Australian Conservation Foundation

Submission to:
STO8-1: EP161 Beetaloo Basin Appraisal Pilot Environment Management Plan

Addressed to:
Department of Lands, Planning and Environment (NT), Petroleum Regulations Unit

Submission from:
Australian Conservation Foundation, Level 1, 60 Leicester Street,
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Date:
19 December 2025

AUSTRALIAN CONSERVATION FOUNDATION | Nature needs us, now

About the Australian Conservation Foundation

The Australian Conservation Foundation is Australia's national environment organisation. Since 1965, we've protected the nature we all love – our unique wildlife and our beautiful beaches and bush.

Driven by the power of people, we won World Heritage listing for the Great Barrier Reef and Kakadu National Park, and returned precious water to the rivers of the Murray-Darling.

We influence governments and businesses to protect the animals, rivers and reefs close to our hearts and hold decision-makers to account without fear or favour. Everything we do is evidence-based and helps nature and people thrive for generations to come.

We won't give up until Australia's nature is protected and regenerated.

The Australian Conservation Foundation acknowledges that First Nations Peoples of Australia hold unique knowledge and rights inherited from their ancestors and Country and have cared for this country since time immemorial. We pay our respect to First Nations Peoples of Australia, past, present and future. We respect their leadership in caring for Country and support their rights to continue to do so. We recognise that sovereignty was never ceded, and that colonisation was unjust, often violent and continues to adversely impact on First Nations Peoples today. As Australia's national environment organisation, we understand we have a responsibility to help right this historical wrong. We support their authority to speak for Country, right to self-determination and recognise that rightful recognition of and genuine reconciliation with First Nations Peoples is fundamental to protecting nature in Australia. We support First Nations-led campaigns that protect Country and seek win-win outcomes for our environment and for the rights, wellbeing and advancement of First Nations Peoples

To find out more about the Australian Conservation Foundation's work visit www.acf.org.au

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Introduction

The Australian Conservation Foundation (ACF) welcomes the opportunity to make a public comment to the Northern Territory Department of Lands, Planning and Environment (the department) on the Environment Management Plan ('EMP') submitted for assessment under the Petroleum (Environment) Regulations 2016 (NT) ('Regulations') by Santos QNT Pty Ltd (Santos) on 19 November 2025 in relation to Exploration Licence EP161.

It is ACF's view that the EMP submitted by Santos is inadequate and that the risks posed by the activity have not been reduced to As Low As Reasonably Practicable (ALARP) or to an acceptable level. Our comments are limited to the risks the project poses to ground and surface water, biodiversity, management of flowback water and greenhouse gas emissions.

The EMP methodology is insufficient to enable the Minister to understand the full environmental impacts and risks of the proposed activities, as required by the governing legislation. Regardless, the environmental risks posed by drilling and hydraulic fracturing in the Beetaloo Basin are unacceptable, and further exploration drilling should not be allowed to occur.

In our opinion, due to the risks the proposed activities pose to water resources and threatened species, the project should be submitted to the Federal Government for assessment under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) by virtue of the Territory's referral power under s 69(1) of the EPBC Act.

Recommendations

1. **The Northern Territory Government should not approve any further gas exploration drilling and hydraulic fracturing in the Beetaloo Basin area.**

2. **The EMP should be referred to the NTEPA under s 50(2)(c) of the *Environment Protection Act 2019* (NT), and the application should not be considered until the EMP is referred and a decision is made on the referral.**

3. **Alternatively, the Minister should reject the EMP because it does not comply with the Petroleum (Environment) Regulations 2016 (NT).**

4. **The project should be referred for assessment under the EPBC Act for impacts on water resources and threatened species**

Further gas exploration should not be approved in the Beetaloo Basin area

ACF is opposed to the practice of hydraulic fracturing, and the approval of further gas exploration drilling in the Beetaloo Basin area.

The purpose of this appraisal project is to assess the commercial viability of the shale gas reservoir in the project area. If onshore gas production is permitted to reach full-scale in the Beetaloo Basin, thousands of wells could be drilled, producing an estimated 1.2 billion tonnes of greenhouse gas emissions over 25 years to 2050.[1]

The cumulative impacts of these wells could pose serious risks to the Territory's water resources, biodiversity and climate.

The EMP should be referred to the NTEPA

ACF submits that s 50(1) of the *Environment Protection Act 2019* (NT) applies.

Accordingly, we submit that the EMP should be referred to the NTEPA under s 50(2)(c) of the Act, and that the application should not be considered until the EMP is referred and a decision is made on the referral – as per s 50(2)(a) of the Act.

The EMP does not comply with the Regulations and should be rejected

ACF submits that the EMP does not comply with the Petroleum (Environment) Regulations 2016 (NT), due to the issues identified below. ACF also notes the further issues identified in the submission put forward by Environment Centre NT (ECNT) in their submission to the EMP consultation. Accordingly, the Minister should reject the EMP.

Ground and surface water risks

Despite the proposed Jibera South and Newcastle South wells being located at the eastern edge of the Beetaloo Basin where there is known to be large uncertainty in the local hydrogeology, to our knowledge Santos has not undertaken its own assessment of the interaction between saline and potable groundwater sources and surface formations including springs such as Hot Springs Valley and Mataranka, which respectively feed into the Roper River and Limmen Bight River catchments.

Santos has also failed to adequately assess how these might impact on groundwater-dependent ecosystems, newly discovered stygofauna or species such as the Gulf Snapping Turtle (federally listed as endangered) and the Largetooth Sawfish (listed as vulnerable in the Northern Territory and endangered federally). Instead, the company has relied on a "Groundwater Desktop Self Assessment Technical Report", which is not publicly available, to substantiate its claims regarding the potential impacts on aquifers and surface water formations.

The Gas Industry Social and Environmental Research Alliance (GISERA), which the proponent participates in and funds, has acknowledged this uncertainty as recently as May 2025, stating that "this newly identified eastern extension of the Sub-basin was

[1] Thomas Houlie and Bill Hare, *Emissions Impossible: Unpacking CSIRO GISERA Beetaloo and Middle Arm fossil gas emissions estimates* (2023) Climate Analytics https://climateanalytics.org/publications/emissions-impossible

not entirely included in these research programs and the potential impacts on water resources and water dependent ecosystems from unconventional gas exploration and development in this area remains poorly understood."[2]

Similarly, the Commonwealth Government's Independent Expert Scientific Committee noted the potential for risks of impacts to ground and surface water outside of the Beetaloo Biophysical Study Area, including catchments fed by the Hot Springs complex, risks that have not been assessed.[3] We note that contamination or connection between aquifers could lead to impacts that are irreversible.

The Strategic Regional Environmental Baseline Assessment (SREBA) Regional Report noted the need for the industry to "prioritise investigations of the Hot Springs Valley area, especially those companies undertaking work within 50km of the springs", as is the case for this project. [4] While GISERA has begun an investigation into the source of those springs, this work is incomplete and will not be completed until April 2025.

Furthermore, the proponent has not undertaken groundwater drawdown modelling associated with the 193.5ML annual water requirement of the project. The company has simply noted its compliance with the NT Code of Practice requirement for drilling not to occur within 1km of a groundwater bore. This does not demonstrate that the potential impacts of groundwater drawdown have been reduced to ALARP or to an acceptable level, given no assessment has been made of baseline drawdown and recharge rates or modelled impacts of extraction.

Biodiversity

The project will require clearing and fragmentation of mostly remnant vegetation dominated by lancewood-bullwaddy woodland and redfruited bloodwood, with edge effects and the potential for introduction of invasive species in a mostly weed-free environment. These ecosystems are characteristic of the Sturt Plateau Bioregion, which forms part of the world's largest intact savannah landscape.

The Pepper Inquiry acknowledged the low level of understanding of conservation values within the Beetaloo Basin, noting that "the likelihood of onshore shale gas development occurring in currently undocumented areas of high conservation value in the NT is 'high', given the lack of comprehensive and systematic information on the biodiversity assets of prospective regions, including virtually no information on invertebrate faunas."[5] As a result of this paucity of information, the SREBA was intended to be carried out over five years. However, it was truncated after two years due to the unforeseeable disruption caused by the response to the Covid-19 pandemic.

Despite this lack of information, Santos has relied almost entirely on the SREBA and a

[2] GISERA, 'Groundwater connectivity between the CLA and the surface in the Eastern Beetaloo Sub-basin extension' (2025) https://gisera.csiro.au/wp-content/uploads/2025/05/Water-38-Project-Order.pdf
[3] Independent Expert Scientific Committee on Unconventional Gas Development and Large Coal Mining Development, *Advice on unconventional gas - IESC 2024-150: Beetaloo Basin - Unconventional gas exploration and appraisal* (2024) https://www.iesc.gov.au/sites/default/files/2024-12/iesc-advice-beetaloo-basin-2024-150.pdf
[4] Department of Environment, Parks and Water Security, *Regional Report: Strategic Regional Environmental and Baseline Assessment for the Beetaloo Sub-basin* (2022) DEPWS Technical Report 41/2022, p 108 https://environment.nt.gov.au/media/docs/onshore-gas/sreba/sreba-beetaloo-regional-report.pdf
[5] Scientific Inquiry into Hydraulic Fracturing in the Northern Territory, *Final Report of the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory* (2018) p 186 https://frackinginquiry.nt.gov.au/inquiry-reports/final-report

desktop assessment to inform its assessment. A single field assessment was undertaken in the wet season in December 2024, and unlike other proponents in the region, the company has not undertaken any assessment at other times in the year. Bird surveying was limited to a 15-minute call playback, where 44 species were identified, with only the fork-tailed swift (listed as migratory under the EPBC Act) identified as a known federally listed matter. This does not assist the Minister in understanding whether the project's design will reduce impacts to biodiversity from habitat clearing, fragmentation, edge effects and exposure to flowback water, or the incursion of invasive species to ALARP or an acceptable level.

Santos also appears to have missed identifying nationally listed species during its assessment, as some species are identified only to the family rather than species level, including where all members of the family likely to exist in the area are in fact listed as endangered. The project should not be approved without a comprehensive assessment of biodiversity values at risk.

Management of flowback water

It is unclear from the proposal how Santos intends to manage the significant volumes of contaminated flowback water generated from the activity, with the EMP contemplating using evaporation ponds that have the potential to attract birds during the dry season.

As drafted, this flowback water could be stored aboveground for the life of the project, posing risks of spills and leaks, with flood modelling indicating that a flooding event similar in scale to the 1974 flood would inundate significant sections of the project area. Santos also contemplates burying the resulting waste onsite, a practice that to our knowledge has never been accepted for any gas exploration project in Australia, and one which falls well short of good practice by industry, risking spreading toxic chemicals throughout the floodplain during periods of heavy rainfall.

Greenhouse gas emissions

Santos estimates lifetime emissions of 27,741tCO2-e of Scope 1 emissions based on National Greenhouse and Energy Reporting (NGER) methodology. The company has not disclosed within the EMP Scope 3 emissions arising from the project on the basis that they are from "sources not owned or controlled by the Interest Holder". This is inconsistent with Recommendation 9.8 of the Pepper Inquiry, which held that there was to be no net increase in the lifecycle greenhouse gas emissions emitted in Australia from any shale gas produced in the Northern Territory.[6]

Santos' proposal to use Method 1 of the NGERS to report on its wellhead emissions would lead to a high level of uncertainty regarding the accuracy of these emissions, and we would therefore recommend that the company be required to use Method 2 or 3 and use CEMS technology to align with best practice. The company should also report emissions from all non-routine flaring or venting.

As the project's Scope 1 emissions will not meet the 100,000tCO2-e per annum threshold to trigger obligations under the Safeguard Mechanism, there is no relevant

[6] Ibid [Recommendation 9.8], p 239.

federal or territory emissions mitigation scheme that will incentivise or obligate Santos to reduce its carbon pollution. There is nothing in the EMP to demonstrate that Santos has taken any action to abate these emissions beyond expressing a preference to flare rather than vent where possible. The Northern Territory is particularly vulnerable to the impacts of climate change, with dangerous extreme heat days expected for the majority of the year under climate scenarios consistent with two degrees of global average warming.[7]

Given that the purpose of exploration is to ultimately make way for a producing gas field, and that every incremental tonne of greenhouse emissions increases the risks from climate change, the climate impacts of further exploration activity in the Beetaloo Basin area should be considered by the government. The project should be assessed with reference to the cumulative impact of existing and proposed projects in the Beetaloo Basin. In assessing this EMP, the government should address the inconsistency between increasing gas production and the need to achieve the rapid reductions in emissions needed to limit warming to 1.5 degrees and avoid further climate harm to the Territory's ecosystems, communities and economy.

