caused people chronic stress, negative mental health outcomes and depression … spoke in depth about the stress of uncertainty regarding risks and impacts on their health … feelings of powerlessness in the face of extensive environmental change and lack of trust in government regulations and monitoring.

There have been only three studies which have examined possible direct links between proximity to oil and gas operations and mental health disorders. Casey et al. (2018) explored relationships between disordered sleep and symptoms of depression and proximity to active oil and gas wells in Pennsylvania. These authors found an 18% increase (4–34%) in the likelihood of experiencing symptoms of depression among those living in close proximity to both larger wells and greater numbers of unconventional gas wells in Pennsylvania. However, no associations were observed for disordered sleep. Casey et al. (2019) further explored whether anxiety and stress among pregnant women associated with living near oil and gas wells might be associated with adverse birth outcomes such as described in Section 5.1. While this study did again demonstrate a higher (4.3%, 1.5–7%) frequency of anxiety and depression among pregnant women living close to oil and gas wells, no relationship between these presentations and adverse birth outcomes was observed (Casey et al., 2019). However, childhood mental health outcomes are known to be impacted by prenatal depression and anxiety, with increases in childhood anxiety disorders and behavioural problems with attention and aggression (Park et al., 2014; Donnici et al., 2021).

In perhaps the only epidemiological study of mental health impacts on young people of living in high intensity oil and gas regions, Gorski-Steiner et al. (2022) observed a 15% (6–25%) increased likelihood of experiencing new onset internalising disorders among females living near high intensity, compared to low intensity, oil and gas operations. Internalising disorders include anxiety and depression, and associated experiences of distress, social withdrawal, loss of interest and fatigue.

These impacts are particularly important when considering the potential psychosocial and spiritual impacts of unconventional gas developments on Aboriginal people and communities.

Clearly there is insufficient literature which understands these multiple, complex and often profoundly negative impacts of life within oil and gas production regions from a mental health and wellbeing perspective. Most of the research done has considered these stressors as social impacts, rather than health concerns with significant implications for both physical and mental health. Furthermore, while there is a wealth of information on psychosocial stressors, there is extremely little literature on how these stressors impact on the mental health and wellbeing, aspirations and life opportunities of young people. This impact stretches from the immediate environment where extraction is occurring to global harms to the wellbeing of young people.

These impacts are particularly important when considering the potential psychosocial and spiritual impacts of unconventional gas developments on Aboriginal people and communities. While there are no research publications to date, many Aboriginal and Torres Strait Islander people are leading efforts to protect the environment and health in the face of challenges from gas developments and climate change (See Section 5.3).

Summary

To summarise this literature, unconventional oil and gas developments have been associated with:

- **Mental health conditions – Depression and anxiety (Casey et al., 2018; 2019; Hirsch et al., 2018) and new onset of internalising disorders (anxiety, depression, social withdrawal, fatigue) among adolescent females seeking treatment in Pennsylvania (Gorski-Steiner et al., 2022)**
- **Demoralisation and anxiety that the government is not transitioning away from fossil fuels despite the climate imperative (Hickman, 2021; Sustainability Victoria, 2020; Ogunbode et al., 2022).**
- **Distress and division within and between families and communities who support and are opposed to oil and gas developments (Ferrar et al, 2013)**
- **Disempowerment, loss of control, hopelessness, loss of livelihood, loss of belonging and isolation, particularly of women (Sharma and Rees, 2015; Kriesky 2012; Perry, 2012; Moffatt & Baker, 2013; Hossain et al., 2013; Eaton and Kinchy, 2016; Lai et al., 2017; Fisher et al., 2018)**
- **Crime and loss of moral character of community (Carrington et al., 2011; Carrington and Periera, 2011; Sharm and Rees, 2015; Sangaramoorthy et al., 2016; James and Smith, 2017)**
- **Solastalgia and anxiety from destruction of nature, farmlands and industrialisation of landscapes, loss of identity (Albrecht, 2005; Connor et al., 2004; Willow et al., 2014; Morgan et al., 2016; Elser et al., 2020)**
- **Disturbances from lights, noise, traffic, reduced property values, fear of future (Allhouse et al., 2019; Richburg and Slagley, 2019)**
- **Traffic and pedestrian injuries and fatalities (Retzer et al., 2013; Graham et al., 2015; Blair et al 2017, Xu and Xu, 2020).**
- **Local, regional & broader unfavourable economic changes, boom bust cycles (Walton et al., 2014; Rifkin 2015)**
- **Fear for one's own and children's health and future (Morgan et al., 2016)**

As oil and gas operations are also contributing substantially to the acceleration of global warming, the many mental health impacts and losses associated with climate change will also accelerate. A detailed review of 114 studies and meta-analysis of 19 studies by Thompson et al. (2023) revealed significant increases in suicide rates, hospital attendance and admissions for mental illness associated with hotter weather, which is, in turn, increasing with climate change. Extreme heat is already increasing throughout Australia, especially across northern regions which, if current climate policies remain unchanged and climate action is not sufficient, may become uninhabitable by 2080 (Lenton et al., 2023).

Further potential impacts of expanded gas production in Australia on social, emotional, cultural and spiritual health of Aboriginal people and increased exposure to sexual violence and crime of particular concern to residents of remote communities are discussed in Section 5.3 and 5.4, respectively.

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5.3 Additional physical, cultural and spiritual impacts of gas industry on Aboriginal communities and people in Australia

This Section does not seek to speak for Aboriginal people on the challenges faced by oil and gas developments on their Country. Rather we echo some of the voices that have spoken publicly, from consultations and analysis in formal documents, in open letters and in submissions to government inquiries. Those voices have spoken the enduring science of this Land for millennia. Many of the voices express outrage, fear of harms to Country, to water and to their health. They also express frustration and continued defiance about the processes that have been forced upon them, the lack of free, prior and informed consent, and impacts that all aspects of gas development would have on their lives. These are in addition to all the risks described in Sections 5.1, 5.2 and 5.4. This section provides a small snapshot of Aboriginal people's voices regarding the challenges that they have had to face in protecting their Lands, cultures and identities.

For over 65 thousand years, Aboriginal and Torres Strait Islander people have nurtured the health and diversity of ecosystems of their Country, including the Lands, inland waters, coasts and sea. This is a tradition of science that is now being recognised. Social, spiritual and physical connection to these systems, knowledge of their importance and a profound sense of responsibility for the protection of their integrity is embedded within Indigenous cultures worldwide.

This section provides a small snapshot of Aboriginal people's voices regarding the challenges that they have had to face in protecting their Lands, cultures and identities.

Threads of this wisdom are echoed in some of the foundational pillars of global health and wellbeing, such the Ottawa Charter for Health Promotion (World Health Organization, 1986), the Sustainable Development Goals and in Climate Change 2022: Impacts, Adaptation and Vulnerability (IPCC, 2022).

In 2023, Aboriginal and Torres Strait Islander People continue to lead strident efforts to protect Country against inappropriate developments and climate change inaction. This is despite bearing much cultural and spiritual loss from the devastation of social, linguistic, ecological, geological and biological diversity which commenced in 1788 and continues today. The State of the Environment Australia 2021 (Department of Climate Change, Energy, the Environment and Water, 2021) reports:

> *There has been devastation of cultural practices since European colonisation began. Indigenous land and sea management has been greatly impacted. Colonisation continues to interrupt many cultural practices and the intergenerational transmission of our knowledge needed to keep us and Country strong.*
>
> *The continuing legacy of colonial management of Country has disenfranchised and marginalised Indigenous peoples in their stewardship of Country. Legislative regimes, and rights to land and sea, vary across the states and territories, perpetuating inequity for Indigenous peoples. Access to Country has been impacted. Indigenous peoples' rights have been impacted.*
>
> *Our knowledge of Country, developed through scientific practice, careful observation and interaction over millennia, has been portrayed as myth and legend. People were taken from Country and treated as outsiders. There have been limited rights*

> *for heritage, water, land and seas – and we have often been powerless to protect our totems, plants and animals.*

Sadly, many Australians have little awareness that the impact of this history and the continuing circumstances of environmental and social injustice continue to drive challenges for the health and wellbeing of Aboriginal and Torres Strait Islander peoples today. Perhaps most distressing is that many leaders and decision-makers in Australia are still not listening and, as shown in Section 3, time is running out. Again, the State of the Environment reports:

> *Future management of Country must be premised on Indigenous-led approaches to strengthening and sharing our knowledge of caring for Country. Sharing of knowledge must recognise our Indigenous cultural and intellectual property and respect the ancestors who gave us the knowledge.*
>
> *Management practices should be about revitalising and strengthening cultural practice and enable reconnecting to Country and kin, which delivers healing and rehabilitation of Country. Support for intergenerational transfer of customary knowledge and practices, and respect for cultural authority and customary law, are vital.*
>
> *Self-determination is a key focus, having people employed in and leading data collection and monitoring projects as well as providing evidence of how to heal Country. There must be nothing about us without us. We must not just be given a seat at the table; we must set the menu. Empower us and you empower yourselves – no group of people are more invested in caring for the environment and keeping it healthy than Indigenous peoples.*

Physical and mental health concerns

There are additional concerns when considering the potential physical, cultural and spiritual impacts of unconventional gas developments on Aboriginal people and communities. Aboriginal people are highly overrepresented in the rural and remote areas where most developments are proposed, especially in the Northern Territory and Western Australia, and would clearly be disproportionally affected by disturbance of their lives and their communities and all of the potential harms from the gas developments.

A seminal paper by former Aboriginal and Torres Strait Islander Social Justice Commissioner Mr Tom Calma (2007) summarised a human rights-based approach to promoting the social determinants and health of Indigenous Australians. He emphasises:

> *the right of self-determination includes the right of peoples to freely 'dispose of their natural wealth and resources' and that 'in no case may a people be deprived of its own means of subsistence … supporting traditional culture – including customary law and governance structures – is likely to help improve the health status of people living in remote communities. In practice, this also means ensuring Indigenous peoples have access to their traditional lands. While Indigenous commentators have highlighted the social and culturally related health benefits of access to land, many possible positive health impacts are likely including improved diet, exercise, and the reconnection of Indigenous peoples with their traditional economic bases.*

Because of the historical and contemporary impacts of colonisation and losses described by Calma (2007) and above, Aboriginal people already experience substantially higher burden from all of the health conditions that have been associated with exposure to unconventional gas developments (Section 5.1). These conditions include heart and respiratory conditions (including asthma and chronic obstructive airway disease), low birth weight, some cancers, mental health challenges and traffic accidents (Australian Indigenous Health InfoNet, 2023). The environmental health conditions that Aboriginal people living remotely experience are often substandard and not protective against air pollution and extreme

Because of the historical and contemporary impacts of colonisation and losses … Aboriginal people already experience substantially higher burden from all of the health conditions that have been associated with exposure to unconventional gas developments

heat, and water supplies are difficult to monitor and maintain (Water Services Association of Australia, 2022; Quilty et al., 2022; Australian Indigenous Health InfoNet, 2023).