Furthermore, the proponent's Methane Emissions Management Plan does not propose continuous monitoring, reporting and verification of all methane emissions associated with emissions from drilling, hydraulic fracturing, emissions from flowback water, leaks from pipelines and gas transport, and during suspension and following abandonment. Experience from development of the Marcellus Shale in the United States has found similar shale gas development to lead to substantial fugitive methane emissions both during the exploration and production phase and following the plugging and abandonment of the wells.[8]

Need for EPBC referral

Due to the risks to water resources and threatened species identified above, ACF recommends full assessment of the proposal under the EPBC Act by Environmental Impact Statement (EIS), by virtue of the Territory's referral power under s 69(1) of the EPBC Act. Application of the precautionary principle requires this referral, given the risks and uncertainties identified above, and noting the further issues raised in the submission put forward by ECNT to the consultation.

[7] Commonwealth Science Industrial Research Organisation, 'Northern Territory's Changing Climate' https://www.climatechangeinaustralia.gov.au/en/changing-climate/state-climate-statements/northern-territory/
[8] Lauren E Dennis et al, 'Measurements of Atmospheric Methane Emissions from Stray Gas Migration: A Case Study from the Marcellus Shale' (2022) 6(4) *ACS Earth & Space Chemistry* 909 https://pmc.ncbi.nlm.nih.gov/articles/PMC9037607/

Respondent No: 11
Login: Anonymous
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Responded At: Dec 19, 2025 16:01:21 pm
Last Seen: Dec 19, 2025 16:01:21 pm
IP Address: n/a

Q1.	**Given name**	Adrian
Q2.	**Family Name**	Tomlinson
Q3.	**Location**	ALICE SPRINGS, NT
Q4.	**Stakeholder type**	Community member
Q5.	**Email address**	adrianjtomlinson@gmail.com
Q6.	**Interest area**	Social and cultural Flora and fauna Water Climate change
Q7.	**Please provide your comments** Refer attached file	
Q8.	**Add an attachment - Max file size: 5MB**	https://s3-ap-southeast-2.amazonaws.com/ehq-production-australia/56ebbdc62df5e782d46ac5e01710e87c502551b9/original/1766125849/75a2e775d5f5e98ce7e7da31dcd00ef3_Letter%20A%20Tomlinson%20-%20Santos%20Beetaloo%20Basin%20Appraisal%20Pilot%20Environment%20Management%20Plan%20%28EMP%29.pdf?1766125849
Q9.	**Tick this box if you wish for your name and contact details to be confidential**	not answered

Adrian Tomlinson
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Alice Springs NT 0870

19 December, 2025

Department of Lands, Planning and Environment
Petroleum Regulations Unit
PO Box 3675, Darwin NT 0801
Uploaded to: https://haveyoursay.nt.gov.au/emps-under-assessment/surveys/tam1-emp1

To Whom it May Concern,

RE: Santos Beetaloo Basin Appraisal Pilot Environment Management Plan (EMP)

I am writing to object to this EMP. If not refused, I request the proposal be subject to the highest degree of scrutiny, via the approach outlined in my conclusion.

Concerns

1. Impacts on groundwater dependent ecosystems and waterways.

- This project could have a profound impact on both surface and groundwater in the region. The project will drill through the Cambrian Limestone Aquifer (CLA), feeding important ecological and cultural sites in the Roper system, but may also discharge locally or sustain terrestrial GDEs locally.
- This EMP notes that surface water from two proposed sites flows directly into the catchment for the Limmen River and Limmen National Park, 80 km downstream.
- I am concerned that this area has significant complexity in regard to connections with other aquifers and faulting. The SREBA[1] highlights a series of springs in Hot Springs Valley on Tanumbirini Station which are likely sourced from deeper Mesoproterozoic formations. It reports that:
    a. Based on the recorded temperatures at the vent of Beauty Creek hot springs and the recorded Beetaloo Sub-basin formation temperatures presented in Evans et al. (2020), the groundwater source could be from at least 1000-1100 m bGL.
    b. The Lagoon Creek Gorge spring has a lower temperature (42 °C), but it is still above average ambient surface temperatures, which indicates a source that could be 200-500 m bGL.

  This adds risk and complexity. The proposed wells may intersect multiple aquifers which support surface ecosystem values and increase the potential for cross contamination of aquifers.
- The unique characteristics of springs recharged by deep groundwater also mean a higher likelihood of refugia, species endemism, including stygofauna and climate change resilience.

[1] file:///Users/Guest/Downloads/sreba%20beetaloo%20regional%20report.pdf (p86)

2. Biodiversity

The northern blue-tongue skink, which is listed as Critically Endangered under the EPBC Act, may be present in the impacted area, with recent records within 40 km of the site.

The EMP claims there is unlikely to be stygofauna present in the project's disturbance footprint, however no targeted stygofauna surveys were conducted at nearby bores as part of surveys for this EMP. Given the complexity of springs systems in the area, especially Hot Spring Valley which are fed by multiple aquifers, there may be a higher degree of endemism amongst stygofauna species and other species in these areas. Surveys should be conducted beyond the immediate well footprint.

Additional EPBC listed species that may be found at the project location include: Gouldian finch; Red goshawk; Grey falcon; Northern shrike-tit; Plains death adder; and the Yellow-spotted monitor.

3. Greenhouse Gas emissions

The EMP states that the project will generate 27,741 tCO2-e of scope 1 greenhouse gas emissions over the next 5 years. The methodology used to reach this figure should be examined closely, as projects of a similar size (e.g. Beetaloo Energy's Carpentaria Project) projects an estimated 180,000 tCO2-e of scope 1 greenhouse gas emissions with only 9 wells over the same period, 3 wells less than the 12 proposed as part of this project.

4. Land clearing

The proposal involves clearing 87 hectares of savanna woodland and floodplain, in an area where there are few weeds and a diverse array of relatively undisturbed habitat. The NT has some of the last remaining large swathes of undisturbed savanna. I am opposed to this clearing. These risks warrant a detailed environmental impact assessment.

Conclusion

Given the immense risk and uncertainty, and implications to protected matters (impacts on water resources and listed species) under federal environmental law, I request that the Minister reject this version of the proposed EMP and require that

A. The project undertake a full Environmental Impact Statement under the Environment Protection Act 2019 (NT);
B. The project be referred to the Federal Environment Minister under the *Environment Protection and Biodiversity Conservation Act 1999.*

Yours sincerely,

Adrian Tomlinson
Copies to:
Federal Minister for the Environment

From:	BirdLife Top End
To:	SantosPetroleum DLPE
Subject:	Submission: STO8-1: EP161 Beetaloo Basin Appraisal Pilot Environment Management Plan (EMP)
Date:	Friday, 19 December 2025 3:48:37 PM
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Good afternoon,

Please find attached the submission from BirdLife Top End for STO8-1: EP161 Beetaloo Basin Appraisal Pilot Environment Management Plan (EMP).

Thanks so much!

Regards,

Mitch Rose | Co-Convenor
BirdLife Top End
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topend@birdlife.org.au | birdlife.org.au
ABN 75 149 124 774

I acknowledge that I live and work on Larrakia Country and pay my respects to the Elders past, present and emerging.

19 December 2025

Department of Lands, Planning and Environment
Petroleum Regulations Unit
PO Box 3675
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By email: Santos.ep161@nt.gov.au

Submission: STO8-1: EP161 Beetaloo Basin Appraisal Pilot Environment Management Plan (EMP)

Introduction

BirdLife Top End (BTE) welcomes the opportunity to provide comments on the STO8-1: EP161 Beetaloo Basin Appraisal Pilot Environment Management Plan (EMP) submitted by Santos QNT Pty Ltd under the Petroleum (Environment) Regulations Act 2016.

This submission reflects BirdLife Top End's commitment to the conservation of bird populations and their habitats across the Top End, including within and adjacent to petroleum exploration and appraisal areas. In preparing this submission, BLTE has reviewed the EP161 EMP and its associated documents published on the *Have Your Say* portal, including the primary EMP report and accompanying appendices encompassing environmental assessments, baseline data, and management proposals.

We refer to the following documents:
a. STO8-1 Beetaloo Basin Appraisal Pilot EMP_Redacted
b. Appendix A-K Redacted
c. Appendix L Redacted
d. Appendix M-P_Redacted. (together, the Referral).

Recommendation Summary

BirdLife Top End submits that section 50(1) of the *Environment Protection Act 2019* (NT) applies in relation to STO8-1: EP161 Beetaloo Basin Appraisal Pilot Environment Management Plan (EMP).

BirdLife Top End therefore recommends that the Minister:

i. refer the EMP to the Northern Territory Environment Protection Authority (NTEPA) under section 50(2)(c) of the *Environment Protection Act 2019 (EP Act)*; and

ii. decline to consider the application unless and until the EMP has been referred to the NTEPA and a decision has been made on that referral, in accordance with section 50(2)(a) of the Act.

BirdLife Top End also submits that the EMP should be referred for assessment under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act), as the proposed activities have the potential to result in significant impacts on Matters of National Environmental Significance, including listed threatened species and water resources.

Alternatively, if the EMP is not referred, BirdLife Top End submits that the Minister should reject the EMP on the basis that it does not comply with the *Petroleum (Environment) Regulations 2016* (NT), because:

i. environmental risks have not been demonstrated to be managed to a level that is as low as reasonably practicable (ALARP) or acceptable;

ii. the EMP does not include the information required under Schedule 1 of the Regulations.

Introduction

About BirdLife Top End

BirdLife Top End is a volunteer branch of BirdLife Australia, an independent, non-partisan grassroots charity dedicated to the conservation of Australia's native birds and their habitats. BirdLife Australia is the national partner of BirdLife International, the world's largest conservation partnership, and has played a central role in monitoring and safeguarding Australia's birdlife. This work includes major long-term threatened species programs and collaborative projects with communities, Traditional Owners, government and industry.

As part of BirdLife Australia's nationwide community of more than 30 branches, over 400,000 supporters, thousands of volunteers and citizen scientists, the Top End branch contributes to a legacy of almost 120 years of bird conservation, scientific research, advocacy, education and on-ground habitat protection. Within this broader network, BirdLife Top End provides the focal point for community-led bird conservation in the Northern Territory's 'Top End.' The branch is entirely volunteer-run and operates in alignment with BirdLife Australia's core mission and values: to make a real and positive difference for Australia's birds.

Our region spans from the Barkly Tablelands to the northern tip of the continent, including the Tiwi Islands, Groote Eylandt, and all other offshore islands. Volunteers and members across the Top End lead and support a wide range of activities: bird research and long-term monitoring programs; community capacity-building initiatives; advocacy for species and habitats under threat; and public engagement through education and outreach. This grassroots effort forms an integral part of BirdLife Australia's national conservation work and helps protect the unique birdlife of northern Australia.

The proposed action

The proponent proposes to undertake petroleum appraisal activities within Exploration Permit 161 (EP161) on Tanumbirini Station, Northern Territory. The proposed action involves the construction, operation and eventual decommissioning of up to twelve petroleum appraisal wells across two well pad locations, referred to as Jibera South and Newcastle South.

The proposed action includes clearing and earthworks to establish two new well pads and associated ancillary infrastructure, followed by the drilling of up to twelve appraisal wells. Wells would subsequently undergo testing, operation and maintenance, with decommissioning to occur following completion of appraisal activities. Hydraulic fracture stimulation is proposed for up to twelve wells, with an average of approximately 60 fracture stages per horizontal well and up to four stages per vertical well. The intensity of hydraulic fracturing proposed, particularly for horizontal wells, represents a high-impact industrial activity with the potential to generate significant and prolonged disturbance.

Wastewater generated during drilling and hydraulic fracture stimulation would be managed onsite at each well pad through the use of evaporation ponds, storage tanks, drilling sumps, cutting pits and associated transfer infrastructure. Wastewater will contain significant amount of chemicals used throughout the process and would be transported and disposed of unless otherwise approved for reuse or burial. These activities introduce ongoing risks associated with wastewater containment, handling and transport, including the potential for spills, leakage and contamination of surrounding terrestrial and groundwater environments.

Additional infrastructure and activities required to support the appraisal program include the installation of water supply bores, groundwater monitoring bores, clean water storage tanks or dams, borrow pits, airstrip operations, offices, workshops, laydown areas, bulk material transport and storage, temporary camps at each well pad, and traffic management measures. Collectively, this suite of infrastructure substantially expands the spatial footprint, duration and complexity of disturbance beyond that associated with drilling alone, increasing the likelihood of indirect impacts such as habitat fragmentation, altered fire regimes, increased access and edge effects.

Each well pad is proposed to occupy approximately 15 hectares, with additional disturbance associated with access roads, borrow pits and groundwater bores. The proponent defines a broader Project Area within which the final disturbance footprint would be located, allowing flexibility in the placement of well pads and ancillary infrastructure. While presented as a design refinement measure, this flexibility reduces spatial certainty and limits the ability to accurately assess site-specific impacts on sensitive habitats and species prior to approval. The maximum disturbance footprint for clearing and earthworks is estimated at approximately 87.34 hectares across both well pad locations, comprising new remnant vegetation disturbance and areas previously disturbed by existing tracks, grazing paddocks and fence lines.

The proposed action is presented as an appraisal-scale activity; however, the scale, intensity and breadth of infrastructure are more consistent with early-stage development and contribute to cumulative impacts when considered alongside other approved and proposed activities within the Beetaloo Basin. In the absence of comprehensive, species-specific baseline surveys and robust assessment of indirect and cumulative impacts, there remains a high degree of uncertainty regarding the consequences of the proposed action for threatened species, ecological communities and landscape-scale processes.

Our Concerns:

Adequacy of Environmental Assessment Report (Appendix J)

Environmental assessment reports are a mandatory component of the Commonwealth and Northern Territory approval frameworks and are intended to provide sufficient, reliable information to determine whether proposed actions are likely to have significant environmental impacts. Under the EPBC Act, proponents must identify and assess potential impacts on Matters of National Environmental Significance, including listed threatened species, using established significance guidelines. At the Territory level, the *Petroleum (Environment) Regulations 2016*, *Environment Protection Act 2019* and *Territory Parks and Wildlife Conservation Act 1976* require proponents to demonstrate that environmental impacts, including impacts to protected and threatened species, have been adequately assessed and can be avoided or managed.

The Environmental Assessment Report[1], states that field surveys were undertaken to document environmental values within the project disturbance footprint to inform Santos of potential constraints that will require specific environmental mitigations and that "The survey was conducted generally in accordance with the NT Guidelines for Assessment of Impacts on Terrestrial Biodiversity (NTEPA, 2011)".[2]

For reasons detailed below, we submit that the Environmental Assessment Report relies on fauna survey data that are insufficient in scope, effort and methodology to meet the requirements of the *Territory Parks and Wildlife Conservation Act 1976* (NT) (TPWC Act) and the *Environment Protection and Biodiversity Conservation Act 1999* (Cth). Survey work has not followed accepted guidelines for threatened species detection, including appropriate seasonal timing, survey duration, repeat visits, or the use of species-specific methods. As a result, the referral fails to provide a robust baseline understanding of species presence, distribution or habitat use within the proposed project area.

Insufficient field surveys

The fauna surveys presented in Santos' Environmental Assessment Report do not meet the standard required to support assessment under the EPBC Act or the TPWC Act. Survey effort was limited to brief 10–15 minute site visits at 18 locations, without the use of standardised quadrats, repeated daylight counts, or nocturnal surveys. This approach is inconsistent with recommended survey methodologies, which require multiple bird counts within defined quadrats to account for detectability, temporal variation and species accumulation. As a result, the surveys are unlikely to reliably detect cryptic, low-density or habitat-specialist species, including listed threatened birds likely to occur within the project area.

Targeted survey effort was largely confined to the use of call playback for Crested Shrike-tit (*Falcunculus frontatus*) during 10-15 minute surveys. While call playback was undertaken, the survey design, duration, timing and effort do not align with the species-specfic *Survey guidelines for Australia's threatened birds* under the EPBC Act[3] and are insufficient to support the conclusions presented.

There were no equivalent, species-appropriate survey methods applied for Carpentarian Grasswren (*Amytornis dorotheae*), Gouldian Finch (*Erythrura gouldiae*) or Red Goshawk (*Erythrotriorchis radiatus*). In particular, the absence of repeated early-morning surveys, dry-season targeting, habitat-specific sampling and abundance recording significantly limits the ability to detect Gouldian Finch, whose presence is highly seasonal and closely linked to specific feeding, nesting and watering habitats. These methodological deficiencies undermine the conclusions that impacts to threatened species are unlikely or negligible.

We note with urgency, and in relation to the potential occurrence of *Carpentarian Grasswren (Amytornis dorotheae)* as discussed in the '*Independent report regarding the possible occurrence of Carpentarian Grasswren (Amytornis dorotheae) on Tanumbirini Station, Northern Territory*.'[4] subsequent confirmation

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[1] *Environmental Assessment Report: Beetaloo Basin Appraisal Activity*, The Beetaloo Appraisal Environmental Management Plan (EMP), 13 November 2025.
[2] Section 3.3 in (n. 3)
[3] Page 72-73 Department of the Environment 2011, *Survey guidelines for Australia's threatened birds: Guidelines for detecting birds listed as threatened under the Environment Protection and Biodiversity Conservation Act 1999*, Commonwealth of Australia, Canberra.
[4] Stoetzel, H.J. (2025). *Independent report regarding the possible occurrence of Carpentarian Grasswren (Amytornis dorotheae) on Tanumbirini Station, Northern Territory*. Prepared by Conservation Partners, Malanda, Queensland, 17 December 2025. See Annexure to the Submission of the Environment Centre NT to this EMP.

would likely meet the definition of a “critical occurrence of a threatened species” under Section 8.4.1 of the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (Pepper Inquiry).[5]

Adequacy of fauna surveys and assessment of cumulative impacts

BirdLife Top End holds serious concerns that impacts to threatened bird species have not been adequately assessed. In most cases, this is primarily due to the absence of targeted, species-appropriate surveys capable of reliably detecting these taxa. Without such surveys, conclusions regarding likelihood of occurrence and impact significance are speculative and unsupported. We submit that, due to the Environmental Assessment Reports reliance on incomplete surveys, lack of species-appropriate methodologies and failure to assess cumulative and indirect impacts,this EMP has not met the intent or requirements of regulatory frameworks and therefore cannot support informed, lawful approval decisions.

Potential Impacts on Threatened Bird Species

The Project has the potential to adversely affect several nationally and Northern Territory-listed threatened bird species within and adjacent to the Disturbance Footprint. Of particular concern are the Carpentarian Grasswren (*Amytornis dorotheae*), Gouldian Finch (*Erythrura gouldiae*), Red Goshawk (*Erythrotriorchis radiatus*), and Crested Shrike-tit (*Falcunculus whitei*), due to their restricted distributions, specialised habitat requirements, and sensitivity to disturbance.

Carpentarian Grasswren

The Carpentarian Grasswren is a highly range-restricted species associated with dense spinifex and rocky savanna habitats. Fauna surveys reported in the Environmental Assessment Report recorded an individual identified only as “Grass wren” (*Amytornis* sp.) during surveys undertaken on Tanumbirini Station in December 2024[6]. The record was not resolved to species level, and no supporting diagnostic information was provided. On this basis, the Environmental Assessment Report concludes that the observation does not correspond to a species listed under either the *Environment Protection and Biodiversity Conservation Act 1999* or the *Territory Parks and Wildlife Conservation Act 1976*. This conclusion is not adequately supported by the information presented.

The Carpentarian Grasswren has undergone severe population declines, largely driven by altered fire regimes, and is now known from only two small, isolated populations in the Northern Territory. The species is widely regarded as having been extirpated from the northern part of its former range, including areas west of Borroloola. A confirmed detection at Tanumbirini Station would therefore be of major conservation significance. Despite this, the EAR does not apply a precautionary approach to the record and does not undertake targeted verification surveys to confirm or refute the species’ presence.

Given the poor survey efforts conducted as part of the Environmental Assessment Report, it is remarkable that a potential Carpentaria Grasswren was observed. It is curious that the observation was not resolved to species level, indeed, just a few minutes seeking more information online, in guidebooks or other resources commonly used by those conducting Environmental Impact Assessments would have indicated this was an observation that warrants further investigation.

[5] As indicated in section 4.2, (n. 4)
[6] See Table 55, ‘Fauna Species within the Project Area’, (n. 1)

If the Carpentarian Grasswren is present, the proposed works have the potential to result in both direct and indirect impacts, including clearing of suitable habitat, disturbance from construction noise and activity, degradation of water quality, increased predation pressure from feral cats, and the introduction or spread of invasive weeds.[7] Fire represents a particularly significant risk for this species; accidental ignitions or changes to fire regimes associated with project activities could result in the loss of mature *Triodia* habitat, which is critical for shelter, foraging, and breeding.

The Environmental Assessment Report also does not adequately consider the potential importance of local water sources, threats from consuming or coming into contact with the numerous toxins that will be present on site. The Carpentarian Grasswren has been observed using water points, potentially for thermoregulation during extreme heat. Project-related impacts on natural water sources also represent an additional, poorly understood risk pathway that has not been assessed in a meaningful way.

Given the unresolved identification of the *Amytornis* record and the severe conservation status of the Carpentarian Grasswren, the conclusion that the Project will not impact threatened grasswren species is premature. The current assessment does not provide sufficient evidence to exclude the presence of the Carpentarian Grasswren, nor does it adequately evaluate the potential consequences should the species occur within or adjacent to the Project Area.

BirdLife Top End agrees with recommendations in the Independent Report and urges the NT EPA and federal counterparts ensure targeted verification surveys to resolve this uncertainty. These should include repeated call-playback surveys undertaken by experienced observers, using standardised protocols and conducted under appropriate seasonal and weather conditions. Until such surveys are completed, the extent of potential impacts, the need for mitigation measures, including fire management, and the appropriateness of project approval cannot be determined with confidence.

Gouldian Finch

This submission raises serious concerns regarding the potential impacts of the Project on the nationally threatened Gouldian Finch (*Erythrura gouldiae*), and the inadequacy of the impact assessment in identifying, assessing, and mitigating those impacts. The Environmental Assessment Report relies on survey effort that is insufficient to determine Gouldian Finch presence, habitat use, or vulnerability to project activities, and therefore cannot support defensible conclusions about impact significance.

The Project involves the clearing of up to 46.9 hectares of woodland and associated water sources, which may remove breeding, foraging, and dispersal habitat used by Gouldian Finches. The species is highly mobile and moves seasonally between late dry-season water points and wet-season foraging areas. Habitat loss within the Project Area therefore has the potential to reduce access to critical water sources and food resources, disrupt dispersal corridors, and contribute to local population declines, particularly when considered in combination with existing pressures from grazing and other land uses in the region.

Despite these risks, surveys reported in the EAR were insufficient in duration, spatial coverage, and seasonal timing to reliably detect Gouldian Finches or assess their use of the Project Area. The survey design did not account for seasonal movements or intermittent presence, and did not include extended observations at water points or repeated surveys during periods of peak detectability. As a result, the likelihood of Gouldian Finch use of the Project Area has been underestimated, and the potential impacts of clearing and ongoing disturbance have not been adequately assessed.

[7] See section 4 and 6 of (the EAR (n. 1)

The assessment further underestimates impact by applying an unduly narrow interpretation of habitat importance, focusing primarily on preferred breeding habitat while discounting foraging, dispersal, and seasonal habitats that are essential to species persistence. While the EAR acknowledges the presence of suitable woodland, potential nesting trees, and wet-season foraging grasses within and adjacent to the disturbance footprint, it nonetheless concludes that the area does not constitute important habitat. This conclusion is not supported by the available evidence and fails to account for cumulative, indirect, and landscape-scale impacts associated with habitat loss and fragmentation.

Given the scale of proposed clearing, the reliance of Gouldian Finches on a network of habitats and water sources, and the inadequacy of survey effort, the conclusion that the Project will not have a significant impact on the species is premature and unsupported. Uncertainty arising from insufficient surveys should be addressed conservatively, not used to discount potential impacts on a nationally threatened species.