There are no specific research publications on the impacts of gas developments on Aboriginal peoples' health to date. However, a submission to the draft Final Report of the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory by the Aboriginal Medical Services Alliance NT (AMSANT, 2018) concluded:

> *imposing fracking against the wishes of large sections of the Aboriginal community is likely to worsen health and wellbeing through increased community discord, and heightened levels of depression and anxiety with subsequent effects on physical health and wellbeing. Aboriginal health is connected to the health of the land and water- so threatening the physical environment directly affects Aboriginal wellbeing. Aboriginal people already suffer unacceptable rates of mental health issues and chronic disease. The benefits in terms of employment are likely to be limited and short term. AMSANT considers fracking to be an unacceptable risk to the health and wellbeing of Aboriginal people in the NT with the risks clearly outweighing the benefits.*

These sentiments expressed by AMSANT were also recorded in consultations undertaken for the Independent Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) which stated:

> *Aboriginal people from regional communities who made submissions to the Panel almost universally expressed deep concern about, and strong opposition to, the development of any onshore shale gas industry on their country…*
>
> *The Panel received an abundance of evidence that the broader Aboriginal community was not being appropriately informed about fracking or the potential for an onshore shale gas industry more broadly.*
>
> *The responses to the presentation by the Panel at community consultations on the processes involved in fracking for onshore shale gas suggests that the knowledge of the likely impacts of this industry within the Aboriginal community in the Beetaloo Sub-basin, and more widely, is wholly inadequate.*

An Open Letter to Parliament from Traditional Owners with over 35,000 signatures (Knowles 2021) stated:

> *Our connections to Country have been established and proven time and time again by the white man's law. We hold the Native Title and Land Rights — a system that is meant to protect and enforce our rights. These have been denied to us… For years, we have been told lies by the gas and oil corporations. That there would be no damage to the Country or poison in our waters. These companies won't even answer the most basic of questions — where they plan to drill or how many wells they want to build.*

The Traditional Owners noted the lack of respect shown to them by gas corporations, saying they have failed to *"follow proper process in consultation with us, failed to acquire consent, failed to provide transparency in their dealings with us, and have systemically excluded our voices from the decision-making process for activities on our Country."*

The letter to Parliament also noted their feelings regarding the behaviour of the Federal Government. *"This Federal Government coming in over the top of what little processes we have undermines our land rights as Northern Territory Traditional Owners,"* and *"The same Government who has never come out to our communities to sit with us or meet with us. They are failing to represent us."*

The statements are supported in a literature review commissioned by The Jumbunna Institute for Indigenous Education and Research (n.d.). This review examined whether the principles of free, prior and informed consent were met in the determinations with Traditional Owners that led to the current progression of plans for oil and gas development in the Northern Territory. Examining documentation of the circumstances of the processes used in communicating with Traditional Owners, the review concluded:

> *Given these findings, and from the findings and recommendations of the Pepper Inquiry, there is adequate information to form the conclusion that most, if not all, exploration permits issued in the Northern Territory for unconventional gas were issued in the absence of FPIC, as it is conceived of under international law.*

In 2009 Australia formally committed our nation, including state and territory governments, to all the principles embedded in the UN Declaration on the Rights of Indigenous Peoples (United Nations, 2007; Australian Human Rights Commission, n.d). In signing, Australian government committed to *"recognising the urgent need to respect and promote the inherent rights of Indigenous peoples which derive from their political, economic and social structures and from their cultures, spiritual traditions, histories and philosophies, especially their rights to their lands, territories and resources"*. Among many references to rights to health, Land and custodianship, the Declaration specifies that:

> *Indigenous peoples have the right to the lands, territories and resources which they have traditionally owned, occupied or otherwise used and acquired (Article 26(1))*

> *Indigenous peoples have the right to conservation and protection of the environment and the productive capacity of their lands, territories and resources. States shall establish and implement assistance programmes for Indigenous peoples for such conservation and protection, without discrimination.*

Twelve years after signing the UN Declaration on the Rights of Indigenous Peoples a report on "Implementing UNDRIP" from the Australian Human Rights Commission (2021) showed that the Australian Government has not taken steps to implement UNDRIP into law, policy and practice; has not negotiated with Indigenous peoples a National Action Plan to implement the UNDRIP; and has not audited existing laws, policies and practice for compliance with the UNDRIP.

What has been observed in the Northern Territory, the Kimberley, Narrabri and across the country where unconventional gas operations have threatened or commenced, is that the obligations of governments and industries to respect the rights committed to in UN Declaration have been contravened. These harms impact on the physical, social, emotional and spiritual wellbeing of Aboriginal people even before the processes of road building, site preparation, drilling, hydraulic fracturing, gas production, wastewater retrieval, transportation and handling and compressor stations begin proliferating across their lands. Despite these deep wounds, Aboriginal people who are against these developments are maintaining leadership in the battle to protect their Country. To proceed with these invasive impacts on Country against Traditional Owners wishes is likely to have devastating impacts.

> ***There is an urgent need for evidence from Indigenous peoples' perspectives, and investments in Indigenous knowledges in science, energy use and caring for Country, especially because these uphold cultural protocols of intergenerational transfer of knowledge and supporting young people as leaders of the future who inherit climate crises.***
>
> Professor Megan Williams, personal communications

Summary

This Section has brought forward just a few voices from the countless Aboriginal and Torres Strait Islander people who have stood up to protect their Lands and waters from harmful development for over 230 years. Some Traditional Owners have spoken out about the lack of respect for their right to self-determination and to make decisions over their Lands with free, prior and informed consent that they have experienced with proponents of the oil and gas industry. These rights are enshrined in the UN Declaration for the Rights of Indigenous Peoples which Australia committed to in 2009. In addition to the risks and harms to physical, psychosocial and mental health and safety described in Section 5.1 and 5.2, the oil and gas developments clearly threaten the cultural and spiritual health of many Aboriginal Australians.

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5.4 Sexual violence: Threats to the safety of girls and women with evidence from the United States, Canada and Australia

Globally, the introduction of gas and oil extractive industries into remote areas with a transit and fly in-fly out workforce has brought many safety risks and disturbances to local populations, including increased crime rates, antisocial behaviour, truck traffic and accidents as discussed in Section 5.2. For example, Ruddell et al. (2014) reported higher crime rates and an 18.5% increase in violent crime reported between 2006 and 2012 in communities impacted by oil extraction, and a decrease of 25.6% in a matched sample of counties that had no oil or gas production.

However, the most disturbing of these are accounts of sexual and related violence. This Section first describes this based on reports prepared by First Nations Canadians and Native Americans on how their people are subjected to workforces conducting extreme extraction in remote areas. The Section then describes how the circumstances that enable such behaviour and suffering are clearly evident in Australia.

Most relevant of these to Australia is the identified association between oil and gas industry operations in the US and Canada and sexual violence as described within their Missing and Murdered Women and Girls research and investigations.

The submission documents the connection between extreme extraction and sexual violence against Native women…

First Nations People's experience in the US and Canada

An article and artwork published in *Indian Country Today* (2015) depicts what is widely seen in Canada as an epidemic of sexual violence.

The publication reports:

On April 21, 2015, a coalition of Native American and women's organizations filed a submission to the United Nations Expert Mechanism on the Rights of Indigenous Peoples to be tabled in the Fourteenth Session of the UN Permanent Forum on Indigenous Issues. This submission requested UN intervention in the epidemic of sexual violence brought on by extreme fossil fuel extraction in the Great Lakes and Great Plains region (Indian Country Today, 2015).

The submission documents the connection between extreme extraction and sexual violence against Native women in the Bakken oil fields of western North Dakota and eastern Montana, and the Tar Sands region of Alberta, Canada, where vast "man camps" of temporary labor have become lawless hubs of violence and human trafficking. It also contextualizes this epidemic within the history of colonization, genocide and systemic violence against Indigenous peoples, which has always disproportionately affected women and girls.

Four years later, "Reclaiming Power and Place: The Final Report of the National Inquiry into Missing and Murdered Indigenous Women and Girls in Canada" (2019) recorded many similar statements and stories regarding the unsafe circumstances created through extractive industries, particularly oil and gas, and suffering among Indigenous women and children. For example:

> *The industrial system of resource extraction in Canada is predicated on systems of power and domination. This system is based on the raping and pillaging of Mother Earth as well as violence against*

> *women. The two are inextricably linked. With the expansion of extractive industries, not only do we see desecration of the land, we see an increase in violence against women. Rampant sexual violence against women and a variety of social ills result from the influx of transient workers in and around workers' camps.*

(Statement by Melina Laboucan Massimo, of the Lubicon Cree First Nation. page 586)

The Report concluded:

- "There is substantial evidence of a serious problem demonstrated in the correlation between resource extraction and violence against Indigenous women, girls, and 2SLGBTQQIA+ people. Work camps, or "man camps," associated with the resource extraction industry are implicated in higher rates of violence against Indigenous women at the camps and in the neighbouring communities.
- This increased rate of violence is largely the result of the migration into the camps of mostly non-Indigenous young men with high salaries and little to no stake in the host Indigenous community.
- Industries that create "boom town" and "man camp" environments are implicated in increased rates of drug and alcohol-related offences, sexual offences, domestic violence, and gang violence, as well as sex industry activities in the host communities. These occurrences disproportionately impact Indigenous women, girls, and 2SLGBTQQIA+ people.
- The influx of people as a result of "man camps" near or within Indigenous, remote and rural communities further results in stress on already limited social infrastructure, such as policing, health, and mental health services".

A lack of reporting of sexual violence and, in some cases, police vigilance regarding missing and harmed women hampers quantification and effective response to these crimes, however mixed methods research using both qualitative and quantitative approaches are starting to document trends and linkages.

Martin et al. (2019) compared changes in frequencies of violence in the Bakken region of North Dakota before and after shale oil extraction began, and in a similar region without oil or gas developments. They reported 70% increases in rates of reported violent victimisation, 44.8% increase in unlawful sexual contact, and 47% increases in serious domestic and stranger violence during shale oil extraction, while decreases were evident in regions without extractive operations.

First Peoples Worldwide (2019; 2020), University of Colorado at Boulder, disaggregated these data by ethnicity and found that violent victimisation of Blacks and Native Americans occurred at 2.5 times that of white residents. Unlawful sexual contact, particularly statutory rape cases, increased 53% among Native women in the extraction region. These findings support earlier work demonstrating higher rates of violent victimisation among Native women (Martin et al, 2012; Finn et al., 2017; Jayasundara et al., 2018; Grisafi, 2020). The report also emphasised the serious underreporting of these crimes, especially among Indigenous people, due in part to mistrust of government agencies and fear of reprisal.

There are clear similarities in the circumstances present in these North American settings and many of the locations under Gas Exploration Licenses and slated for development through the 'gas-led recovery' scheme in Australia. All contributing factors to these circumstances are highly present in these regions: from FIFO workforces, sharp economic disparities, over-representation of Aboriginal communities in the impacted areas, privilege and power imbalances, patriarchal social forces embedded in the remote context, enduring impacts of colonisation, higher background levels of domestic and family violence as a result of

colonisation, to underpolicing and poor service access. As remote communities in Australia often struggle to meet basic needs, women can be vulnerable to sexual exploitation for money, food or addictive substances.

Evidence of risk in Australia

While no direct data are available regarding sexual violence and gas developments in Australia, there is now substantial evidence of sexual harassment and abuse against women working within the FIFO mining environment.

In its Fifth National Survey on Sexual Harassment in Australian workplaces, the Australian Human Rights Commission (2022) found a high prevalence of sexual harassment in the mining industry, with 62% of the females and 25% of males in the workforce affected within the previous five year period, compared with 31% across all workforces.

The reality and details of these behaviours within the FIFO mining setting are revealed in a landmark Report published in June 2022 entitled "Enough is Enough: Sexual Harassment against women in the FIFO mining industry" in Western Australia. The Report described high levels and detailed experiences of sexual harassment and sexual assault by male workers towards their female colleagues which shocked the Members of the Inquiry Committee, as described by the Chairperson:

> *Our first line of questioning was to establish how prevalent sexual harassment is across the sector. The shocking conclusion we had to draw was that sexual harassment has long been and continues to be prevalent across the industry. This was in line with what the Australian Human Rights Commission identified in 2020 – that mining was one of the worst five performing industries. What we were not prepared for, and what we only learned because so many brave individuals shared their stories with us, was the appalling range of behaviours that women have endured in this industry* (p xiii).

The Committee described their experience as "*We heard a staggering range of abuse, harassment and assault.*" (p 11)

Please note: readers who are concerned about the impact of these stories might choose to skip the following quoted section.

In her Forward to the Enough is Enough Report, the Chair summarised:

> *There were stories of sex dolls put in front of women's dongas, and sex toys hung on their doors. Stories of unsolicited and unwelcome sexual attention, stalking, texting of explicit and lewd material, and horrifying stories of sexual assault. We heard details of unwanted touching, sexual comments, provocative photo requests and grooming. We heard of powerplay behaviour known as 'shovelling' where iron ore would be dumped on the cab of trucks operated by women if they didn't comply with sexual requests. These stories and the others we heard illustrate the full range of behaviours that make up sexual harassment and sexual assault as well providing examples of general incivility – which is well-recognised as a precursor to worse behaviour.*

Other comments made by informants included:

> *There was 'an expectation that the few woman [i.e. other workers] that these men encounter on remote exploration sites will be available to have sex with them.*

One witness compared the situation to "*witnessing bloodhounds on the trail*".

> *This is a culture on a mine site; it is normal. You walk in and you know what you are getting yourself into, you just do not realise how bad it is, that these guys in a lot of ways are grooming these young girls. We are talking young apprentices, young wannabe digger operators, stuff like that.* (p 23)

The Committee found that:

- The West Australian FIFO industry embodies the main risks to sexual harassment
- The culture of mining has perpetuated poor behaviour
- Underreporting is endemic as reporting such experiences are often negative to the victim and ineffective at impacting the perpetrator.
- There is clearly a power imbalance in the mining and resources sector.

Although the report does not attempt to quantify the proportion or suggest that 'most' men working in the industry commit sexual harassment and sexual violence, the Committee confirmed acceptance of a culture and circumstances where this can flourish. The very high proportion of women working in the industry who experience this behaviour demonstrates the widespread harms caused by those that do. The Committee made an important point when stating that male workers who say they are "unaware of" or "have never seen" these behaviours present in their workplace is not evidence that it is not occurring. These findings are consistent with theoretical understandings of sexual violence against women in male dominated settings (DeKeseredy and Donnermeyer, 2022).