Targeted Gouldian Finch surveys are required to adequately assess project-related threats. These should include repeated late dry-season surveys, extended observation at water sources, and habitat assessment at a landscape and seasonal scale by experienced observers. Until such surveys are undertaken, conclusions regarding Gouldian Finch presence, habitat importance, and impact significance remain unreliable, and the current assessment cannot be considered adequate to inform approval or mitigation measures.

Red Goshawk

Although no breeding habitat occurs within the Project Area, the Disturbance Footprint contains marginal foraging and dispersal habitat for transient Red Goshawks. The species has very large home ranges and can travel substantial distances outside the breeding season, making it likely that juveniles or dispersing adults could use the area intermittently. Habitat clearance and disturbance could disrupt movement corridors, reduce prey availability, and indirectly impact survival and fitness. The EAR's reliance on limited field observations and narrow habitat definitions underestimates the potential significance of these impacts.

Northern Shrike-tit

The Northern Shrike-tit occurs primarily north of the Project Area, with few records south of -16.25° latitude. While the likelihood of occurrence within the Disturbance Footprint is low, marginal foraging or dispersal habitat may exist. Habitat clearing and disturbance could reduce availability of feeding resources and interrupt connectivity between core populations. Even low-likelihood occurrences warrant consideration under EPBC and NT legislation, particularly in the context of cumulative impacts.

Cumulative and Indirect Impacts

For all four species, cumulative impacts from habitat fragmentation, altered fire regimes, and landscape-scale clearing could exacerbate risks. Mobile and dispersing individuals, along with species with patchy distributions such as the Grasswren, are particularly vulnerable to habitat loss and disturbance. Removal of ephemeral water sources, foraging grounds, and dispersal pathways may disproportionately affect populations already sensitive to environmental change. These impacts must be assessed in accordance with both Commonwealth and NT law, which require precautionary approaches where threatened species may be affected.

In addition, BLTE is concerned about the inadequacy of the EMP's impact on water resources and groundwater dependent ecosystems, and potential for contamination through groundwater recharge pathways or potential inter-aquifer connectivity. In the EMP, Santos has not modeled or assessed potential contamination pathways, and in doing do has not adequately described the potential risks and impacts of contamination in relation to regional groundwater quality and the species that rely on the Territory's network of rivers, springs, creeks and groundwater-dependent ecosystems.

Conclusion

BirdLife Top End recommends that the Minister refer the EMP to the Northern Territory Environment Protection Authority and defer consideration until a decision on that referral is made. The EMP should also be referred under the EPBC Act due to potential impacts on Matters of National Environmental Significance, including threatened species and water resources. Alternatively, if not referred, the EMP should be rejected because it fails to demonstrate that environmental risks are managed to ALARP and does not provide the information required under Schedule 1 of the Petroleum (Environment) Regulations 2016.

Kind regards,

Mitch Rose
Co-convenor – BirdLife Top End

From:	Cyan Glamor
To:	SantosPetroleum DLPE
Subject:	EP161 Beetaloo Feedback
Date:	Thursday, 11 December 2025 9:03:46 PM
Attachments:	EMP_Feedback.pdf

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,

Please find attached my feedback for EP161 Beetaloo Basin Appraisal Pilot Environment Management Plan.

The EMP and Appendices contain numerous inconsistencies between referenced values, formatting errors, and activity descriptions that raise concerns regarding document completeness and quality assurance. The regulatory authority is requested to clarify how this document has been determined suitable for public assessment, and to justify the single public comment period given the apparent draft status of key sections. The proposed scope of activities requires clarification to enable effective stakeholder review and regulatory assessment.

1. DLPE should require Interest Holders to provide a fully searchable document and table of contents that correctly link to sections.
2. The EMP does not identify the authors or their qualifications. Confirmation is required that the EMP was developed by suitably qualified and experienced person(s) in accordance with regulatory requirements.
3. The proponent references significant concurrent developments in the NT including Barossa in their foreword. These concurrent projects should be included in the cumulative impact assessment to comply with regulatory requirements for comprehensive environmental assessment.
4. The proponent makes broad socioeconomic commitments in promotional materials including: Local jobs and attraction of interstate migration to the NT, growing the taxation base and the population to support expanded and higher-quality services and infrastructure

- Contracting and supplier opportunities for local companies
- Increased regional and Aboriginal employment and procurement opportunities
- Royalties paid to the Territory contributing to improving local community services, regional roads, more police, schools, hospitals and infrastructure
- Important community investment programs developed in partnership with Traditional Owners.

However, these commitments are not translated into enforceable performance measures or management actions within the EMP documentation.

6. The potential evaporation estimates of 0.35 and 0.25 require technical justification including methodology, data sources, and temporal variability. The rainfall assumptions underpinning these estimates should be explicitly stated and justified.
7. The EMP proposes up to 14ML of open fluid storage for evaporation on each well pad. Critical information is absent regarding management protocols for significant rainfall events, tank configurations, and contingency measures to prevent overflow.

8. The proponent states a key objective to demonstrate safe and sustainable shale development with minimal environmental impact. This objective requires independent verification given the documented recordable incidents across the proponent's onshore NT operations since 2019. Additionally, Figure 8 indicates Mt Brown well pad infrastructure is located within or immediately adjacent to a drainage line, which appears inconsistent with best practice for minimizing hydrological and riparian zone impacts.
9. The operator liaison person contact details are redacted in the EMP. Stakeholder access to operator contacts should be provided in accordance with transparency and community engagement requirements.
10. Figure 1 contains blue solid lines without legend identification or explanation. All map features require clear labeling for effective document review.
11. Multiple bores are documented within 1km of proposed well pads. One pastoralist bore is described as 'believed' to be abandoned without evidence of landholder consultation or field verification. The EMP should clarify the status of all nearby bores and address the risk of future bore reactivation if formal decommissioning has not occurred.
12. Site selection criteria are presented for specific points, yet the proponent seeks flexibility to relocate well pads within the broader project area. The EMP should clarify whether relocation would invalidate the presented selection criteria and environmental impact assessments. The positioning of Mt Brown well pad within a riparian zone establishes a precedent that requires regulatory scrutiny for future well pad locations.
13. The indicative nature of infrastructure plans creates uncertainty regarding the maximum number of sumps, spatial compatibility of proposed infrastructure including up to 16 tanks and 10 water bores per well pad, and firebreak locations. Given well pads may extend to 15 hectares, engineering drawings should depict maximum-case design scenarios to enable proper assessment of environmental impacts and spatial requirements.
14. Table 13 contains inconsistencies in disturbance area calculations. The size requirements and area allocations for ancillary infrastructure are insufficiently detailed to validate the total proposed disturbance footprint.
15. The utilization of pre-disturbed land does not exempt the proponent from rehabilitation obligations. Clear rehabilitation standards and completion criteria should be specified regardless of pre-existing disturbance status, in accordance with the NT Rehabilitation Guide 2020.
16. The EMP indicates up to 12 wells may be drilled on a single well pad, but does not provide corresponding analysis of spatial requirements, infrastructure footprint, or operational sequencing. Assessment of maximum-case scenarios is required.
17. The EMP is very light on beneficial use and how they will do this?
18. The EMP does not specify minimum separation distances between storage tanks. With up to 16 tanks proposed per well pad, the cumulative buffer requirements for safe operation and emergency response may substantially affect the total disturbance footprint and should be quantified.
19. The EMP maintains a high level of generality with limited absolute commitments, creating substantial ambiguity regarding the actual scope and nature of proposed activities. The regulatory authority should require the proponent to define and assess all reasonably

foreseeable scenarios within the envelope of flexibility sought, ensuring environmental impacts are not underestimated.

20. Inconsistencies exist between Table 14 and Figure 9, including hydraulic fracture stimulation (HFS) start dates. The activity schedule appears to cover only 11 wells, requiring clarification given the proposal for 12 wells across two well pads.

21. The operational schedule proposes hydraulic fracture stimulation activities during the wet season when surface water risks and access constraints are elevated. Technical justification should be provided for wet season operations, including risk mitigation measures and contingency protocols for rainfall events and flooding.

22. Access tracks are specified at up to 20m width without technical justification for double-width construction requirements. The need for 20m width should be substantiated with reference to equipment specifications, passing bay requirements, or other operational constraints.

23. The term "area free of overland flow" requires definition and spatial delineation. Clarification is needed regarding whether additional clearing beyond the stated disturbance footprint would be required to achieve overland flow avoidance.

24. Critical infrastructure specifications are absent including sump/dam dimensions, capacities, and quantities. This consistent lack of detail for supporting infrastructure impedes effective assessment of environmental impacts and operational feasibility.

25. Civil construction specifications including firebreak dimensions and locations should be presented in the main EMP body rather than appendices to facilitate document review and ensure regulatory compliance requirements are clearly identified.

26. Bund specifications for storage tanks are not provided including dimensions, capacity, and design standards. These details are required to assess containment adequacy and compliance with relevant codes of practice.

27. Civil engineering details for borrow pits are absent including excavation depth, pit dimensions, slope stability analysis, and rehabilitation methodology. These specifications are necessary to assess safety risks and environmental impacts.

28. The operational feasibility of drilling and stimulating 12 wells on a single well pad requires demonstration including spatial layout, equipment mobilization sequences, and well spacing to prevent subsurface interference. Engineering drawings should show how drilling rigs and hydraulic fracture stimulation equipment will operate safely within the constrained pad area.

29. Table 13 references groundwater monitoring areas without clarification of whether these represent additional civil disturbance requiring clearing, infrastructure installation, or access tracks. All disturbance areas should be quantified in the total project footprint.

30. Leak detection systems are specified for tanks but not for sumps. Given the volumes and chemical composition of fluids stored in sumps, equivalent leak detection and monitoring protocols should be specified.

31. The environmental and occupational health impacts of imported sand require assessment including wind dispersion of fines, management of damaged bags, and crystalline silica exposure risks for workers. The total sand volume requirements and associated trucking movements

appear underestimated and should be verified against hydraulic fracture stimulation specifications.
32. Weed hygiene protocols for imported sand and fill materials should include third-party certification of weed-free status in accordance with best practice standards for biosecurity management.
33. The EMP acknowledges "historical problems encountered in the area (lost returns, irregular hole erosion, poor hole cleaning, poor cement displacement etc.) are considered during the design process." Specific mitigation measures and design modifications to address these documented technical challenges should be detailed to demonstrate learning from previous operations.
34. The EMP assumes a beneficial use agreement will be secured. The EMP should address alternative scenarios including if a beneficial use agreement cannot be obtained.
35. The EMP references completed flare modeling but does not provide the modeling results, methodology, or validation. This information should be included to enable independent review of air quality impacts.
36. Liquid hydrocarbon (oil/condensate) storage requirements are not clearly specified. Clarification is required whether hydrocarbon storage tanks are included within the 16-tank limit per well pad, and if not, the total tank numbers, secondary containment specifications, freeboard monitoring protocols, and leak detection systems for hydrocarbon storage.
37. The volume of oil/condensate requiring off-site disposal via vacuum truck should be quantified to assess transport movements and waste management requirements.
38. The EMP references completed noise modeling but does not provide the modeling results, methodology, parameters, or validation. This information should be included to enable independent review of noise impacts on sensitive receptors.
39. Noise impact assessment should comprehensively address all major noise sources including drilling rigs, hydraulic fracture stimulation equipment, and cementing units. The cumulative noise impacts from concurrent operations require assessment.
40. Figure 21 is inconsistent with the well pad design presented elsewhere in the EMP. Discrepancies between engineering drawings should be resolved to ensure accurate representation of proposed infrastructure.
41. The EMP should specify well spacing tolerances, directional drilling accuracy standards, and subsurface collision avoidance protocols for the proposed 12-well pad configuration. Anti-collision monitoring systems and procedures should be detailed.
42. Section 3.9.5 commits to maintaining sufficient enclosed storage capacity to transfer all produced water and flowback fluid in advance of significant rainfall events. The design should address how tank vents will be protected from inundation during extreme rainfall, including vent design specifications and height above design flood level.
43. The EMP proposes transferring waste drilling fluids into onsite wastewater tanks as an alternative to sump storage. Total fluid volumes and tank capacity should be reconciled to demonstrate sufficient storage capacity for all operational scenarios.