Twenty four recommendations were made to address this often criminal behaviour and to help women workers in the mining industry feel and be safe and also be heard when an incident of sexual harassment or abuse is perpetrated upon them.

However, there is no mention in the Report about women and children living in communities nearby mining sites, and those living in communities along trucking routes. While enhanced rights and protections of women working in the industry are important, there appears to be no equivalent effort to protect women and children impacted by

Twenty-four recommendations were made to address this often criminal behaviour and to help women workers in the mining industry feel and be safe and also be heard when an incident of sexual harassment or abuse is perpetrated upon them.

this culture who do not work in the industry. It is plausible that a perpetrator may perceive the risk of losing their job or facing legal consequences is lower for sexual violence crimes committed in a nearby community rather than in the workplace, especially if the workplace recommendations of the Inquiry are implemented. This is especially true for a community trying to cope with the immense disruption of their lives from being in a gas field zone where, for example, law enforcement agencies and assault services become overstretched (Carrington et al., 2011; Ruddell et al., 2014; Jayasundara et al., 2018).

Lockie (2011) explored intimate partner abuse and its impact on women's health in the Bowen Basin, considered Australia's premier coal mining region, near the regional city of Mackay in Central Queensland. Police records for the two statistical divisions in the region revealed a substantially higher rate of reported sexual offences (361 and 430 per 100,000 people) compared to the rest of Queensland (169 per 100,000). A survey completed with 532 women living in the region revealed a range of factors influencing the likelihood of women experiencing physical, psychological or financial abuse, including growing up in a mining town and partnering with men in the mining profession.

As suggested above, women and children in remote areas may face enhanced vulnerability due to factors such as lack of resources, ongoing impacts of colonization and

transgenerational trauma, fear of reporting to authorities and lack of adequate services for their protection.

Mass truck movements through communities

There is a lack of studies on the impact of long-haul truck drivers on individuals and communities along their routes, especially related to any role they may play in the spread of drugs and direct or indirect sexual violence in vulnerable communities. McCree et al. (2010) described the circumstances involved and evidence of risky sexual behaviour, often associated with drug addictions, among commercial sex networks accessed by truck drivers in New Mexico. Similar circumstances are described among truckers in Florida (Stratford et al. (2002) and Arizona (Apostolopoulos et al., 2012).

Equivalent studies are not apparent in Australia, where research has focused on truck drivers' health. A national cross-sectional survey of 1320 truck drivers in Australia by van Vreden et al. (2022) revealed a high prevalence of multiple physical and mental health problems, including moderate and severe levels of distress especially among younger drivers. Participants in the Driving Health Study described a wide range of circumstances contributing to distress, including being away from home, experiencing break up and divorce as a result, unrealistic demands, and lack of respect and support systems (Pritchard et al., 2020). More research is needed, especially among truck drivers specifically associated with the remote area mining industry.

Exceptionality and invisibility of these risks

The instruments and reports used in Australia to assess the health impacts of the gas industry on people living in nearby communities contain no evidence of an intention to protect women and children. The concerns for these communities subjected to the massive influx and passage of FIFO workers in the proposed gas developments and the associated rampant and appalling behaviours are rendered completely invisible (Scientific Inquiry into Hydraulic Fracturing in the Northern Territory, 2018; Regional Report: Strategic Regional Environmental and Baseline Assessment for the Beetaloo Sub-basin, 2022; Environmental Health Baseline Report: Population Health, 2022).

For example, in the 327 page Regional Report: Strategic Regional Environmental and Baseline Assessment for the Beetaloo Sub-basin (SREBA) (used by the NT government to green light the development), the word 'sexual' is mentioned eight times, all followed by sexually 'transmitted diseases' (Department of Environment, Parks and Water Security, 2022). The words 'assault' and 'violence' are mentioned zero and two times, respectively. Furthermore, the full Environmental Health Baseline Report for the SREBA published by Flora and Fauna Division of the Department of Environment, Parks and Water Security (Jacobs 2022) mentions the word 'sexual' 10 times in the phrase 'sexually transmitted disease', 'assault' zero times and 'violence' only once.

Besides the oversights which potentially contravene obligations under the United Nations Declaration of the Rights of Indigenous Peoples, Article 22 specifically requires signatories (including Australia) to protect the Safety of Women and Children (Article 22(1&2). Section 1 states that "*Particular attention shall be paid to the rights and special needs of Indigenous elders, women, youth, children and persons with disabilities in the implementation of this Declaration*". Section 2 requires that "States shall take measures, in conjunction with Indigenous peoples, to ensure that Indigenous women and children enjoy the full protection and guarantees against all forms of violence and discrimination".

Furthermore, the UN Women (2020) have prepared a Programme brief entitled, Extractive industries, gender and conflict in Asia Pacific to address the harms that women can experience as a result of male dominated processes. The oversight of women's and children's safety both within FIFO mining operations and in affected communities across the risk assessment documentation on Australia's gas expansion plans is also consistent with the findings identified in this Brief, for example:

> *Gender-blind policies and practices create contexts where women are routinely denied access to and control over the benefits of mining, while their needs and interests are excluded from decision-making processes… Not only do women receive fewer of the benefits from extractive industries, they are also more adversely affected by their negative impacts, as shown by an increasing number of studies.*
>
> (UN Women, 2020, p3).

These gender-specific problems are duly compounded by the overall lack of free, prior informed consent raised by Aboriginal people whose Traditional Lands would be affected by gas operation processes and infrastructures (Jumbunna Institute for Indigenous Education and Research, n.d.).

Interestingly, the Department of Foreign Affairs and Trade's Child Protection Guidance Note on Extractive Industries (2017), reported:

> *Often, in-migration causes or escalates the sexual abuse and exploitation of children (including prostitution and trafficking), the rate of teenage pregnancy, and the spread of communicable diseases. When companies transport materials by truck, the abuse and exploitation of children along transport routes can increase.*
>
> *Mining sites can attract children and young people (to sell market goods, for employment as housekeepers, to look at machinery, to get sweets and gifts from labourers) thus allowing opportunities for children and young people to be exploited and abused.*

However, no such considerations are raised in deliberations about the health and safety impacts and risks to children in Australia's remote communities.

The oversight of this serious threat to the health and wellbeing of women in the vicinity of remote gas operations opens the door to the extreme mental health consequences and lifetime, and often transgenerational, impacts of sexual violence on a child's or woman's life. To summarise, these include depression, anxiety and intense fear of repeated attacks, pregnancy and sexually transmitted diseases, post-traumatic stress disorder, poor educational attainment, difficulty in partner and parental attachment, sexual promiscuity, victim-perpetrator cycles, alcohol and drug addiction, low self-esteem and self-worth, restricted social activities, view of the world as unsafe and dangerous, incarceration and suicide (ODDONE Paolucci, 2001; Boyd, 2011; Phoenix Australia, n.d.).

Furthermore, research on the body's response to severe trauma, such as sexual violence, is revealing how hormones induced by traumatic stress cause long term impacts on the endocrine, central nervous and immune systems in the body. Persistent emotions, such as humiliation, guilt, fear, and self-blame, may promote suicidal thoughts and feelings of 'unbearable secrecy' which prevent help-seeking and resolution (Sigurdardottir and Halldorsdottir, 2021). This ongoing suffering can program the body towards inappropriate inflammatory responses, which enhance the development of mental and physical health problems, such as depression, anxiety, suicidal thoughts, chronic pain and back problems, eating disorders, diabetes and heart disease (Sigurdardottir and Halldorsdottir, 2021; Kuhlman et al., 2017).

While appropriate therapeutic support is vital for recovery, this is rarely available in remote Australian settings. These settings are the most likely to experience the risks known to be associated with major gas developments, especially amongst Indigenous people as revealed by the US and Canadian experience.

Governments must exercise duty of care to prevent circumstances that are clearly known to foster and enable these kinds of crimes, most often committed against women and children, sometimes even within the mining workplace itself.

Summary

Evidence has been presented that highlights the particular risks and occurrence of sexual harassment and violence that has been perpetrated in the United States and Canada, particularly of First Nations women and children. Evidence from Australia about disregard for women's safety within the FIFO mining workforce suggests that these same risks would equally apply in the Australian context. The West Australian Inquiry demonstrated the high proportion of women experiencing harassment and violence, the enabling work culture and circumstances, the diversity of both sexual harassment and violence behaviours among the FIFO workforce, lack of accountability for punishing perpetrators and the reasons for non-disclosure borne by women working in Australia's mines. With no acknowledgement of the likelihood that this dangerous situation will harm communities nearby these operations, it appears that governments are not recognizing their responsibility for the protection of women and children in their jurisdiction subjected to these harms outside the mining setting. The massive truck movements through the developing areas during and after the boom phase (described in 5.3) are likely to amplify these risks.

The behaviour of the gas industry and approving governments in Australia ignoring these risks or considering them to be 'exceptional' rather than sources of immense pain, physical and mental harm and loss, often compounding immense grief and loss, is consistent with that found globally (Togalagba, 2020). To consider only sexually transmitted disease (Jacobs 2022), rather than also considering the possibility of these diseases having occurred because of heinous crimes and deep wounds against women and children, exposes a serious problem in health impact assessment and baseline monitoring. Regardless of attitude, the government's relentless push to create circumstances known to enable this harm in areas where women and children are particularly vulnerable, must be addressed in any assessment of the industry's severe psychosocial and physical health costs.

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6. Discussion and conclusions

This Report brings together and reviews the extensive body of research on the breadth and magnitude of potential direct and indirect risks to human health and wellbeing associated with gas and oil developments. The research has helped to identify, characterise and quantify these risks. Our ability to understand and document the various avenues for potential chemical contamination of air and water and consequent human exposure has improved as studies have identified a wide array of potential toxicities of chemicals used in hydraulic fracturing and those naturally occurring in produced wastewater. This work clearly indicates that these complex mixtures of chemicals have the capacity to cause negative health outcomes in exposed infants, children and adults.

Health practitioners, medical professionals and affected community members are particularly concerned by the rapidly accumulating evidence of associations between proximity to high intensity gas extraction activities and the incidence of asthma exacerbations and respiratory hospitalisations, sinus conditions, depression and anxiety and hospitalisations for heart attacks and heart failure. Studies on infants have associated lower birth weights and higher pregnancy complications, birth defects and blood cancers with their mothers' residence near oil and gas developments during pregnancy. While most of these studies have been conducted in the United States, exploratory hospital-based studies comparing regions with and without coal seam gas mining suggest that similar trends in these outcomes may be emerging in Queensland. These health and developmental effects may appear disparate, but they are all known potential manifestations of exposure to volatile organic compounds, ground level ozone, oxides of nitrogen and other chemicals linked to oil and gas operations.

We have special concerns about infants and children, who face higher risks than adults from toxic exposures after birth due to their higher metabolic and respiration rates (breathing in more toxins), smaller body size and smaller and immature organs, including the liver, lungs and kidneys that deal with or store toxins entering the body. Children are also exposed to toxins in the environment through outdoor play activities. Conversely, it is also concerning if children do not feel safe to play outside, as lack of physical activity is also associated with poorer physical and mental health.

The American Academy of Pediatrics' Policy Statement on Ambient Air Pollution: Health Hazards to Children (Brumberg et al., 2021) identified the significant contribution of oil and gas operations to airborne hazards affecting American children. Similarly, the Academy's Policy Statement on Drinking Water from Private Wells and Risks to Children (Woolf et al., 2023) highlighted the significant potential for unconventional gas operations to introduce toxins into groundwater resources and potentially impact drinking water wells in the United States. Serious concern was also expressed about the potential for other health effects not yet characterised.

The lifetime impacts of antenatal and childhood exposures are unknown. Studies of longer-term impacts, such as the likelihood of developing adult cancers and chronic diseases, are limited because not enough time has elapsed since the beginning of potential widespread exposure to oil and gas activities for these diseases to manifest.

Like most complex scientific research, these studies have progressed in both volume and sophistication as funding and research opportunities have grown. First to emerge were risk assessments based on measurements of pollutants being emitted from industry activity, along with small community assessments of symptoms being experienced relative to closeness to wells. These initial findings were then followed by larger regional studies using routinely collected health data to compare disease rates before and after, close to and further away from and/or in high and low density oil and gas production areas. Increasing numbers of publications are now modelling health harms and health care costs due to air pollution impacts of the now mature, but still growing, unconventional gas industry. The most recent of these publications presented detailed estimations of deaths, morbidity and health costs in the United States associated with air pollution exposures. Difference-in-differences methodology, which reduces the chances for confounding effects (by studying the same population before and after drilling) and demonstrates temporality (indicating that exposure to active wells came before the detected health outcome measured), has also yielded increasingly precise findings. As the literature has grown, there has been no indication that the associations observed in initial studies have disappeared; rather, newer research has consistently added more extensive, robust and refined evidence supporting potential causation.

The accumulating evidence from areas outside the the United States corroborates and extends the findings regarding the many predictable concerns about, and impacts associated with, unconventional oil and gas developments. Chief among these concerns are the wide range of potentially harmful chemicals being used; the large and increasing amounts of water used for gas extraction and of wastewater produced; the stress placed on affected individuals and communities disrupted by social changes and loss of physical amenities; and the alarming contributions to increased greenhouse gas emissions at this critical time.

We are deeply concerned about the cultural and spiritual wounds that are already being felt and would be further afflicted on Australia's Aboriginal people by large developments threatening to destroy the integrity of their Lands and corrupt their waters. The report revealing poor adherence to free, prior and informed consent protocols in industry and government interactions with Traditional Owners in the Beetaloo planning process is not acceptable and has caused much pain. The risk of sexual violence against women and girls has been all but ignored in oil and gas development planning. The experiences of First Nations Canadian and Native American women and the shocking findings from the Western Australian Inquiry into the sexual harassment against women in the fly in-fly out workforce have demonstrated the seriousness of this risk.

We conclude that current research does not confirm that gas and oil developments are safe for the environment and for people. While no study is wholly conclusive on its own, the large body of work that has accumulated makes a strong case that the industry enhances risks to the health of people, especially developing foetuses and babies, and to the environmental determinants of health (climate, water and food security) on which we depend.

The limitations of this work include the possibility that some research findings may have been missed, that study quality was not individually assessed, and that the economic impacts of the industry, which may have influenced health and wellbeing, were generally omitted. It is considered likely that socioeconomic status will have advanced for some people, and declined for others, especially in Australia where landholders do not own the rights to underground minerals.

Arguably the most important implication of continuing and expanding oil and gas developments in Australia and globally is its vast carbon footprint. Substantial research has highlighted the industries' major contribution to fugitive methane and CO_2 emissions during clearing, exploration, production, storage, transportation and combustion. Particularly in remote Australia, it can be presumed that efforts to legislate, monitor and enforce over hundreds to thousands of wells will be difficult to initiate and even more difficult to sustain as the industry is allowed to grow.

From these findings, we broadly recommend that in the short term, existing and already developed gas reserves should be used judiciously to assist in the rapid transition away from coal and gas fired power stations towards clean energy resources, i.e. wind, solar, and hydroelectric energy. Domestic gas may play a small role in extenuating circumstances for some years before being phased out. Our Australian Energy Market Operator has a plan, and we must strive to adhere to it in our domestic lives. The International Energy Agency also has a global plan that shows no need for new fossil fuel expansion, and we must support it in our export policies and decisions. State, territory and federal governments need to demonstrate that they hear the voices, especially of Indigenous people and young people, who fear the future that is advancing upon us all.

As clearly demonstrated in the most recent Intergovernmental Panel on Climate Change report (IPCC, 2018), if we are to limit global warming to 1.5°C or even 2°C, the use of gas must be curtailed as quickly as possible and give way for renewable energies to take over the powering of Australia and the world. To participate appropriately in the face of this global urgency, Australia should do all in its power to assist developing countries to transition away from gas power, rather than developing an industry that would continue to push vast quantities of gas onto the world market.

We point out that the cost and feasibility of such transitions has been repeatedly demonstrated through research across the world, including Australia (Diessendorf and Elliston, 2018; Brown et al., 2018; Institute for Energy Economics and Financial Analysis, 2018). Political will is a critical requirement. We urge the Australian government to take the necessary steps to lead Australia away from fossil fuel production and into a clean energy domestic and export future that can support the health and wellbeing of current and future generations all over the world.

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Acknowledgements

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From:	Have Your Say Northern Territory
To:	imperial ep187+
Subject:	Anonymous User completed Carpentaria Pilot Project EP187 Environment Management Plan
Date:	Friday, 19 April 2024 6:19:47 PM

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Anonymous User just submitted the survey Carpentaria Pilot Project EP187 Environment Management Plan with the responses below.

Given name

[redacted]

Family Name

[redacted]

Location

LEANYER, NT

Stakeholder type

Community member

Email address

[redacted]

Interest area

Well integrity
Water
Chemicals
Flora and fauna
Waste management
Human health
Regulation and compliance

Please provide your comments

My concern is this project has not submitted a full Environmental Impact Statement under the Environment Protection Act 2019 (NT). Has this project been referred to the Federal Environment Minister under the Environment Protection and Biodiversity Conservation Act 1999 as it is likely to have a significant impact on water resources? Further concerns are the following water resource and environmental points: ● Use 950 million litres of water and millions of litres of chemicals over four years, mostly for fracking ● Project

plans to take up to 950 million litres of water from the productive Cambrian Limestone Aquifer system which is facing growing extraction pressure and which is essential to support culture, nature and communities in the area. ● The risks of aquifer connectivity between the deeper aquifers where fracking will occur and shallower aquifers relied on by communities is poorly understood, and there are risks of cross-contamination and depressurisation. ● The water licence they intend to apply for equates to roughly 9% of the total volume of groundwater allocated for fracking the Georgina Wiso Water Allocation Plan, and doubles the volume of water entitlements granted to gas companies to date. ● Only recover 5% of water and chemicals used in fracking, with the rest remaining underground ● Produce 35 million litres of toxic wastewater per well that will need to be disposed of ● Clear 225 hectares of vegetation for well-pads, gravel pits, a gas plant and a water handling station, plus gas and water flowlines. Also concerns have been raised that the project claims it will produce 25 terajoules (TJ) of gas a day, but the McArthur River Pipeline only has capacity for 15TJ a day. There's no mention or explanation of this difference in the draft EMP and no estimation of emissions from flaring the excess gas. Concerns regarding waste water: ● There are serious risks of flooding leading to pollution and environmental damage, because the project is in the headwaters of two catchments, and crosses Relief Creek and the area around it that floods. ● Wells will be located just outside the 1 in 100 year flood zone, which means they are likely to flood in more extreme events and be at greater risk with climate change. ● The waste management plan proposes that some of the 35 million litres of contaminated fracking wastewater at each well may be held in open tanks, even during the wet season and transferred in trucks to be disposed of in unspecified locations, risking spills and leaks. Government is a representative body of the people. If government continues to approve projects not in the best interest of the people then who are they representing?

Tick this box if you wish for your name and contact details to be confidential

Make my name and contact details private

From: [redacted]
To: imperial ep187+
Cc: Minister.Plibersek@dcceew.gov.au
Subject: EP187 Environment Management Plan IMP5-1 Carpentaria Pilot Project
Date: Friday, 19 April 2024 9:31:02 PM

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

To Whom it May Concern,

I am writing today to express my concerns over the proposed Carpentaria Pilot Production. This EMP needs to be rejected as the impacts and risks of the project are just simply too significant. I am a teacher located in Alice Springs, a resident of the Northern Territory, I am a mother and a very concerned citizen. There are so many gaps in the information provided by Imperial Oil and Gas to even consider allowing this EMP. The full impacts need to be investigated by the EPA, I am asking that because of the many unknown factors that this EMP is referred to the EPA for a full Environmental Impact Statement under the *Environment Protection Act 2019 (NT).* There are many questions that need addressing.
1.What is going to happen during the wet season when roads are cut off, like we have recently witnessed with the flooding of Relief Creek, all in the area of the proposed fracking wells. The EMP has not addressed this huge issue, what will happen to the toxic wastewater during these weather events? There is significant risk of flooding that leads to pollution and damage to the environment. It is stated that the plan proposes to hold fracking wastewater in open tanks, what happens to this when it floods?
2. The pipeline maths doesn't add up. The company is claiming that it will produce 25terajoules of gas a day but the pipeline that they say they want to use, the McArthur River Pipeline only has capacity for 15 terajoules a day. What is happening to the remaining gas??

I am also very concerned with the timing of the opening of this EMP proposal for comment. This was announced as many people were evacuated from Borraloola due to a severe weather event. People's lives have been placed in disarray and having only 1 month for commnet during this time is unfair and extremely unjust.

This project needs to be rejected and I call upon the Federal Environment Minister to act upon this, utilising the water trigger, under the *Environment Protection and Biodiversity Conservation Act 1999* as it is extremely likely to have a very significant impact on water resources, with 950 million Litres of water and millions of litres of chemicals being used over 4 years of fracking.

Yours sincerely,
[redacted]

From: [redacted]
To: imperial ep187+
Subject: Submission to Inquiry
Date: Friday, 19 April 2024 11:38:04 PM
Attachments: [redacted]

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Dear Inquiry
I would like to submit that the proposed fracking of Beetaloo Basin
We have a strong First Nations history in this country and the Traditional Owners have retained the knowledge of their country despite the changes over the last 200 years or so. While this knowledge is expressed at spiritual, that is because it retains a very deep and complex understanding of the land and water of their country
We say we respect out First Nations, so we need to listen to their warning of the effect of such development
Even in mainstream law, it is required to undertake a full Environmental Impact Statement under the Environment Protection Act 2019 (NT)
We request this matter is referred to the Federal Environment Minister under the Environment Protection and Biodiversity Conservation Act 1999 because it is likely to have a significant impact on water resources.

Yours sincerely,

[redacted]

Aboriginal people believe that only when non-Aboriginal people accept the spirit we offer will they really feel at home in this land. To do this all Australians must understand the culture of Aboriginal people and accept it as their own. When non-Aboriginal Australians come to understand Aboriginal people and understand the immense value of Aboriginal culture they will be fit to teach our young.
From Pat Fowell, Education (1988)

CRICOS Provider No. 00300K (NT/VIC) I 03286A (NSW) | RTO Provid

From: [redacted]
To: imperial ep187+
Subject: Submission: Carpentaria Gas Pilot Production.
Date: Friday, 19 April 2024 11:58:46 PM
Attachments: [redacted]

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Please find attached our submission from the No New Gas Coalition for the above EMP.

No New Gas Coalition NT **submission in response to: Imperial Oil and Gas Pty Ltd Carpentaria Pilot Project EP187 Environment Management Plan (EMP)**

19 April 2024

The No New Gas Coalition NT is a growing NT based coalition of individual Northern Territory residents and organisations (including but not limited to Climate Action Darwin, Environment Centre NT, Frack Free NT, Parents for Climate Darwin and NT and unions). Our combined online reach extends to over 34,750 people.

The No New Gas Coalition aims to end new gas projects in the NT. Evidence-based decision making underpins the work and positions taken by the No New Gas Coalition in regards to the impacts of the gas industry on the climate, environment, human health, culture and communities.

Summary

The impacts and risks of the Carpentaria Pilot Production EMP are so significant that the Minister is obliged to reject this EMP and the proposal.

No New Gas Coalition asks that the project:

1. Is referred to the NT EPA under the *Environment Protection Act 2019* (NT) and required to undertake a full Environmental Impact Statement; and
2. Is referred to the Federal Environment Minister under the *Environment Protection and Biodiversity Conservation Act 1999* because it is likely to have a significant impact on water resources.

As set out below, the Tamboran TAM1-1 draft Environmental Management Plan (**D/EMP**) does not comply with,

1. The requirements of the **Petroleum (Environment) Regulations (2016)**.
2. The requirements set out in the **Environment Management Plan Content Guideline - Onshore Petroleum Regulated Activities** (DEPWS 2022).
3. The requirements of the **Code of Practice Onshore Petroleum Activities in the Northern Territory** (2019).

The direct, indirect and cumulative impacts and risks of the proposal, to the extent they have been set out in the D/EMP, are clearly not environmentally sustainable or capable of being approved as environmentally acceptable. **For these reasons the Minister is obliged to reject this D/EMP and the proposal.**

Timing of release

The timing of the release for public comment of Imperial Oil & Gas Pty Ltd's (Imperial's) EMP occurred on United Nations World Water Day and in the midst of a cyclone (for which there was some warning), when heavily impacted residents and communities had homes damaged, were displaced through mandatory evacuation, unable to easily return and under stress to meet the basic necessities of life for much of the public comment period. This timing which could have been easily delayed, erodes public trust and confidence in relation to the assessment and regulation of fracking for fossil methane gas in the Beetaloo sub-basin and given previous similar timings from other companies, is justifiably received with cynicism. We strongly recommend amending the relevant legislation to enable the Minister to grant extensions to public comment periods in such mitigating circumstances.