44. The assessment of impacts on Tanumbirini station homestead should account for the proposed flexibility to relocate infrastructure within the broader project area, ensuring buffer distances are maintained regardless of final infrastructure locations.
45. Section 3.9.6 lacks comprehensive noise modeling details including environmental conditions, concurrent activity assumptions, modeling distances, baseline noise levels, and the acoustic impact of clearing up to 15 hectares of vegetation. Without this information, independent verification of noise impact predictions cannot be conducted. Clarification is required whether the 30 pump scenario accounts for all concurrent noise sources including truck movements and generator operation.
46. The EMP states that layout and equipment selection will be reviewed during detailed noise model refinement. This sequence appears inconsistent with best practice, where equipment specifications should inform initial modeling to enable impact assessment prior to approval. The regulatory authority should require completed modeling based on confirmed equipment specifications.
47. Noise modeling methodology requires clarification regarding how pump noise characteristics have been modeled without finalized equipment selection. Generic equipment assumptions and conservative noise estimates should be explicitly stated.
48. Section 3.10.2 specifies up to 28ML of flowback per well. For a 12-well pad configuration, the cumulative flowback volume of up to 336ML requires comprehensive storage and management planning. The EMP should demonstrate how maximum-case flowback volumes will be safely contained and managed.
49. The EMP proposes adding covered ponds as a solution for excess flowback volumes. The technical and logistical feasibility of this contingency measure during significant rainfall events requires demonstration, including procurement timeframes for additional storage infrastructure in remote NT locations and site preparation requirements during wet conditions.
50. The EMP should include an unambiguous commitment to maintain sufficient enclosed storage capacity for all on-site fluids under all operational and weather scenarios, or alternatively provide a technically robust justification for temporary open storage with quantified environmental risk assessment.
51. The activity schedule and drilling rate commitments require clarification. If the proponent intends to limit drilling to four wells per year per site, this should be stated as an enforceable commitment to enable accurate assessment of temporal environmental impacts.
52. The enhanced evaporation equipment specifications require clarification including whether vapor drift evaporators are the only technology to be employed. The EMP should demonstrate how vapor and aerosol emissions will be contained within tank systems and prevented from environmental release. The presence of a dedicated evaporation area in Appendix P suggests alternative evaporation infrastructure beyond above-ground tanks; all evaporation methods and associated containment should be comprehensively described.
53. The EMP should specify monitoring protocols to detect off-site drift of vapors or aerosols before environmental harm occurs, including monitoring locations, detection limits, and trigger levels for corrective action.

54. The proposal to utilize flowback water for dust suppression raises significant environmental concerns given the chemical composition of flowback fluids. A comprehensive risk assessment should be provided addressing potential soil contamination, groundwater infiltration, vegetation impacts, and chemical exposure pathways. This practice may not comply with waste management hierarchy principles requiring appropriate treatment and containment of contaminated fluids.
55. Fluid level monitoring protocols for sumps should be specified including monitoring frequency, technology (automated level sensors versus manual gauging), and trigger levels for management actions.
56. Infrastructure sizing and impact assessments appear predicated on four-well pad configurations despite the proposal for up to 12 wells across two well pads. The EMP should clarify the design basis and confirm that assessments account for maximum-case scenarios. Additionally, the operational sequence and timing assumptions require clarification, particularly whether sumps will be decommissioned between wells and whether flowback fluid will be fully evaporated or reused before subsequent well operations.
57. Total sump capacity requirements for a 12-well program should be quantified and reconciled with available space on well pads. The EMP should demonstrate adequate sump capacity and spatial configuration for maximum-case operational scenarios.
58. Engineering drawings in Appendix P contain apparent calculation errors for sump dimensions. The specified Width2 and Length2 values appear inconsistent with the proposed vertical to horizontal (V:H) slope ratios. Furthermore, volumetric capacity calculations appear incorrect; for example, Newcastle North sump dimensions would yield approximately 2,950m³ gross volume, which reduces to less than 2,400m³ after accounting for required freeboard. These dimensional and capacity discrepancies require resolution to ensure adequate containment capacity.

An inconsistency exists between freeboard specifications: Appendix P specifies 1.5m freeboard while other sections reference 1.1m. The EMP should clarify which freeboard standard applies to sumps and provide technical justification for the selected value.

59. The domestic water usage estimate of 200L/day/person should be validated against industry standards and operational experience. The upper range of water consumption should be specified to enable worst-case impact assessment.
60. The proposed irrigation of at least 21,000L of wastewater per day represents a substantial land application program. A comprehensive irrigation management plan should be included in the EMP detailing application rates, irrigation area dimensions, soil suitability assessment, loading calculations, vegetation establishment, and environmental monitoring protocols.
61. Downstream receptors and environmental values potentially affected by irrigation should be identified and assessed including surface water bodies, groundwater-dependent ecosystems, and sensitive vegetation communities.

62. Section 3.10.6 states the EMP does not seek approval for wastewater reuse, yet wastewater reuse is listed as a method to reduce flowback volumes. This inconsistency requires resolution to clarify whether wastewater reuse is part of the proposed activity scope.
63. The proposal to "investigate options to apply waste management hierarchy in operations" including reuse of wastewater for petroleum activities without treatment creates unacceptable regulatory uncertainty. All proposed waste management options should be fully described, assessed for environmental risk, and included within the approval scope, or alternatively excluded from the operational envelope.
64. The calculation of 5ML per camp per year is inconsistent with the stated water usage rate of 200L/person/day for 105 personnel (which equates to approximately 7.7ML per year). Additionally, this volume is inconsistent with Table 10. The regulatory authority should require clarification and reconciliation of wastewater irrigation volumes, and should not approve irrigation of 5 million litres per year without a comprehensive irrigation management plan.
65. The classification of "evaporation loss" as a water use category requires clarification. This terminology is potentially confusing and should be explained with reference to whether it represents natural evaporation from open storages, enhanced evaporation as a waste management method, or evaporative losses during water transport and application.
66. Several water use estimates appear substantially higher than comparable petroleum operations. Activity-specific water consumption estimates should be justified with reference to equipment specifications, operational methodology, and industry benchmarks for similar activities.
67. The dust suppression water requirement of 4ML per month for 5 years (total 240ML) requires technical justification including area to be suppressed, application rates, frequency, and comparison to similar remote operations in the NT.
68. Water volume requirements for hydraulic fracture stimulation require clarification. The EMP should specify whether 8ML is required for the vertical section and 145ML for the horizontal section per well, and confirm the total of 153ML per fracture stimulation. Additionally, the statement that 20% flowback would equal 30.6ML appears inconsistent with other sections specifying up to 28ML flowback per well. These contradictions should be resolved.
69. Water extraction calculations require reconciliation. If Schedule 9 indicates four wells per year at 153ML per fracture stimulation plus 60ML for drilling and completion per well, the annual requirement would be 852ML [(153 × 4) + (60 × 4)], yet the application seeks 750ML. The discrepancy requires explanation. Furthermore, the indicative status of Schedule 9 creates uncertainty regarding whether more than four wells per year could be drilled, which would further increase water requirements. The EMP lacks assessment of cumulative groundwater drawdown impacts from extraction of 750ML or greater, including potential effects on the Tanumbirini station homestead water supply located approximately 4km from extraction bores. Hydrogeological impact assessment including drawdown modeling should be provided.
70. Water volume inconsistencies exist between tables. Table 26 specifies 34ML for two pads and tracks, while Table 25 indicates 30ML. These discrepancies should be reconciled to ensure accurate water extraction assessment.

71. The rationale for Table 26 using a May 1 to April 30 timeframe should be explained, particularly if this differs from other reporting periods or the operational schedule presented elsewhere in the EMP.
72. The specification of "up to 10 water bores installed near each well pad" requires clarification including spatial locations, associated clearing requirements, bore specifications, and confirmation that all disturbance areas are accounted for in the total project footprint.
73. Figure 25:
    1. The figure appears to depict only 11 wells, creating uncertainty regarding whether 145ML per hydraulic fracture stimulation is correctly applied to all proposed wells.
    2. The term "Evaporation" in this context requires definition and clarification of its relevance to the water balance or activity schedule.
74. The clearing requirements for water bores along access roads should be quantified and confirmed as included within the total disturbance footprint assessment.
75. The statement "where practicable no additional clearing extents have been allowed for freshwater lines" requires clarification. The conditions under which additional clearing would be deemed impracticable should be defined, and potential additional clearing areas should be quantified for worst-case assessment.
76. Maintenance and surveillance frequencies for leak detection require specification. The EMP should demonstrate that inspection intervals are sufficient to detect leaks before significant environmental harm occurs, and should define what constitutes "surveillance" in operational terms.
77. The discharge criteria for stormwater from cuttings pits require clarification. If the proponent proposes to discharge stormwater that meets specified criteria, the discharge protocol, monitoring requirements, and environmental protection measures should be fully described.
78. The water quality testing limits presented in Table 27 should be justified with reference to relevant guidelines, receiving environment characteristics, and protection of environmental values including groundwater quality and ecosystem health.
79. Borrow pit dimensions and gravel extraction volumes should be specified and reconciled with disturbance area calculations. The EMP should clarify whether the proposed disturbance footprint accounts for all borrow pit requirements including potential expansion of the existing Mount Brown pit.
80. Maximum excavation depths for borrow pits should be specified with assessment of geotechnical stability and safety risks. Pit design should address cattle safety including fencing, signage, and exclusion measures to prevent livestock access and drowning risk.
81. Borrow pit rehabilitation methodology should be detailed including backfilling requirements, final landform objectives, topsoil replacement, revegetation approach, and success criteria. Rehabilitation commitments should be enforceable through the EMP conditions.
82. The EMP should clarify whether gravel from borrow pits will be used for airstrip construction or maintenance, and if so, quantify the volumes allocated to airstrip activities versus other uses.
83. The specification of "appropriate containment" for diesel, fuels and other hazardous materials requires definition with reference to specific codes of practice. Containment design

should be demonstrated as compliant with relevant standards including AS1940 for flammable liquids storage.

84. The maximum camp occupancy requires clarification including whether 105 personnel represents the capacity of each camp individually or both camps combined. Wastewater generation rates and irrigation loading calculations should be verified against maximum occupancy scenarios.

85. Sewage treatment plant specifications should be provided including treatment technology, design capacity, effluent quality standards, and compliance with relevant wastewater treatment guidelines. The system should be designed for maximum occupancy scenarios (potentially 210 people if both camps operate at full capacity simultaneously).

86. Newcastle South well pad is located approximately 800m from a permanent groundwater-dependent ecosystem (GDE). The EMP should demonstrate that wastewater irrigation will not cause nutrient loading, salinity impacts, or surface runoff affecting the GDE over the proposed 5-year irrigation period. A site-specific irrigation management plan should address GDE protection including buffer distances, loading limits, and monitoring protocols.

87. Detailed mapping of areas covered under previous EMPs that are being absorbed into this EMP should be provided showing current infrastructure status, disturbance extent, and rehabilitation progress. This baseline documentation is necessary to assess cumulative impacts and ongoing management obligations.

88. The EMP should clarify whether all activities covered under previous EMPs are now subject to the management controls and performance standards specified in the current EMP, or whether previous commitments remain in effect. Any changes to environmental management requirements should be explicitly identified and justified.

89. Water usage estimates should comprehensively account for all activities drawing from the water extraction license including Mt Brown 3H evaluation, rehabilitation activities, and civil works on historical infrastructure. A breakdown of water allocation by activity type and location should be provided.

90. The environmental management commitments and performance standards for Mt Brown well activities should be reconciled with those proposed in this EMP to ensure consistency and avoid conflicting requirements or management gaps.

91. Section 3.12.1 indicates substantial existing infrastructure will be utilized for proposed activities. This existing infrastructure should be clearly identified on mapping and included within the effective Project Area for impact assessment purposes. The cumulative footprint of new and existing infrastructure should be accurately quantified.

92. Environmental impacts from ongoing activities at existing wells should be quantified including personnel requirements, water consumption, noise generation, greenhouse gas emissions, and equipment use. These impacts should be included in the cumulative impact assessment for the project.

93. The chemical risk assessment should explicitly confirm whether it encompasses all chemicals to be used at existing well sites, or whether separate chemical risk assessments exist for those locations. Chemical inventory and risk profiles should be comprehensive across all operational areas.