1. Requirements under relevant legislation and regulation

As set out in regulations 8 and 9 and Schedule 1 of the Petroleum (Environment) Regulations (2016), the EMP MUST include or satisfy the following requirements:

- *a **description of the regulated activity** to which the plan relates*
- *be **appropriate for the nature and scale** of the regulated activity to which the plan relates*
- *address **all direct and indirect environmental impacts and risks***
- *address the **cumulative effects** of those impacts and risks*
- *provide **comprehensive information** about all relevant matters*
- ***demonstrate** that the activity will be carried out in a manner by which the environmental impacts and environmental risks of the activity will be reduced to a level that is (a) as low as reasonably practicable and (b) acceptable.*

2. Failure to adequately address scale and associated risks of major hazardous industry project

Contrary to the requirements of the legislation, the EMP fails to provide comprehensive information that is appropriate to the nature and scale of the project to enable an assessment of the project's impacts and risks.

- The proposal outlined in the EMP amounts to a major, hazardous industrial project in a remote region of the Northern Territory which is increasingly experiencing extreme temperatures and severe heatwaves, large scale bushfires and high intensity rainfall events.
- The project would occur within a jurisdiction, the Northern Territory, which has repeatedly demonstrated limited and inadequate capacity for the environmentally responsible regulation of large scale hazardous extractive projects.
- The NT government has made clear its political determination to rapidly proceed with fracking across the Beetaloo in spite of its failure to implement the recommendations of the Pepper Inquiry[1] and the SREBA study.[2]
- The overall project will clear up to 229 hectares of native vegetation and wildlife habitat, bringing the total cumulative clearing approved in the area for fracking activities to nearly 1,200 hectares.
- The project would involve **hundreds of 'B-triple' heavy truck movements**, carrying chemicals, contaminated wastewater, sand (proppant) etc, along highways and dirt roads to access each of the twelve well sites.
- The EMP indicates that over four years, the project plans to take **950 ML (million litres)** of groundwater from the Gum Ridge Formation, part of the productive Cambrian Limestone Aquifer (CLA) system, mostly for fracking. This water is essential to supporting culture, nature and communities in the area but is facing growing extraction pressure.
- However, Imperial will apply for a licence to extract up to **750ML *per year***, roughly 9% of the total volume of groundwater allocated to petroleum in the Georgina Wiso Water Allocation Plan, to remove this water from the Gum Ridge Formation. This is roughly 9% of the 8GL of water allocated to gas activities in the Georgina Wiso water plan. If granted, this 750ML licence would effectively double the volume of water entitlements granted to petroleum companies so far and occur without adequate impact/risk assessment or monitoring.[2,4] The Anthony Lagoon and Gum Ridge formations are the two major aquifers in the Cambrian Limestone Aquifer within the Georgina Basin.
- The 12-well project would entail the transport, storage and pumping down-well of **millions of litres of chemicals** (excluding sand/proppant) over four years, mostly for fracking. At least **33** of the chemicals could be '**high concern**' due to potential toxicity.[3]
- Based on figures provided in the EMP, the project would involve the generation, storage, movement and disposal of **35 million litres of toxic flowback wastewater** per well that will need to be disposed of off-site. Arrangements for this are unclear.
- As only 5% of chemical-laced frack fluid per well is recovered as "flowback", this means **0.95 x 950,000,000 = 902,500,000 litres** of water, plus the millions of litres of fracking chemicals, many of them toxic, will remain underground in fractured geological formations.

  *There remain substantial knowledge gaps regarding the geological architecture of the SREBA area, from the deep Beetaloo Basin rocks through to the shallow Cambrian and Cretaceous aquifers...The 2021 review also noted that there was a 'poor' understanding of inter-aquifer connectivity across all of these units and the **Gum Ridge Formation**, and 'moderate' to 'poor' understanding of aquifer hydrogeological parameters in these units.[4]*

- The MP proposes the installation and operation of 60 kilometres of plastic (polyethylene) piping to create a 'gathering network' to transfer contaminated wastewater and methane gas between well sites. **The adoption of this high risk activity is based at least in part on cost-cutting by Imperial**.
- Although Tamboran attempts to confuse the actual numbers, the proposal would generate approximately (at least) **~954,000 tCO2-e greenhouse gas emissions over four years.**

[1] *Final Considerations* letter to Chief Minister from Dr David Ritchie, Independent Oversight Hydraulic Fracturing Implementation (2023).
[2] Final technical report of SREBA (DEPWS, Dec 2022) which includes numerous recommendations for further and improved assessment, monitoring and ecosystem protections **which the NT government has completely ignored.** See: *Regional Report: Strategic Regional Environmental and Baseline Assessment for the Beetaloo Sub-basin (41/2022)*
[3] "An environmental risk assessment was undertaken during the GBA Program of 116 chemicals associated with drilling and hydraulic fracturing operations in the Beetaloo region, **of which 33 were of potentially high concern**. Future groundwater monitoring programs aimed at detecting contamination from onshore gas activities should be informed by identified chemicals of potential concern." SREBA final report (2022)
[4] SREBA Expert Review – Groundwater. Professor Matthew Currell and Dr Christopher Ndehedehe. Accessed at: www.ecnt.org.au/reports

3. Failure to present and address key project components, impacts and risks

3.1 'Gathering network' of polyethylene pipes for wastewater and methane gas transfer

The proponent is proposing wastewater and gas 'gathering networks' of polyethylene piping to transport wastewater and hydrocarbons between well sites **over a combined distance of ~60 km**.

There is insufficient information in the EMP about the operation, impacts and risks of the proposed **60km** 'gathering network' of polyethylene pipelines transferring wastewater and hydrocarbons from well site to well site across the project area.

Such a network of plastic pipes carrying toxic and hazardous materials raises serious issues including the risk of methane leakage, the risk of fire or explosion and the risk of contaminated wastewater leakage resulting in pollution of streams and wetlands.

The risk and consequence of methane gas or liquid hydrocarbon leakage from the gathering network igniting during bushfire emergencies is not adequately addressed or assessed in the EMP – in a region experiencing increasingly severe fire weather and extensive, long-duration bushfires as a result of climate change.

Based on the record of multiple reportable and recordable incidents at existing fracking well sites in the Territory, the safe management of such a complex and extensive system cannot be assured.

In order to comply with the requirements of the relevant legislation and regulation, a full, unambiguous description of all aspects of the proposed polyethylene pipe network needs to be presented and be subject to informed assessment.

3.2 Down-well 'loss' of millions of litres of drilling fluid and frack fluid

With 950 ML of groundwater being used, the likely loss of millions of litres of drilling fluids and fracking fluids at each well due to the nature of the geological formations being accessed via this proposal requires deeper consideration.

It is known that commonly during the drilling of the Gum Ridge Formation (GRF), partial to total losses of drilling fluid have been observed due to high permeability conduits, fractures and cavernous zones expected in karstic formations.

> *The CLA, comprising the Gum Ridge Formation and the Anthony Lagoon Beds, is an extensive, multi-layered regional aquifer system covering at least 200,000 km2 that forms the principal water resource in the Beetaloo Sub-basin, (SREBA, 2022).*

*The CLA is a **highly productive aquifer** that has **high regional connectivity** due to the development of **significant fracture and karstic secondary porosity** (SREBA, 2022). Across parts of the Beetaloo Sub-Basin, undifferentiated Cretaceous deposits form the uppermost aquifer are targeted for stock use. Notably, a basal sandstone unit immediately overlying the CLA produces yields of at least 10 L/s (SREBA, 2023). Shallow, perched groundwater has also been recorded in the laterised zone within the permit area with groundwater levels recorded between 1 and 6 mBGL. These systems are dynamic with periodic saturation resulting from recharge during the wet season with no documented groundwater use. **The CLA, comprising the Gum Ridge Formation and the Anthony Lagoon Formation, is an extensive regional aquifer system that forms the principal water resource in the Beetaloo Sub-Basin. The limestone in the CLA is commonly fractured and cavernous**; in the Katherine region, bore yields of up to 100 L/s have been recorded from this aquifer (SREBA, 2023).*

*Imperial anticipates that a potential load fluid recovery of **5%** of injected stimulation fluid.*

If only ~5% of frack fluid is recovered, this means that, in addition to the loss of much or all of the drilling fluid, 902.5 ML of chemical-laced frack fluid contamination will remain underground.

Inadequate information is provided in the EMP as to the **potential cumulative impacts and risks** of this quantity of chemical-laced drilling and fracking fluid remaining underground post-fracking. If this project proceeds and hundreds more wells are drilled and fracked as planned, the potential cumulative load of contaminated water remaining underground would run to hundreds of billions of litres.

In order to comply with the statutory requirements of the relevant legislation and regulation, a full, unambiguous description of all aspects of water use, transportation and greenhouse gas emissions, and an assessment of their impacts, needs to be presented and be subject to informed assessment.

3.3 Greenhouse gas emissions

The full lifecycle greenhouse gas emissions from the project will be substantial, but Imperial doesn't even attempt to quantify them. They acknowledge that emissions from the project would equal approx 475,000 tCO2-e per annum if they flared all the gas, but they do not estimate the downstream emissions if the gas is transported elsewhere via the McArthur River Gas Pipeline, as they propose.

Imperial claims it will produce 25 terajoules (TJ) of gas a day, but the McArthur River Pipeline only has capacity for 15TJ a day. There's no mention or explanation of this difference in the draft EMP and no estimation of emissions from flaring the excess gas or the downstream emissions from burning it.

Imperial says it plans to apply to "use the gas on an appraisal basis" meaning that instead of flaring it onsite, they want to secure a connection to the McArthur River mine gas pipeline, use their gas plant to process the gas and sell it into the network.

Recent reports have highlighted:

(a) the extreme level of emissions expected to be produced through full development of the Beetaloo sub-basin, if projects such as this from Imperial are approved.

(Climate Analytics (2023). *Emissions impossible: Unpacking CSIRO GISERA Beetaloo and Middle Arm fossil gas emissions estimates.)*

(b) the inability of emissions offsets to abate the emissions involved, due to the amount required, the cost and the lack of suitable offsets with integrity:

*In calculating the carbon costs for a broad range of Beetaloo sub-basin development scenarios, from 200 TJ/day to 3,400 TJ/day, outcomes indicate that – in each case – the overlay of carbon costs to offset the Australian component of lifecycle emissions implies a **high risk of developed shale gas assets becoming economically stranded**.*

An interim report from CSIRO's Gas Industry Social and Environmental Research Alliance into the use of

*offsets for lifecycle GHG emissions for onshore gas in the NT has similarly signalled that, "**the cost of offsetting Australian emissions from consumption of NT gas would be prohibitive**" for scenarios considering offsetting more than 200PJ/year (548TJ/day) of domestic consumption (GISERA2021).*

Reputex Energy (2021). *Analysis of Beetaloo gas basin emissions and carbon costs*. Australian carbon advisory, September 2021

(c) the world-wide failure of carbon capture and storage (CCS) as an abatement strategy: ***Conclusion:***

Failed/underperforming projects considerably outnumbered successful experiences

The immediate inference from the projects reviewed is that the number of failures and the underperformance of these projects with carbon capture technology has outnumbered the successful projects considerably. Ten of the 13 flagship projects reviewed, comprising 90% of the total capture capacity in our sample, have failed or are underperforming mostly by large margins...Further, recently published research by the Imperial College London on the capture performance of operating projects since 1996 confirms the underperformance of most projects against their designed/claimed capture capacity...Successful CCUS exceptions mainly existed in the natural gas processing sector serving the fossil fuel industry, leading to further emissions.

Institute for Energy Economics and Financial Analysis (2022). The Carbon Capture Crux: Lessons Learned

(d) statements from leading global bodies including IPCC, United Nations and IEA that development of large new fossil fuel basins, such as the Beetaloo sub-basin, is not needed and cannot proceed if the world is to avoid catastrophic climate change.

In summary,

- The company fails to clearly state or address the project's full lifetime emissions, including scope 3 emissions, expected from the development of the Beetaloo sub-basin, and the fact that it will not be possible to abate these emissions using credible carbon offsets or reliable carbon capture and storage (CCS/CCUS).
- The company fails to include emissions from key project components including mining and transport of huge quantities of sand (proppant) and disposal of large volumes of wastewater;
- Concerns exist regarding methane leak detection activity with significant risk of significant methane fugitive emissions could occur without detection.
- Based on its annual emissions, **475,000 tCO_2-e**, this proposal clearly falls within the scope of the NT government's 'Large Emitters Policy' which,

  *"Applies to new projects and expansion of existing projects that are considered to be 'large emitters'. The Large Emitters Policy defines 'large emitters' as projects that meet or exceed emissions thresholds: ○ The industrial project threshold is **100 000 tonnes carbon dioxide equivalent (tCO2-e) (scope 1) in any financial year** over the life cycle of a project.*

As a result of the failure of the EMP to comprehensively and accurately present the carbon emissions and climate impacts and risks of the proposal, the EMP is again in breach of the relevant legislation and regulations.

3.4 Chemical threats to air quality

In regards to air quality, emissions of nitrogen oxides, carbon monoxide, volatile organic compounds (VOCs) and the vast array of other chemicals that are known to be released into the air during all steps of the fracking process, including but not limited to: polyaromatic hydrocarbons, radioactive materials, hydrogen sulphide, acrolein and heavy metals are of profound concern

It is known through the body of scientific literature assessing the potential local, regional and global health-related impacts associated with this industry (more than 2000 peer-reviewed publications within the last decade, see Haswell *et al.*, 2023), that a cocktail of additional chemicals form in the atmosphere, including formaldehyde, particulate matter from aerosols and ground level ozone, which travel long distances damaging

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As a result of the failure of the EMP to comprehensively and accurately address the body of scientific literature that would have Imperial define risk scenarios and sources for these chemicals and, if possible, present rigorous risk mitigation measures, the EMP is again in breach of the relevant legislation and regulations.

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A "*substantial quantity of increasingly rigorous research evidence has accumulated from studies across oil and gas basins, especially in the United States of America… Finding a greater burden of health loss among those most exposed to oil and gas operations and infrastructure.*

Reported health risks include:

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- *higher injury and fatality rates from increased large truck traffic volumes*
- *higher incidences of depression, anxiety, social withdrawal among young females and*
- *higher prevalences of sexually transmitted infections, linked to the impacts of oil and gas operations on home and community life.*

Furthermore, multiple studies have detected interference with normal development of unborn babies. This includes higher risk of low birth weight, preterm delivery and spontaneous abortion, severe birth defects and risk of acute lymphoblastic leukaemia. Many studies have demonstrated that these outcomes occurred after, not before, gas development commenced, while others have shown that these outcomes specifically occur downwind and/or downstream (groundwater flow) of gas operations. Most studies have controlled for a wide range of potential confounders (other explanations for the observed differences)."

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The impact of this water removal on the flow of groundwater locally and regionally is largely undescribed.

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Clearly, in the absence of crucial hydrogeological information as set out above, the proponent cannot claim to adequately understand the impacts or assess the risks of its proposed drilling and fracking operations.

Given limited knowledge of the CLA, a full Environmental Impact Statement is required that properly investigates the hydrological properties of the aquifer, its cultural and ecological values and the impact of this water removal on those values.

The potential groundwater risks of this project are not addressed in the EMP, in breach of the relevant legislation and regulations.

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If there are large or multiple failures in the plastic pipe network, in a severe rainfall event, the reduced storage tank availability may result in large scale contaminated water releases to the environment.

Such a high risk strategy, using untested plastic pipe networks to replace wastewater storage tanks, cannot be approved.

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Three nationally-listed threatened species are recorded or likely to be present in the area, the Grey Falcon, Painted honeyeater and Gouldian finch as well as five migratory birds protected under national environment law.

4. Failure to comply with legislation, regulation, codes and guidelines

In addition to the failure to comply with the requirements for a EMP set out in the Petroleum (Environment) Regulations (2016), as discussed above, the EMP also fails to comply with the DEPWS 'EMP Content Guideline' and the **Code of Practice Onshore Petroleum Activities in the Northern Territory (2019)**.

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It is important, therefore, that EMPs:

- *are assessable by the Minister for Environment, through inclusion of:*
  - ***all required content under the Regulations***
  - ***clear, systematic and rigorous identification of all environmental impacts and risks*** *based on* ***well-defined activity descriptions*** *and* ***reliable environmental information***
  - ***clear demonstration of ALARP and environmental acceptability and how activities may be carried out in a manner consistent with the principles of ESD***
  - *a fit-for-purpose implementation strategy that outlines the inspection, audit, monitoring and reporting programs that will be used to confirm the effectiveness of risk mitigation measures and measure and respond to environmental performance;*
- *are auditable by the regulator, through inclusion of:*
  - ***measurable and specific environmental outcomes, performance standards, and risk controls***
  - ***clearly defined scopes for inspections, audits and monitoring programs***
  - *clear identification of regulatory reporting requirements under the Regulations and other applicable legislation.*
- *are outcome based to allow interest holders flexibility as to how a regulated activity is undertaken • clearly describe stakeholder engagement processes and outcomes, and how the EMP has been informed by consideration of impacts to stakeholders*
- ***clearly explain to the public how activities will be carried out and how impacts and risks will be managed***
- ***incorporate the most up-to-date scientific research*** *into the NT's onshore gas industry available at the time.*

Conclusion

As cited in 'The Risks of Oil and Gas Development for Human Health and Wellbeing: A Synthesis of Evidence and Implications for Australia', Haswell *et al.*, 2023' there is "now extensive evidence demonstrating multiple direct and indirect health and wellbeing risks from oil and gas developments.

The report identifies and discusses an extensive body of recent, peer-reviewed scientific and public health literature (more than 2,000 publications from the last decade) on five areas of extreme concern, namely:
1: the procedural risks posed by oil and gas operations to biodiversity, water and food security, 2: contributions to the climate emergency,
3: the vast array of potentially harmful chemicals involved,
4: contamination pathways into water and air and
5: resulting physical, social, emotional, spiritual health losses associated with extensive disruption of life near oil and gas fields and its sprawling infrastructure."

For these reasons and those set out in this submission, Imperial's EMP does not comply with legislative requirements for the approval of an Environmental Management Plan and, based on the incomplete and inadequate information provided, is environmentally unsustainable and unacceptable. Therefore the Minister is obliged to reject the D/EMP and the project.

From: [redacted]
[redacted] imperial ep187+
Subject: Re: Submission: Carpentaria Gas Pilot Production.
Date: Saturday, 20 April 2024 12:16:10 AM
Attachments: [redacted]

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

To Whom It May Concern:

We apologise but the document attached in our submission 10 minutes ago incorrectly contained three references to 'Tamboran' where these should have either been omitted or referred to the proponent as 'Imperial'.

We therefore humbly request that the attached submission with very minor edits and no material change to the content, facts, references or conclusions of the submission be accepted.

We hope you find this request reasonable and would be grateful for your accommodation of it. If you would let us know be reply e-mail as to your acceptance or rejection of it we would be grateful.

Sincerely,

No New Gas Coalition

On Fri, 19 Apr 2024 at 23:58, No New Gas Coalition [redacted] wrote:

> Please find attached our submission from the No New Gas Coalition for the above EMP.

No New Gas Coalition NT **submission in response to: Imperial Oil and Gas Pty Ltd Carpentaria Pilot Project EP187 Environment Management Plan (EMP)**

19 April 2024

The No New Gas Coalition NT is a growing NT based coalition of individual Northern Territory residents and organisations (including but not limited to Climate Action Darwin, Environment Centre NT, Frack Free NT, Parents for Climate Darwin and NT and unions). Our combined online reach extends to over 34,750 people.

The No New Gas Coalition aims to end new gas projects in the NT. Evidence-based decision making underpins the work and positions taken by the No New Gas Coalition in regards to the impacts of the gas industry on the climate, environment, human health, culture and communities.

Summary

The impacts and risks of the Carpentaria Pilot Production EMP are so significant that the Minister is obliged to reject this EMP and the proposal.

No New Gas Coalition asks that the project:

1. Is referred to the NT EPA under the *Environment Protection Act 2019* (NT) and required to undertake a full Environmental Impact Statement; and
2. Is referred to the Federal Environment Minister under the *Environment Protection and Biodiversity Conservation Act 1999* because it is likely to have a significant impact on water resources.

As set out below, the Environmental Management Plan (**EMP**) does not comply with,

1. The requirements of the **Petroleum (Environment) Regulations (2016)**.
2. The requirements set out in the **Environment Management Plan Content Guideline - Onshore Petroleum Regulated Activities** (DEPWS 2022).
3. The requirements of the **Code of Practice Onshore Petroleum Activities in the Northern Territory** (2019).

The direct, indirect and cumulative impacts and risks of the proposal, to the extent they have been set out in the EMP, are clearly not environmentally sustainable or capable of being approved as environmentally acceptable. **For these reasons the Minister is obliged to reject this EMP and the proposal.**

Timing of release

The timing of the release for public comment of Imperial Oil & Gas Pty Ltd's (Imperial's) EMP occurred on United Nations World Water Day and in the midst of a cyclone (for which there was some warning), when heavily impacted residents and communities had homes damaged, were displaced through mandatory evacuation, unable to easily return and under stress to meet the basic necessities of life for much of the public comment period. This timing which could have been easily delayed, erodes public trust and confidence in relation to the assessment and regulation of fracking for fossil methane gas in the Beetaloo sub-basin and given previous similar timings from other companies, is justifiably received with cynicism. We strongly recommend amending the relevant legislation to enable the Minister to grant extensions to public comment periods in such mitigating circumstances.

1. Requirements under relevant legislation and regulation

As set out in regulations 8 and 9 and Schedule 1 of the Petroleum (Environment) Regulations (2016), the EMP MUST include or satisfy the following requirements:

- *a **description of the regulated activity** to which the plan relates*
- *be **appropriate for the nature and scale** of the regulated activity to which the plan relates*
- *address **all direct and indirect environmental impacts and risks***
- *address the **cumulative effects** of those impacts and risks*
- *provide **comprehensive information** about all relevant matters*
- ***demonstrate** that the activity will be carried out in a manner by which the environmental impacts and environmental risks of the activity will be reduced to a level that is (a) as low as reasonably practicable and (b) acceptable.*

2. Failure to adequately address scale and associated risks of major hazardous industry project

Contrary to the requirements of the legislation, the EMP fails to provide comprehensive information that is appropriate to the nature and scale of the project to enable an assessment of the project's impacts and risks.

- The proposal outlined in the EMP amounts to a major, hazardous industrial project in a remote region of the Northern Territory which is increasingly experiencing extreme temperatures and severe heatwaves, large scale bushfires and high intensity rainfall events.
- The project would occur within a jurisdiction, the Northern Territory, which has repeatedly demonstrated limited and inadequate capacity for the environmentally responsible regulation of large scale hazardous extractive projects.
- The NT government has made clear its political determination to rapidly proceed with fracking across the Beetaloo in spite of its failure to implement the recommendations of the Pepper Inquiry[1] and the SREBA study.[2]
- The overall project will clear up to 229 hectares of native vegetation and wildlife habitat, bringing the total cumulative clearing approved in the area for fracking activities to nearly 1,200 hectares.
- The project would involve **hundreds of 'B-triple' heavy truck movements**, carrying chemicals, contaminated wastewater, sand (proppant) etc, along highways and dirt roads to access each of the twelve well sites.
- The EMP indicates that over four years, the project plans to take **950 ML (million litres)** of groundwater from the Gum Ridge Formation, part of the productive Cambrian Limestone Aquifer (CLA) system, mostly for fracking. This water is essential to supporting culture, nature and communities in the area but is facing growing extraction pressure.
- However, Imperial will apply for a licence to extract up to **750ML *per year***, roughly 9% of the total volume of groundwater allocated to petroleum in the Georgina Wiso Water Allocation Plan, to remove this water from the Gum Ridge Formation. This is roughly 9% of the 8GL of water allocated to gas activities in the Georgina Wiso water plan. If granted, this 750ML licence would effectively double the volume of water entitlements granted to petroleum companies so far and occur without adequate impact/risk assessment or monitoring.[2,4] The Anthony Lagoon and Gum Ridge formations are the two major aquifers in the Cambrian Limestone Aquifer within the Georgina Basin.
- The 12-well project would entail the transport, storage and pumping down-well of **millions of litres of chemicals** (excluding sand/proppant) over four years, mostly for fracking. At least **33** of the chemicals could be '**high concern**' due to potential toxicity.[3]
- Based on figures provided in the EMP, the project would involve the generation, storage, movement and disposal of **35 million litres of toxic flowback wastewater** per well that will need to be disposed of off-site. Arrangements for this are unclear.
- As only 5% of chemical-laced frack fluid per well is recovered as "flowback", this means **0.95 x 950,000,000 = 902,500,000 litres** of water, plus the millions of litres of fracking chemicals, many of them toxic, will remain underground in fractured geological formations.