94. The risk of threatened and endangered fauna, particularly avian species, interacting with flowback fluids and open cuttings pits requires assessment. Mitigation measures should address wildlife attraction, exclusion methods, monitoring protocols, and contingency responses for wildlife incidents.
95. Greenhouse gas emissions estimates lack sufficient detail to enable independent verification. Methodology, emission factors, activity data, and assumptions for all emission sources (including land clearing) should be provided to support transparency and enable third-party validation.
96. The cumulative greenhouse gas emissions assessment should include all of the proponent's NT operations including the Barossa project to provide an accurate representation of the proponent's total NT emissions footprint and demonstrate consistency with emissions reduction commitments.
97. Greenhouse gas emissions from activities covered under historical EMPs that are being absorbed into this EMP should be quantified and included in the project emissions inventory. The emissions accounting boundary should be clearly defined.
98. The emissions inventory should comprehensively account for all emission sources including camp operations (two 105-person camps), diesel-powered vehicles, drilling rigs, generators, and other equipment. Zero-emission assumptions require substantiation or correction.
99. The emissions inventory should include contingency scenarios such as the emissions profile if a beneficial use agreement for produced water cannot be secured, as this may affect disposal methods and associated emissions.
100. The EMP should demonstrate that alternatives to flaring and venting have been evaluated including gas capture systems, compression and trucking to processing facilities, or other beneficial use options in accordance with waste hierarchy principles and emission reduction best practices.
101. The greenhouse gas emissions comparison baseline is inappropriate for regulatory assessment. Emissions should be benchmarked against comparable onshore gas operations in the NT and other Australian jurisdictions. Furthermore, the EMP should detail specific emission reduction initiatives and quantified emission reduction targets consistent with Commonwealth and Territory climate commitments.
102. The Project Area definition appears inconsistent. While defined as locations for entirely new projects, the EMP also proposes work in areas shown in Figure 26 that include existing infrastructure. This definitional inconsistency may result in gaps or inaccuracies in the Description of Environment. The Project Area should be comprehensively defined to include all areas where activities will occur.
103. The data sources for climate description and freeboard calculations should be explicitly stated to enable verification of consistency. Clarification is required whether SILO data is used for both climate characterization and freeboard design rainfall estimates.
104. Flood modeling presented in Figure 32 indicates Jibera South well pad will likely be isolated during 1% AEP flood events. The EMP should provide technical justification for this location selection including risk assessment for emergency response, personnel evacuation, spill response capability, and operational continuity during flood conditions.

105. Section 4.3.14 references survey locations that are not clearly identified on mapping. Survey site locations should be spatially referenced to enable assessment of survey coverage and representativeness. October Creek, if located near proposed well pads, represents a potentially sensitive receptor requiring specific impact assessment.
106. The environmental impact assessment should explicitly address indirect impacts including downstream effects, cumulative ecosystem changes, secondary clearing for maintenance activities, and induced access by third parties. Indirect impact pathways should be identified and assessed.
107. Stakeholder engagement logs should clarify whether noise impacts and noise modeling results have been communicated to affected landholders. Landholder feedback on noise tolerance and sensitive land uses should inform impact assessment and mitigation design.
108. The environmental risk assessment appears incomplete. All material environmental risks should be systematically identified, assessed for likelihood and consequence, and addressed through specific management measures in the EMP.
109. Table 61 presents greenhouse gas emissions that appear substantially lower than recently approved EMPs from other petroleum operators. The methodology and assumptions underlying these comparatively low emissions estimates should be explained and verified to ensure accurate comparative assessment.
110. Table 61 should include emissions data from the proponent's other NT EMPs to enable complete assessment of cumulative emissions and consistency of estimation methodologies across the proponent's operations.
111. Table 62 indicates the proponent seeks authorization for disturbance to indigenous and cultural heritage sites. The spatial extent, cultural significance, and proposed management measures for affected heritage sites should be comprehensively detailed, with evidence of appropriate consultation and consent from Traditional Owners.
112. The performance standard "rehabilitated to comparable functionality" requires definition with specific, measurable criteria. Comparable functionality should be defined with reference to quantified parameters including vegetation structure, species composition, soil function, and land use capability.
113. The performance standard "injury and disturbance to threatened fauna will be minimised" lacks specificity and enforceability. Measurable performance indicators should be specified including maximum acceptable injury rates, disturbance buffer distances, and trigger levels for adaptive management responses.
114. The performance standard prohibiting clearing outside the project area is ambiguous given that the defined project area excludes existing borrow pits that are planned for use. Clarification is required whether borrow pit expansion would constitute non-compliant clearing, and if so, borrow pit boundaries should be spatially defined and monitored.
115. The performance standard that "noise complaints will be minimised" is inadequately defined. Specific noise criteria should be established with reference to relevant guidelines (e.g., NT EPA noise guidelines), monitoring protocols, complaint response procedures, and trigger levels for additional mitigation implementation.

116. The commitment to "no release of contaminants that results in long term contamination" is insufficient to protect environmental and human health. Several concerns arise:

First, this standard appears to permit short-term contamination releases provided they do not persist, without defining the acceptable duration or concentration thresholds for "short-term" releases.

Second, the performance standard does not define "long term," creating regulatory ambiguity regarding acceptable impact duration.

Third, the standard addresses only water and groundwater contamination, omitting soil contamination and human health pathways. Protection standards should comprehensively address all environmental receptors and exposure pathways including naturally occurring radioactive material (NORM) which may accumulate in produced fluids and cuttings.

117. Compliance evidence based solely on record-keeping is insufficient to demonstrate effective environmental management. For example, recording chemicals used during drilling does not demonstrate proper storage, handling, spill prevention, or disposal. Performance measures should include inspection results, compliance monitoring data, and outcome-based metrics rather than solely records of activities conducted.

118. Performance standards should address both impact limits and proactive management requirements. Impact-only standards are reactive and may not prevent environmental harm. The EMP should include performance standards for management system implementation, monitoring adequacy, and preventative control effectiveness.

119. Section 7 should provide a complete index of all appendices with brief descriptions of content to facilitate document navigation and ensure all supporting technical reports are properly referenced and assessed.

120. Erosion and sediment control (ESC) monitoring annually and only after significant rainfall events is insufficient to ensure control effectiveness. ESC infrastructure should be inspected at regular intervals during construction and operational phases, with additional inspections following all substantial rainfall (not just significant events) to identify and rectify failures promptly.

121. The term "active operations" requires clear definition to avoid ambiguity in monitoring and inspection requirements. Infrastructure and environmental risks may be present even when drilling or stimulation activities are not occurring, requiring ongoing oversight.

122. The distinction between "active operations" and "operations" should be clearly defined with specific examples to ensure monitoring obligations are unambiguous and appropriate for the environmental risk profile during different activity phases.

123. Effluent quality testing requirements should be specified including parameters, frequency, and trigger levels for corrective action. Management measures to prevent vermin attraction should be detailed including waste management protocols, food waste storage, and monitoring for pest populations.
124. The purpose and application of annual fire mapping should be explained. Mapping results should inform fire management planning, rehabilitation monitoring, and assessment of fire-related environmental impacts. The proponent should commit to providing mapping results to relevant land management authorities.
125. Spill monitoring protocols during periods of no regulated activity require clarification. If chemicals and wastewater remain on-site during operational pauses, inspection and monitoring should continue at appropriate frequencies to ensure containment integrity.
126. The rationale for reduced ESC monitoring frequency when regulated activity is not occurring requires justification. ESC infrastructure may deteriorate over time and remain at risk of failure during rainfall regardless of operational status.
127. Table 66 frequency column contains entries that are not temporal frequencies (e.g., event-based triggers). Monitoring and inspection frequencies should be clearly specified as time intervals with supplementary event-based triggers listed separately to avoid confusion.

Appendix A

1. The scope of monitoring and maintenance activities for existing infrastructure requires detailed specification including activities to be conducted, frequencies, responsible personnel, and environmental protection protocols.
2. The McArthur Basin Drilling program status requires clarification. If well drilling and rehabilitation activities are ongoing, the EMP should specify whether these activities are being transferred into this EMP's regulatory framework or will continue under separate approval. Regulatory obligations and environmental commitments for ongoing activities should be clearly defined.
3. The Mount Brown well pad camp is being incorporated into this EMP. Comprehensive details should be provided regarding effluent management areas, historical spills and remediation status, current chemical storage and handling arrangements, and wastewater management systems to enable assessment of existing environmental risks and ongoing management requirements.
4. Water consumption and greenhouse gas emissions from maintenance of access tracks and lease areas should be quantified and included in the project's cumulative environmental impact assessment.
5. The equivalency between environmental outcomes and performance measures under previous EMPs versus the current Appraisal Pilot EMP requires demonstration. Historical performance measures appear more specific and measurable compared to the generalized

standards in the current EMP. The regulatory authority should assess whether the proposed standards provide equivalent or improved environmental protection, and require justification for any reductions in monitoring frequency or performance measure specificity.

For example, previous EMPs required daily inspection of pits and dams, whereas reduced frequencies are now proposed. Historical commitments included backfilling borrow pits upon completion, yet this commitment does not appear in the current EMP despite those borrow pits being absorbed into the new approval. The rationale for removing or reducing historical performance measures should be provided, with demonstration that environmental protection outcomes will not be diminished.

Fire management plan

1. Firebreak dimensions including width and clearing extent should be specified to enable assessment of disturbance area and fire management effectiveness.
2. The fire management plan should address the fire risk associated with permitting smoking on well pads where flammable hydrocarbons and gases may be present. Designated smoking areas and ignition source controls should be specified.
3. The methodology for measuring or modeling radiant heat intensity of 6.31 kW/m² should be provided including equipment specifications, measurement locations, and validation against design specifications.
4. The 35m vegetation exclusion radius around flares addresses ignition risk to vegetation. The fire safety assessment should also address thermal radiation hazards to personnel, equipment, and flammable materials on the well pad including safe approach distances and emergency response protocols.
5. The term "non-routing flaring works" requires definition. Routine versus non-routine flaring scenarios should be clearly distinguished with specific management protocols for each.
6. Flare stack design specifications including 100 km/h wind resistance and 98% combustion efficiency should be justified with reference to relevant standards. The 98% efficiency threshold should be compared to industry best practice and regulatory requirements to demonstrate adequacy.
7. Fire management objectives are specified for camp facilities but not for well pads and access tracks. The fire management plan should comprehensively address all infrastructure and operational areas where fire risks exist.
8. Fire management protocols should extend to all infrastructure covered by the EMP including existing facilities being incorporated from previous EMPs. A comprehensive fire risk assessment covering all operational areas should be provided.

9. The 10-metre earth buffer specification for campsites should be confirmed as incorporated into site designs with evidence provided through engineering drawings or site plans.

Weed management plan

1. Weed mapping identifies declared weed species within the Jibera South disturbance footprint. The current weed control status should be clarified including whether eradication will be completed.
2. The desktop review identifies weed species without corresponding control methods. Control protocols should be specified for all identified weed species, and the weed induction training curriculum should be documented to confirm comprehensive coverage of weed identification and control procedures.

Chemical Risk Assessment

1. The effectiveness of fauna exclusion measures around fluid storage areas requires validation. Field monitoring data or peer-reviewed studies demonstrating exclusion effectiveness for target fauna groups should be provided.
2. NT-specific chemical fate and transport data should be provided, or alternatively, the transferability of US-based environmental fate assumptions to NT hydrogeological and climatic conditions should be technically justified with sensitivity analysis.
3. Surface water contamination risks are dismissed based on distance to major tributaries. The assessment should address risks to minor drainage lines, ephemeral watercourses, and groundwater-dependent ecosystems which may be more proximate to operational areas.
4. Chemicals are assessed individually without consideration of combined toxicity effects. Cumulative and synergistic toxicity of chemical mixtures present in flowback fluids and produced water should be assessed consistent with contemporary ecotoxicological risk assessment practices.
5. Contaminant transport modeling relies on 2015 BIOSCREEN modeling which presents several technical limitations:

Identified concerns:

- The Beetaloo Basin geological characterization has substantially improved since 2015, with refined understanding of aquifer properties and connectivity that should inform current modeling.
- BIOSCREEN is designed for homogeneous porous media and is inappropriate for fractured or heterogeneous formations typical of the project area.
- No sensitivity analysis is presented to quantify model uncertainty.
- No uncertainty analysis is provided regarding parameter selection and prediction confidence intervals.

6. Release scenario modeling appears to address only small-volume releases and does not assess multi-tank or cascading failure scenarios despite proposed storage of hundreds of megalitres across multiple tank systems.
7. Wildlife exposure assessment is limited to avian species despite the known presence of numerous fauna groups requiring assessment including:

- Macropods (regionally abundant and significant in NT ecosystems)
- Cattle (landholder economic assets with potential chemical exposure pathways)
- Dingoes (apex predators with potential bioaccumulation pathways)
- Reptiles (diverse NT reptile assemblages including threatened species)
- Amphibians (particularly vulnerable to chemical contaminants in aquatic habitats)

8. Worker exposure assessment limitations are evident: Only hydrotreated light petroleum distillate progresses to Tier 2 assessment. However, additional chemicals warrant detailed occupational exposure assessment:

- Glutaraldehyde exhibits potent respiratory sensitization properties.
- Chlorous acid/sodium chlorite may generate chlorine dioxide gas under certain operational conditions.
- Crotonaldehyde is volatile with known respiratory and mucous membrane irritant properties.

9. The proposal to use mist spray for evaporation enhancement, potentially in combination with dust suppression using flowback water, raises aerosol exposure concerns. A comprehensive assessment of aerosol generation, dispersion, deposition, and inhalation exposure pathways for workers and nearby receptors should be provided.
10. The statement "EMP conditions regulate project reuse" requires clarification. The chemical risk assessment should explicitly address all proposed reuse scenarios to ensure the assessment scope aligns with operational intentions.
11. Comparative assessment of new drilling chemicals against the "existing system" lacks quantitative data. Chemical inventory changes should be quantified including mass usage rates, concentrations, and comparative environmental and health risk profiles.

Spill management plan

1. Table 1 discusses mud tank systems and condensate tanks, are these included in the tank numbers and what does freeboard and monitoring frequencies apply?
2. Is produced fluid the same as flowback?
3. 28 ML per well for produced fluid/flowback should be represented as 12 x 28 ML
4. What recycling of produced fluids is proposed, in what system is this done in?
5. 11,200L per day of effluent does not equal 200 L per person per day for a 105 person camp
6. Irrigation is referenced as being conducted in accordance with a code of practice, but specific irrigation design details are absent. The substantial volume of wastewater requiring irrigation would necessitate sophisticated irrigation infrastructure including storage, distribution systems, soil loading assessments, and monitoring. A comprehensive irrigation management plan should be provided demonstrating technical feasibility and environmental protection.
7. The spill management plan does not address the risk of cascading tank failures where interconnected tanks may release multiple tank volumes if one tank fails. Given that the operational plan includes fluid transfer between tanks for evaporation management and freeboard maintenance, tanks are operationally interconnected. Worst-case spill scenarios should assess multi-tank failure potential, and isolation valve systems should be specified to prevent cascading releases. The plan should clarify tank interconnection configurations and isolation protocols.
8. The tank pad bund design specification states it will contain rainfall inflow to a 0.1% AEP event. Several technical clarifications are required:

The design intent requires explanation: whether the bund is intended to actively retain extreme rainfall volumes, or whether the statement refers to bund freeboard capacity. The term "inflow" should be defined - whether stormwater is designed to flow into the bund area, or whether the bund is designed to exclude stormwater.

Bund water management protocols should be specified including removal timing, pumping equipment, discharge or reuse methods, and management during ongoing rainfall. Construction materials should be specified (e.g., concrete, compacted earth, geomembrane liner) with assessment of structural integrity when holding water for extended periods. The strategy appears to present significant risk if bund volumes are occupied by stormwater, reducing available spill containment capacity. Additionally, given flood modeling indicates Jibera South may be isolated during major flood events, site access for bund water removal during or following significant rainfall requires demonstration.

9. Figure 1 references wind and wave action as a consideration for open fluid storage. Quantitative analysis of wind-generated wave effects on freeboard adequacy and potential overtopping should be provided.
10. The assertion that releases exceeding bund capacity are "unlikely" based on fluid transfer operations assumes all tanks maintain partial fill levels. However, releases during active fluid transfer operations present a higher-risk scenario where a full or nearly-full source tank could fail while transferring to a nearly-full receiving tank, potentially exceeding bund capacity. This scenario should be assessed.
11. The spill detection timeframe of 2 hours for a 50,000L diesel tank spill requires justification. For large-volume storage of hazardous liquids, automated leak detection systems or higher-frequency inspections should be considered to enable more rapid detection and response.
12. Monthly chemical, fluid, and fuel storage inspections appear insufficient to achieve immediate or 2-hour spill detection times. Inspection frequencies should be reconciled with spill detection timeframe commitments, or alternatively, automated leak detection and alarming systems should be implemented.
13. The spill classification system designates Level 1 spills as potentially involving up to 10,000 litres of environmentally hazardous chemicals, yet environmental sampling and analysis appear to be required only for Level 2 incidents. This threshold requires justification, as 10,000 litre releases of hazardous materials may warrant environmental impact assessment and monitoring regardless of incident classification.

Wastewater management plan

1. The spill management plan defines a SRE as greater than 300mm yet minimum freeboard is less than this?
2. WWMP has methodology and basis for on-site burial of cuttings which does not comply with C.4.1.2. The government should request the removal to ensure that the actual residue and drilling fluids present on site are reviewed for suitability.
3. Santos WWMP states that the drilling sumps and transferred to a separate wastewater tank for temporary storage. The fluids will either be reused or transported off-site for disposal. It is unclear if Santos propose to reuse flowback fluid mixed with drilling fluid in drill operations
4. The wastewater management plan says that the drilling sumps have been designed to store up to 2,400 m3 of material, which is the anticipated upper volume for up to four wells per well pad. These well numbers do not match the EMP.

5. The WWMP says that the well pad may consist of 7 13.5 ML tanks, this is not the only scenario.
6. The spill management plan consistently refers to 12ML tanks being the largest?
7. How will Santos manage rainwater on tanks? How will Santos ensure an incident like neighbouring onshore gas company Imperial's reportable incident doesn't occur?
8. What sort of pumps and what sort of redundancy will be in place for SRE?
9. Santos reference both 0.5m and 0.3m dry season freeboards.
10. As per the SMP, how does Santos guarantee that waves in open tanks/sumps caused by wind will not cause overtopping of fluid in a tank or sump with only 0.3 m of freeboard? Is it justified for 0.5m?
11. How accurate is a BOM forecast for this remote region?
12. Wastewater may be transferred between approved sites to maximise the efficient use of tank capacity. Transferral may be via truck or surface/subsurface gathering lines. Gathering lines are not sufficiently detailed in the EMP?
13. There is no meaningful transfer plan in the event of an SRE. How does Santos ensure access leading up to an SRE and during an SRE and do they commit to always having sufficient capacity to enclose all fluid?
14. Enclosed tanks will have vents, how does Santos ensure they do not get inundated by rain or SRE

Waste Water Management Plan Appendix B

1. It's confusing having the main EMP have alphabetical appendices in addition to the appendices having alphabetical appendices. Suggest one be changed to numerical Here is a structured critique of the logical issues in the report you provided. I've focused specifically on logic flaws, internal inconsistencies, unsupported assumptions, or places where the reasoning does not follow.
2. Methodology vs. ARR Guidance — Contradiction The report states:

"ARR does not provide specific guidance for estimating design wet season rainfall totals."

Then immediately proposes its own custom methodology using GEV fitting to a 90-day rolling rainfall AMS. The Code of Practice requires:

"Estimates for the 1 in 1000 ARI rainfall rate using Australian Rainfall & Runoff methodologies."

But instead of using ARR's rare-event procedures, it uses a bespoke statistical process based entirely on SILO data and local annual maxima. ARR Book 2 provides processes for rare events (AEP < 1%).

So, the report is not actually applying ARR rare-event methods, even though this is the Code requirement. They justify deviating from ARR by claiming ARR “doesn’t provide guidance,” which is false, ARR provides methods, just not for seasonal totals, and the Code requires ARR, not seasonal totals. Using season totals instead of ARR durations (up to 7 days) is outside the mandated method.

2. Use of SILO Data for Extreme-Event Analysis — Statistical Invalidity

The report uses SILO patched-point rainfall data to derive 1-in-1000 year extremes.

- SILO infills missing data via spatial interpolation, which smooths extremes and reduces variance.
- Interpolated synthetic data defeats the purpose of extreme-event analysis.
- SILO itself warns against using patched-point datasets for extreme-frequency calculations.
- “The SILO data are carefully checked for quality…”

…but ignore that the same quality-control process removes true extreme values and replaces them with averaged estimates with suppressed peaks.

Thus their 1:1000 estimates are biased low.

3. Annual Maxima Series (AMS) Based on Synthetic Data

They extract annual maxima from 1889–2025, but BOM station 14628 only began in 1973\.

The period 1889–1973 is entirely synthetic (SILO interpolation).

Using synthetic rainfall maxima to fit a GEV distribution for rare-event estimation is statistically invalid.

Logical contradiction:

- They say long-term data is sparse and unreliable.
- They then use more than 80 years of fabricated data to model rare extremes.

4. ANCOLD Justification

- ANCOLD is for dam safety, not wastewater ponds.
- The Code requires rainfall durations relevant to overtopping, not wet-season totals.
- BOM provides data up to 7-day durations because those are physically relevant to storage infrastructure

They took a dam-safety methodology and applied it to wastewater ponds with no justification.

5. Removal of “Low Outliers” in AMS — Dangerous Bias

They say:

“remove low outliers which could unrealistically impact the fitted distribution”

Removing low outliers narrows the variance, artificially steepens the distribution tail, and inflates the 1:1000 estimate.

This directly contradicts:

- ARR guidance (do not manually manipulate AMS).
- Statistical best practice (all AMS values must be retained unless proven erroneous). They remove outliers without defining criteria or providing evidence they are erroneous.

6. No Confidence Intervals or Sensitivity Analysis

GEV fitting from a single AMS without confidence bands is statistically incomplete.

A 1:1000 AEP estimate from \~50 years of real data cannot be precise, but no uncertainty is acknowledged.

7. Evaporation Calculation Is Logically Inconsistent

They calculate freeboard as:

Rainfall – minimum evaporation over 90 days

- Evaporation during a rare 90-day extreme rainfall event is not equal to the minimum historical evaporation, this is contradictory.
- If the event is extremely wet, it is not necessarily the same as the historically lowest evaporation period.
- They did not derive evaporation for the specific extreme rainfall years (coincident calculation).

Result: The freeboard reduction from evaporation is unreliable.

8. Dry Season Freeboard Is Arbitrarily Chosen

They state:

“A dry season freeboard of 500 mm is recommended…”

But their dry-season 1:1000 AEP estimate is only 300 mm.

- It is unclear why Santos have chosen to ignore the recommendation?
- They add an arbitrary safety margin (500 mm) without showing any basis other than “greater than 300 mm.”
- They ignore evaporation entirely during dry season (evap should be very high, reducing required freeboard).

This is inconsistent with the wet-season method.

9. “Significant Rainfall Event” Definition Is Not Linked to Site Risk

They choose:

“a rainfall depth of 315 mm… exceeds the 5% AEP 72-hr rainfall.”

But:

- The Code requires a definition based on local weather patterns and site-specific risks, not just being larger than a 5% AEP value.
- No site analysis is done.
- No vulnerability assessment of pond storage is considered.
- How does adopting a 300mm freeboard and a 300mm significant rainfall event make sense?

No link between rainfall magnitude and operational risk or hydraulics.

10. Misinterpretation of ARR Purpose

ARR is intended for flood estimation, not wastewater pond freeboard.

The report claims:

“ARR is focussed on flood estimation.”

…but then proceeds to apply flood-study methods to a seasonal storage calculation.

They justify using ARR but do not use ARR durations, ARR models, ARR ensembles, or ARR regional data, only the GEV concept.

11. Failure to Address Climate Change

A 1:1000 AEP estimate from historic 1889–2025 data ignores climate trend.

Given NT’s increasing monsoon intensity, this omission is a logical gap in “risk-based” design.

12. The document immediately highlights the codes requirement to have a plan to transfer wastewater in the event of a predicted SRE. No plan is provided

Erosion and Sediment Control Management Plan

1. IECA is designed for construction sites, how are the types of erosion and sediment control proposed suitable for a semi-permanent five year (or more judging by the amount of historic well pads and activities being incorporated into this EMP) of bare earth?
2. Are the proposed access tracks presented in the ESCP figures, correct?

Surface Water and Groundwater Management Plan

1. How does Santos ensure that the impact monitoring bore(s) established for the first well will be adequately positioned for all future wells on the well pad and will catch any impacts?