*There remain substantial knowledge gaps regarding the geological architecture of the SREBA area, from the deep Beetaloo Basin rocks through to the shallow Cambrian and Cretaceous aquifers...The 2021 review also noted that there was a 'poor' understanding of inter-aquifer connectivity across all of these units and the **Gum Ridge Formation**, and 'moderate' to 'poor' understanding of aquifer hydrogeological parameters in these units.*[4]

- The MP proposes the installation and operation of 60 kilometres of plastic (polyethylene) piping to create a 'gathering network' to transfer contaminated wastewater and methane gas between well sites. **The adoption of this high risk activity is based at least in part on cost-cutting by Imperial**.

[1] *Final Considerations* letter to Chief Minister from Dr David Ritchie, Independent Oversight Hydraulic Fracturing Implementation (2023).
[2] Final technical report of SREBA (DEPWS, Dec 2022) which includes numerous recommendations for further and improved assessment, monitoring and ecosystem protections **which the NT government has completely ignored.** See: *Regional Report: Strategic Regional Environmental and Baseline Assessment for the Beetaloo Sub-basin (41/2022)*
[3] "An environmental risk assessment was undertaken during the GBA Program of 116 chemicals associated with drilling and hydraulic fracturing operations in the Beetaloo region, **of which 33 were of potentially high concern**. Future groundwater monitoring programs aimed at detecting contamination from onshore gas activities should be informed by identified chemicals of potential concern." SREBA final report (2022)
[4] SREBA Expert Review – Groundwater. Professor Matthew Currell and Dr Christopher Ndehedehe. Accessed at: www.ecnt.org.au/reports

3. Failure to present and address key project components, impacts and risks

3.1 'Gathering network' of polyethylene pipes for wastewater and methane gas transfer

The proponent is proposing wastewater and gas 'gathering networks' of polyethylene piping to transport wastewater and hydrocarbons between well sites **over a combined distance of ~60 km**.

There is insufficient information in the EMP about the operation, impacts and risks of the proposed **60km** 'gathering network' of polyethylene pipelines transferring wastewater and hydrocarbons from well site to well site across the project area.

Such a network of plastic pipes carrying toxic and hazardous materials raises serious issues including the risk of methane leakage, the risk of fire or explosion and the risk of contaminated wastewater leakage resulting in pollution of streams and wetlands.

The risk and consequence of methane gas or liquid hydrocarbon leakage from the gathering network igniting during bushfire emergencies is not adequately addressed or assessed in the EMP – in a region experiencing increasingly severe fire weather and extensive, long-duration bushfires as a result of climate change.

Based on the record of multiple reportable and recordable incidents at existing fracking well sites in the Territory, the safe management of such a complex and extensive system cannot be assured.

In order to comply with the requirements of the relevant legislation and regulation, a full, unambiguous description of all aspects of the proposed polyethylene pipe network needs to be presented and be subject to informed assessment.

3.2 Down-well 'loss' of millions of litres of drilling fluid and frack fluid

With 950 ML of groundwater being used, the likely loss of millions of litres of drilling fluids and fracking fluids at each well due to the nature of the geological formations being accessed via this proposal requires deeper consideration.

It is known that commonly during the drilling of the Gum Ridge Formation (GRF), partial to total losses of drilling fluid have been observed due to high permeability conduits, fractures and cavernous zones expected in karstic formations.

The CLA, comprising the Gum Ridge Formation and the Anthony Lagoon Beds, is an extensive, multi-layered regional aquifer system covering at least 200,000 km2 that forms the principal

water resource in the Beetaloo Sub-basin, (SREBA, 2022).

*The CLA is a **highly productive aquifer** that has **high regional connectivity** due to the development of **significant fracture and karstic secondary porosity** (SREBA, 2022). Across parts of the Beetaloo Sub-Basin, undifferentiated Cretaceous deposits form the uppermost aquifer are targeted for stock use. Notably, a basal sandstone unit immediately overlying the CLA produces yields of at least 10 L/s (SREBA, 2023). Shallow, perched groundwater has also been recorded in the laterised zone within the permit area with groundwater levels recorded between 1 and 6 mBGL. These systems are dynamic with periodic saturation resulting from recharge during the wet season with no documented groundwater use. **The CLA, comprising the Gum Ridge Formation and the Anthony Lagoon Formation, is an extensive regional aquifer system that forms the principal water resource in the Beetaloo Sub-Basin. The limestone in the CLA is commonly fractured and cavernous**; in the Katherine region, bore yields of up to 100 L/s have been recorded from this aquifer (SREBA, 2023).*

*Imperial anticipates that a potential load fluid recovery of **5%** of injected stimulation fluid.*

If only ~5% of frack fluid is recovered, this means that, in addition to the loss of much or all of the drilling fluid, 902.5 ML of chemical-laced frack fluid contamination will remain underground.

Inadequate information is provided in the EMP as to the **potential cumulative impacts and risks** of this quantity of chemical-laced drilling and fracking fluid remaining underground post-fracking. If this project proceeds and hundreds more wells are drilled and fracked as planned, the potential cumulative load of contaminated water remaining underground would run to hundreds of billions of litres.

In order to comply with the statutory requirements of the relevant legislation and regulation, a full, unambiguous description of all aspects of water use, transportation and greenhouse gas emissions, and an assessment of their impacts, needs to be presented and be subject to informed assessment.

3.3 Greenhouse gas emissions

The full lifecycle greenhouse gas emissions from the project will be substantial, but Imperial doesn't even attempt to quantify them. They acknowledge that emissions from the project would equal approx 475,000 tCO2-e per annum if they flared all the gas, but they do not estimate the downstream emissions if the gas is transported elsewhere via the McArthur River Gas Pipeline, as they propose.

Imperial claims it will produce 25 terajoules (TJ) of gas a day, but the McArthur River Pipeline only has capacity for 15TJ a day. There's no mention or explanation of this difference in the draft EMP and no estimation of emissions from flaring the excess gas or the downstream emissions from burning it.

Imperial says it plans to apply to "use the gas on an appraisal basis" meaning that instead of flaring it onsite, they want to secure a connection to the McArthur River mine gas pipeline, use their gas plant to process the gas and sell it into the network.

Recent reports have highlighted:

(a) the extreme level of emissions expected to be produced through full development of the Beetaloo sub-basin, if projects such as this from Imperial are approved.

(Climate Analytics (2023). *Emissions impossible: Unpacking CSIRO GISERA Beetaloo and Middle Arm fossil gas emissions estimates.)*

(b) the inability of emissions offsets to abate the emissions involved, due to the amount required, the cost and the lack of suitable offsets with integrity:

*In calculating the carbon costs for a broad range of Beetaloo sub-basin development scenarios, from 200 TJ/day to 3,400 TJ/day, outcomes indicate that – in each case – the overlay of carbon costs to offset the Australian component of lifecycle emissions implies a **high risk of developed shale gas assets becoming economically stranded**.*

*An interim report from CSIRO's Gas Industry Social and Environmental Research Alliance into the use of offsets for lifecycle GHG emissions for onshore gas in the NT has similarly signalled that, "**the cost of offsetting Australian emissions from consumption of NT gas would be prohibitive**" for scenarios considering offsetting more than 200PJ/year (548TJ/day) of domestic consumption (GISERA2021).*

Reputex Energy (2021). *Analysis of Beetaloo gas basin emissions and carbon costs*. Australian carbon advisory, September 2021

(c) the world-wide failure of carbon capture and storage (CCS) as an abatement strategy: ***Conclusion:***

Failed/underperforming projects considerably outnumbered successful experiences

The immediate inference from the projects reviewed is that the number of failures and the underperformance of these projects with carbon capture technology has outnumbered the successful projects considerably. Ten of the 13 flagship projects reviewed, comprising 90% of the total capture capacity in our sample, have failed or are underperforming mostly by large margins...Further, recently published research by the Imperial College London on the capture performance of operating projects since 1996 confirms the underperformance of most projects against their designed/claimed capture capacity...Successful CCUS exceptions mainly existed in the natural gas processing sector serving the fossil fuel industry, leading to further emissions.

Institute for Energy Economics and Financial Analysis (2022). The Carbon Capture Crux: Lessons Learned

(d) statements from leading global bodies including IPCC, United Nations and IEA that development of large new fossil fuel basins, such as the Beetaloo sub-basin, is not needed and cannot proceed if the world is to avoid catastrophic climate change.

In summary,

- The company fails to clearly state or address the project's full lifetime emissions, including scope 3 emissions, expected from the development of the Beetaloo sub-basin, and the fact that it will not be possible to abate these emissions using credible carbon offsets or reliable carbon capture and storage (CCS/CCUS).
- The company fails to include emissions from key project components including mining and transport of huge quantities of sand (proppant) and disposal of large volumes of wastewater;
- Concerns exist regarding methane leak detection activity with significant risk of significant methane fugitive emissions could occur without detection.
- Based on its annual emissions, **475,000 tCO_2-e**, this proposal clearly falls within the scope of the NT government's 'Large Emitters Policy' which,

  *"Applies to new projects and expansion of existing projects that are considered to be 'large emitters'. The Large Emitters Policy defines 'large emitters' as projects that meet or exceed emissions thresholds: ○ The industrial project threshold is **100 000 tonnes carbon dioxide equivalent (tCO2-e) (scope 1) in any financial year** over the life cycle of a project.*

As a result of the failure of the EMP to comprehensively and accurately present the carbon emissions and climate impacts and risks of the proposal, the EMP is again in breach of the relevant legislation and regulations.

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  - ***all required content under the Regulations***
  - ***clear, systematic and rigorous identification of all environmental impacts and risks*** *based on* ***well-defined activity descriptions*** *and* ***reliable environmental information***
  - ***clear demonstration of ALARP and environmental acceptability and how activities may be carried out in a manner consistent with the principles of ESD***
  - *a fit-for-purpose implementation strategy that outlines the inspection, audit, monitoring and reporting programs that will be used to confirm the effectiveness of risk mitigation measures and measure and respond to environmental performance;*
- *are auditable by the regulator, through inclusion of:*
  - ***measurable and specific environmental outcomes, performance standards, and risk controls***
  - ***clearly defined scopes for inspections, audits and monitoring programs***
  - *clear identification of regulatory reporting requirements under the Regulations and other applicable legislation.*
- *are outcome based to allow interest holders flexibility as to how a regulated activity is undertaken • clearly describe stakeholder engagement processes and outcomes, and how the EMP has been informed by consideration of impacts to stakeholders*
- ***clearly explain to the public how activities will be carried out and how impacts and risks will be managed***
- ***incorporate the most up-to-date scientific research*** *into the NT's onshore gas industry available at the time.*

Conclusion

As cited in 'The Risks of Oil and Gas Development for Human Health and Wellbeing: A Synthesis of Evidence and Implications for Australia', Haswell *et al.*, 2023' there is "now extensive evidence demonstrating multiple direct and indirect health and wellbeing risks from oil and gas developments.

The report identifies and discusses an extensive body of recent, peer-reviewed scientific and public health literature (more than 2,000 publications from the last decade) on five areas of extreme concern, namely:
1: the procedural risks posed by oil and gas operations to biodiversity, water and food security, 2: contributions to the climate emergency,
3: the vast array of potentially harmful chemicals involved,
4: contamination pathways into water and air and

5: resulting physical, social, emotional, spiritual health losses associated with extensive disruption of life near oil and gas fields and its sprawling infrastructure."

For these reasons and those set out in this submission, Imperial's EMP does not comply with legislative requirements for the approval of an Environmental Management Plan and, based on the incomplete and inadequate information provided, is environmentally unsustainable and unacceptable. Therefore the Minister is obliged to reject the D/EMP and the project.

From: Have Your Say Northern Territory
To: imperial ep187+
Subject: Anonymous User completed Carpentaria Pilot Project EP187 Environment Management Plan
Date: Saturday, 20 April 2024 12:00:06 AM

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Anonymous User just submitted the survey Carpentaria Pilot Project EP187 Environment Management Plan with the responses below.

Given name

[redacted]

Family Name

[redacted]

Location

COCONUT GROVE, NT

Stakeholder type

Non Government Organisation (NGO)

Email address

[redacted]

Interest area

Social and cultural
Water
Climate change
Chemicals
Well integrity
Flora and fauna
Waste management
Human health
Regulation and compliance

Please provide your comments

Please note a submission was also e-mailed.

[redacted]

From: [redacted]
To: imperial ep187+; Onshoregas DEPWS
Subject: Unresolved issues requiring action re Carpentaria Pilot Program Environmental Management Plan EP187
Date: Tuesday, 11 June 2024 11:25:26 AM
Attachments: [redacted]

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Hello,

Please find attached correspondence from Lock the Gate Alliance re. the Carpentaria Pilot Program EMP.

Kind regards,

[redacted]

LOCK THE GATE ALLIANCE
AUSTRALIANS WORKING TOGETHER TO PROTECT OUR LAND, WATER, AND FUTURE

[redacted]

11 June 2024

Department of Environment, Parks and Water Security
Petroleum Operations Unit
By email: imperial.ep187@nt.gov.au, Onshoregas.DEPWS@nt.gov.au;

Re: Unresolved issues requiring action re Carpentaria Pilot Program Environmental Management Plan EP187

Lock the Gate Alliance provided comments on the Carpentaria Pilot Program Environment Management Plan (EMP) on 18 April 2024. This further correspondence is in light of the decision on 14 May 2024 by the Environment Protection Agency (EPA) that activities within the Carpentaria Pilot Program (CPP) do not have the potential to have a significant impact on the environment and does not require an environmental impact assessment for the CPP.

Operation of section 55(4) *Environment Protection Act 2019*

The EPA has relied on section 55(4) *Environment Protection Act 2019* to avoid making a decision as to whether or not activities are likely to have a significant impact on the environment. Section 55(4) is a new, untested provision within the *EP Act* and states:

> *(4) In determining whether a referred action or strategic proposal has the potential to have a significant impact on the environment, the NT EPA may consider other statutory decision-making processes that may mitigate the potential environmental impact of the referred action or strategic proposal.*

The explanatory statement to the *Environment Protection Legislation Amendment Bill 2023* sets out the intention of this new clause:

> *Subsection (4) identifies that when determining whether or not a referred action or strategic proposal has the potential to have a significant impact on the environment, the NT EPA may consider other statutory decision-making processes. This is included for certainty about the matters the NT EPA may consider, and recognises that there may be other statutory processes that will ensure appropriate mitigation and management of environmental impacts that can be relied upon by the NT EPA.*

Despite relying on 'other statutory processes' in its decision not to require an Environmental Impact Statement, the NT EPA failed to use its power to refer this project to DCCEEW under section 69 of the *EPBC Act*, to ensure adequate assessment of water resources. It is now your obligation to refer this matter to DCCEEW, given you have administrative responsibilities in relation to this matter.

Outstanding issues for DEPWS to address before approval

Given the NT EPA relied on the operation of section 55(4) *Environment Protection Act* to offset its responsibilities to other regulatory processes, you, DEPWS, now have a number of unresolved issues raised with the EPA during the process that must be resolved prior to approval of this EMP. These issues include:

- Referral to Commonwealth DCCEEW under the EPBC water trigger, given comments indicating that the claim to "no significant impact" on water resources is not supported by evidence;
- Revision of the greenhouse gas estimates to include a worst case scenario whereby flaring cannot be avoided because commercial sale of appraisal gas does not proceed;
- Revision of the ecological assessment to resolve inconsistencies identified by the Flora and Fauna Division of DEPWS in order to accurately assess the cumulative impact of the activities;
- The need for the proponent to prepare a social impact assessment to address housing, workforce, and other social impacts raised by the Department of the Chief Minister and Cabinet;
- As noted by the Office of the Chief Minister and Cabinet, negotiation with Traditional Owners for a Beneficial Use Agreement, and a further application for Ministerial approval "is required to determine options to be progressed for project activities related to the recovery of petroleum during the appraisal phase." As this matter is material to the greenhouse gas assessment, this information must be sought and provided prior to the EMP being determined;
- It is impossible to determine whether the activities are likely to have an impact on sacred sites until after an Authority Certificate has been finalised and activities adjusted according to the location of sacred sites;
- Requirements for protection and mitigation of cultural heritage have not been met, and the Heritage Branch will provide comment once a revised report is produced. We note that there is a current investigation by the Heritage Branch into the movement of artefacts and failure to report finds at the Carpentaria 4 well site, which is the subject of this EMP application.

The NT EPA accepted a referral from the proponent, Imperial Oil and Gas Pty Ltd, on 14 March 2024. During the consultation period from 27 March 2024 to 26 April 2024, 97 submissions were received, including six submissions from government authorities and 91 submissions from the public.

On 14 May 2024 the EPA set out the statement of reasons for its decision that the proposed action does not have the potential to have a significant impact on the environment and that an environmental impact assessment is not required. In its reasons it considers the CPP's potential to impact six environmental factors, including terrestrial ecosystems (land), hydrological processes and

inland water environmental quality (water), atmospheric processes (air), community and economy and culture and heritage (people). In making its decision that an environmental impact assessment is not required, the EPA did not consider, nor address, a number of issues raised by government agencies and the community.

We now draw your attention to numerous issues raised by NT and Commonwealth government departments with which you will need to be satisfied prior to making a decision on the CPP EMP:

In relation to water resources

The Commonwealth Department of Climate Change, Energy, Environment and Water (DCCEEW) identifies in its submission that a referral for the proposed CPP has not been received by DCCEEW, and that the proponent had not considered the expanded scope of the water trigger provisions in the *Environment Protection and Biodiversity Conservation Act* at the time of application. In particular, the test in section 24D *EPBC Act* is that a proponent must not take action that involves unconventional gas development that "has or will have a significant impact on a water resource, or is *likely* to have a significant impact on a water resource."

DCCEEW raised issues including contaminant migration into water resources and groundwater extraction that have not been addressed against the Commonwealth test. The NT EPA relied on the operation of section 55(4) *Environment Protection Act* to offset its responsibilities to other regulatory processes, and yet no referral has been made to DCCEEW under the EPBC Act to address these issues. **We submit that you cannot make a decision as to whether or not the CPP is likely to have a significant impact on water until this matter has been referred to DCCEEW and a decision made as to whether or not the action is a controlled action.**

DCCEEW's submission also raises the following information gaps in relation to potential impacts to water resources:

- Potentially unrepresentative waste-water spill modelling inputs;
- VLEACH modelling only considers biodegradable contaminants;
- Unintended spill assessment does not consider contaminant dispersal in flood event;
- Absence of hydraulic fracturing water budget.

Finally, the Water Resources Division (of DEPWS) identified the need for a water extraction licence for an increased entitlement to water, and a bore work application.

In relation to air

The Department of Industry, Tourism and Trade noted in its submission that an approved application is required to recover produced gas rather than to flare it, but that no application had been received. The Chief Minister and Cabinet's submission similarly notes that a ministerial approval is required to determine options to be progressed for project activities related to the recovery of petroleum.

The DCCEEW further submitted comments questioning the evidentiary basis of the proponent's claim that avoiding flaring reduces greenhouse gas emissions from the project by 90%. As DCCEEW

reflect, this would only be the case were the gas to be recovered on a production basis. Lock the Gate has previously raised problems along similar lines with the proponent's greenhouse gas assessment. It assumes that consent will be obtained and arrangements made to connect the pilot project to infrastructure that will enable appraisal gas to be sold productively. Should this not occur, gas retrieved during appraisal will have to be either flared or vented, and emissions from the project will be significantly higher than the EMP claims.

We submit that DEPWS cannot grant approval for this EMP on the basis of this unsupported and unstable emissions claim.

In relation to land

The Flora and Fauna Division of DEPWS noted inconsistencies in information provided by Imperial that need to be clarified in order to accurately assess the cumulative impact of the activities. Of particular note are comments that construction of one well pad exceeds the permitted area allowed and that other well pads have not been constructed at all, and the need for infrastructure movement zones to be more tightly defined. **Until this information is received, DEPWS cannot make an assessment as to whether or not criteria in regulation 9 (*Petroleum (Environment) Regulations 2016)* has been met.**

In relation to people

The submission from the Chief Minister and Cabinet noted the significant decline of jobs beyond the 2027 dry season, and advised that further information should be sought in relation to the potential impacts of the project workforce, including specifying the geographic source of the construction and operation workforce and opportunities for recruitment and training in the local, regional and territory context.

CMC also raised significant impacts on housing and accommodation that have not been addressed, and the potential impact of procurement opportunities and risks. The agency raised the need for additional information and assessment of the significance of the potential impacts of workforce accommodation demands, and of onsite workforce accommodation. We note that other jurisdictions have frameworks for the assessment of the social impacts of FIFO and DIDO workforces and employment distortion. **These matters also need resolution prior to a decision on this EMP and DEPWS needs to request from the proponent the information and assessment sought by CMC.**

Further, CMC noted that negotiation with Traditional Owners for a Beneficial Use Agreement, and a further application for Ministerial approval "is required to determine options to be progressed for project activities related to the recovery of petroleum during the appraisal phase." **As this matter is material to the greenhouse gas assessment, this information must be sought and provided prior to the EMP being determined.**

In relation to heritage issues

The submission from the Aboriginal Areas Protection Authority (AAPA) states that an Authority Certificate has not yet been issued. In the absence of an Authority Certificate, sacred sites have not been identified and additional groundwater monitoring may be required if existing monitoring networks are unsuitable to monitor for impacts. In addition, the risk rating cannot be conclusively determined until an Authority Certificate has been issued, and is currently uncertain. Locations for monitoring for weed infestations, erosion and spills cannot be determined until sacred sites are identified.

It is therefore impossible to determine whether the activities are likely to have an impact on sacred sites until after an Authority Certificate has been finalised and activities adjusted according to the location of sacred sites.

Further, the submission from the Department of Territory Families, Housing and Communities (Heritage Branch) notes that the requirements for protection and mitigation of cultural heritage have not been met, and that the Heritage Branch will comment once a revised report is produced. This revised report must also include recommendations that will be followed for mitigation and the unexpected finds protocol.

Section 57AAA of the Petroleum Act

Notwithstanding that it is our belief that the EPA has failed to adequately consider a number of issues that it was required to under law, the EPA's decision has placed the onus on DEPWS to "ensure appropriate mitigation and management of environmental impacts" in making its decision on this EMP. In this regard, we note that submissions by DCCEEW, the Department of Industry Tourism and Trade and the Chief Minister and Cabinet all highlighted that approvals have not yet been granted for the beneficial use of appraisal gas under section 57AAA of the *Petroleum Act.* Imperial relies entirely on the beneficial use of appraisal gas to avoid flaring (and therefore to mitigate its emissions), ensuring that it does not then fall under the Commonwealth Safeguard Mechanism in the *National Greenhouse and Energy Reporting Act 2007*. As such, DEPWS cannot make a decision on this EMP unless and until Imperial obtains an approval for the beneficial use of appraisal gas under section 57AAA.

Regulation 9(1(c)) of the *Petroleum (Environment) Regulations 2016* sets out approval criteria for the plan. In order to be approved, the plan **must**:

> *(c) demonstrate that the activity will be carried out in a manner by which the environmental impacts and environmental risks of the activity will be reduced to a level that is:*
>
> *(i) as low as reasonably practicable; and*
>
> *(ii) acceptable;...*

Without an approval under section 57AAA, the Minister cannot approve this EMP, because in the absence of the further information and assessment identified as necessary by the agencies and in the absence of approval to beneficially reuse gas extracted from the site, the EMP does not

demonstrate that the activity will be carried out in a manner that reduces environmental impacts and risks to a level that is as low as reasonably practicable or acceptable.

Yours sincerely

[redacted]
Legal Coordinator
Lock the Gate Alliance

From:	Have Your Say Northern Territory
To:	imperial ep187+
Subject:	Anonymous User completed Carpentaria Pilot Project EP187 Environment Management Plan
Date:	Wednesday, 17 April 2024 9:15:58 AM

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Anonymous User just submitted the survey Carpentaria Pilot Project EP187 Environment Management Plan with the responses below.

Given name

[redacted]

Family Name

[redacted]

Location

ALICE SPRINGS, NT

Stakeholder type

Landholder/occupier

Email address

[redacted]

Interest area

Social and cultural
Water
Chemicals
Other (please specify) - Very Long Term Water Supply & Eco Health
Waste management
Human health
Regulation and compliance

Please provide your comments

Fracking is very dangerous due to chemicals used and disturbing the geo structural build. The long term issues caused are far from beneficial.

From: [redacted]
To: Onshoregas DEPWS
Subject: Re: Carpentaria EMP
Date: Tuesday, 30 April 2024 11:55:21 AM

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Please see below and confirm as requested.
Thank You.
[redacted]

On Fri, Apr 19, 2024 at 5:48 PM Protect Big Rivers [redacted] > wrote:

> HI,
> The have your say site would only allow 1 attachment. Please find Haswell Report and flood video attached.
> Flood video represents Relief Creek due west of Carpentaria 4. It shows the impossibility of even reaching these wells should an accident occur during a storm event. Also if an accident occured it would be impossible to mobilise any heavy machinery or even walk on the well pads such is the nature of flooding.
> Please find these attachments and comments to supplement our submission.
> Please confirm receipt and admissibility via this email address, given the online portal would only accept 1 attachment. .
> Regards,
> [redacted]
> PO Protect BIg Rivers
>
> IMG_7712.mov