Environmental Assessment Report

1. Survey Effort May Be Inadequate for High-Risk Species

Surveys occurred 16–20 December, which is late wet-season onset and extremely poor timing for detecting:

- threatened finches
- raptors
- cryptic reptiles (death adder, yellow-spotted monitor)
- threatened flora (many are identifiable outside December)

The report acknowledges seasonal limitations but still uses the surveys as justification that habitats are low value. This is internally inconsistent.

2. Gaps in Fauna Survey Protocol

Fauna surveys consist primarily of:

- 10–15 min bird surveys
- call-playback for one species
- opportunistic sightings
- basic active searches

For a project with \>87 ha disturbance and EPBC-listed species risks, the effort is insufficient, yet the report relies heavily on these minimal methods to justify “no significant impact”.

3. Vegetation Mapping Validation Appears Weak

The report uses only 15 vegetation sites \+ 2 check sites to validate 160+ ha of vegetation communities, with some communities represented by a single site. Its conclusion that none are sensitive or significant may be correct, but the sampling density is low and not statistically defensible.

4. Contradiction Between Statement of No Sensitive Veg and Known Presence of Bullwaddy/Lancewood

Bullwaddy and Lancewood communities are commonly regarded as sensitive and slow-recovery habitats in NT guidance.

Communities described (e.g. Macropteranthes kekwickii associations) suggest possible bullwaddy elements, but the report dismisses all vegetation as non-sensitive without demonstrating compliance with the 2025 Pastoral Land Clearing Guidelines' new significance thresholds.

5. Groundwater Risk Conclusions Not Linked to Project Water Extraction

The report asserts extraction will not impact regional springs because total volume is small, but it does not link:

- extraction volumes
- localised drawdown modelling
- proximity to local perched GDEs (which are mapped within the study areas)

There is a disconnect: GDEs are identified in the study area, but extraction impacts to these GDEs are not assessed.

6. Contradiction: "No GDE Risk" but "GDEs Likely Accessing Perched Groundwater"

If perched systems are present near extraction bores, even moderate extraction can influence water availability.

The report's conclusion that "no change to notable GDEs" will occur ignores these local systems entirely.

7. Impact Assessment Appears to Treat Construction-Only Effects as Short-Term

The clearing footprint includes \>87ha:

- well pads (15 ha each)
- borrow pits
- access tracks

- airstrip operations

The assessment does not acknowledge that in NT landscapes, these features persist for decades and often become permanent clearings. Assertions of short-term impact are not supported.

8. Mitigation Measures Are Generic, Not Project-Specific

Section 7 lists standard EMP controls (spotter-catcher, weed hygiene, avoidance where possible).

There is:

- no micro-siting decision framework
- no hollow tree survey methodology
- no weed treatment triggers
- no fire risk mitigation tied to field fuel loads

9. No Consideration of Dust, Emissions, or Noise Impacts to Sensitive Fauna

Even though SREBA air quality baseline data is presented, the project's own dust/noise/flaring emissions are not linked to potential fauna sensitivity (e.g., Gouldian finches near watering points).

10. Flora Survey Limitations Contradict Confidence Statements

The survey concedes grass species could not be identified due to lack of fertile material. This undermines the vegetation classification reliability, especially for ground-layer changes relevant to fire and weed risk.

11. Inconsistent Use of Project Area Terms

"Disturbance Footprint", "Project Area", "Construction Disturbance Zone", and "Study Area" are used interchangeably in narrative sections despite having clear defined meanings.

12. No Explicit Assessment of Borrow Pit Rehabilitation Feasibility

Borrow pits in clayey or Kandosol systems often fail to revegetate properly. The report assumes rehabilitation success without evidence.

Rehabilitation Management Plan

1. Repeated “Error\! Reference Source Not Found.” errors indicate broken document cross-referencing
2. The introduction claims alignment with DEPWS 2020 rehabilitation guide, but major required elements are missing. The plan omits key components normally required under the 2020 NT Rehabilitation Guide, such as:

- measurable short-, medium-, and long-term benchmarks
- clear pathways to relinquishment
- risk-based justification for rehabilitation approach

3. It says the RMP applies to all disturbances related to the current EMP and prior Santos activities, but then excludes landowner infrastructure. It is unclear whether:

- past seismic disturbance included under “prior EMPs” is fully captured
- legacy third-party infrastructure is included
- decommissioned but not rehabilitated areas are included
- What the extent of past disturbance is or includes

4. Controls are generic and not linked to risk severity. Almost every risk (erosion, contamination, fire, weeds) is addressed with “follow Appendix X”. This lacks specificity and does not demonstrate site-based adaptation.
5. No evidence the proposed controls are adequate for the soil types identified. The text describes:

- shallow gravelly sands
- laterite caps
- acid yellow earths
- red clayey sands These are high-risk for erosion, compaction, and poor revegetation. However, the plan does not show:
- modified seed mixes
- ripping depth adjustments
- subsoil amelioration
- soil pH management The controls are too generic for the site’s constraints.

6. The Final Land Use Strategy is vague and not technically justified. “Rehabilitation to be consistent with surrounding land uses and ecological values” is ambiguous. Pastoral stations have substantially modified ecosystems, so referencing “analogue sites” without stating:

- whether analogue sites must be inside pastoral paddocks
- or undisturbed native vegetation leads to possible mismatch.

The plan also states analogue sites “will be selected”, but does not specify selection criteria such as:

- landform
- vegetation community
- soil classification
- fire history
- cattle pressure

7. Success criteria are not measurable enough. Examples:

- “Equivalent to 70% ground cover of analogue site” — ground cover fluctuates seasonally; needs seasonally adjusted thresholds.
- “No declared weed infestations that require management” — does not specify allowable density, treatment timelines, or thresholds for failure.
- “Recognisable as the target vegetation community” — highly subjective without structural/ floristic indicators.

8. The plan expects natural regeneration to dominate, yet this region:

- has intense cattle grazing
- experiences frequent fires
- contains infertile soils
- Is clearing bullwaddy/lancewood areas which are notoriously difficult to rehabilitate
- has poor natural recovery on seismic lines historically These constraints are not addressed.

9. The plan claims to avoid “deep-rooted species” over drilling pits but provides no technical justification. What are the monitoring methods to detect “deep-rooted vegetation”.
10. “Topsoil to be stripped to 100 mm” may be inadequate for the soil profile. Many areas have shallow A-horizons. However, no evidence is provided that 100 mm is appropriate across all soil types, risking mixing A/B horizons and seedbank loss.
11. Monitoring program lacks statistical design There is no description of:

- number of monitoring sites
- replication
- monitoring quadrats
- GPS referencing
- photopoint protocol

12. Clearing numbers on plan on a page seem inconsistent with EMP

13. Hydrological considerations are incomplete. The plan references AEP 1% modelling but does not:

- describe model inputs
- identify flow paths
- explain implications for rehabilitation success
- assess risk of ponding or washouts on pads

14. No criteria for rehabilitation failure or mandatory corrective actions The plan describes corrective actions, but:

- no thresholds
- no triggers
- no timelines
- no escalation procedures are provided.

Emergency Response Plan

1. The plan classifies a level 1 spill as 10 tonnes of hydrocarbons or environmentally hazardous chemicals, equivalent to releasing 10,000 litres. It's unclear how Santos justify releasing 10,000 litres of environmentally hazardous chemicals as a level 1 incident.

Stakeholder Engagement Log

1. The traditional owners have requested a CHMA be developed for the work program. Santos have not effectively demonstrated that concerns regarding cultural heritage risks have been addressed.
2. Stakeholder engagement packs do not clearly articulate the combining of activities from other EMPs into this EMP. Are stakeholders aware that in doing so Santos are effectively being granted another 5-year term on these historical activities which stakeholders may not be aware of.
3. Many details in these packs do not match the EMP, non-exhaustive list:

- Camp capacities
- Water bores only constructed immediately adjacent to the well pads
- Borrow pit activity includes both the establishing of two borrow pits, in addition to, the expansion of historic borrow pits

- Santos claim here that wastewater not to be re-used will definitively be removed from site for disposal
- Decommissioning sumps to occur as soon as reasonably possible after the project. It is reasonably possible for Santos to transport to a licenced disposal facility.

Risk Assessment:

1. ALARP assertions are not substantiated. Many rows label controls as “ALARP” but provide no demonstration (quantitative or qualitative) showing that further practicable measures were considered and rejected. ALARP claims require evidence of cost/benefit or additional mitigation infeasibility.
2. Control descriptions are often generic and not site-specific. Numerous controls refer to “WOMP”, “Wastewater Management Plan”, “Spill Management Plan”, or “Appendix X” without summarising key design parameters (e.g., bund freeboard, liner spec, pumping capacity). A reviewer cannot confirm the controls’ adequacy from the RA alone.
3. Residual risk ratings appear optimistic and unsupported. Many inherently high or medium risks (e.g., uncontrolled release to aquifers, overflow of containment) are reduced to “Low” with generic controls. There is no evidence of sensitivity testing, scenario modelling, or likelihood reduction quantification to justify this.
4. No treatment of scientific uncertainty or worst-case scenarios for HFS. The HFS entries rely on statements like “fracking \>2500 mTVD” and “minimal connecting faulting” without sensitivity analysis for unexpected fracture growth, fault reactivation, or connectivity to shallow pathways. Controls mention modelling but there is no commitment to independent peer review or conservative contingency thresholds.

5. Well integrity / barrier failure consequence underplayed. Blowouts, crossflow, or cement failures are rated but residual risk is set to “Medium/Low” with controls like cement logs and BOPs; there is no time-to-detection, response-time, or likelihood estimate — nor contingency for failed remedial cementing.

6. No clear trigger/action levels for monitoring results. Groundwater, flowback, and emissions monitoring are repeatedly referenced but the RA does not define action triggers (e.g., exceedance thresholds, required investigations, stop-work triggers), and who must act when they are breached.

7. Emergency response responsibilities and resourcing are not explicit. Controls repeatedly reference Emergency Response Plans but do not allocate accountable parties, response resource locations, mutual aid arrangements with the landowner or local services, or exercise/testing schedules.
8. Methane and fugitive emission management lacks quantitative targets. The Methane Emissions Management Plan is cited, but the RA does not present detection sensitivity, leak

repair timelines, monitoring frequency, or thresholds for reporting vs. shutdown — key to validate residual risk to climate and safety.
9. NORM handling and disposal controls are generic. NORM is recognised but the plan simply references ARPANSA guidance and monitoring. What is ARPANSA guidance and monitoring? There is no specific pathway for NORM discovery, transport, storage, worker exposure limits, or long-term disposal/responsibility traceability.
10. Social / community nuisance risks lack formal interface protocols. The RA commits to engagement logs and distance buffers but does not define: complaint response times, compensation or remediation mechanisms for landholder losses, or a formal dispute resolution pathway.
11. Erosion and sediment controls lack design standards. References to an ESC plan are fine, but the RA omits critical design inputs: catchment sizes, design storm (beyond 1% AEP siting), sediment trap sizing, inspection frequency after storms, and performance indicators.
12. Rehabilitation success dependencies are implied but not time-bound. Several residual risk reductions assume progressive rehabilitation will remediate impacts, yet no timeframes, success thresholds, or funding/security mechanisms are documented to ensure rehabilitation occurs and is maintained.
13. Interaction between risks is not addressed (systemic/coupled risks). The table treats risks discretely. It does not evaluate coupled events (e.g., heavy rainfall causing containment failure when monitoring is inadequate, or fire damaging containment leading to release) nor present cascading failure scenarios.
14. Residual risk grading inconsistent across similar hazards. For example, overflow of storage pits and failure of embankments are separately treated but both could lead to the same consequence; their residual risk ratings and required controls differ without justification.
15. Cumulative biodiversity / clearing risk under-quantified. Cumulative vegetation clearing is described in percentage/allocation terms but lacks landscape-scale habitat-loss modelling, species-occupancy projection, or time-lag effects (e.g., hollow loss over decades). The RA treats fragmentation qualitatively rather than quantitatively.

Engineering Drawings

1. It’s unclear why some pond storage areas have bunds but others don’t
2. Flare appears to be quite central to the wells, does that come with an increased risk?
3. Why does only Newcastle south have diversion banks

Respondent No: 13
Login: Anonymous
Email: n/a

Responded At: Dec 19, 2025 16:43:17 pm
Last Seen: Dec 19, 2025 16:43:17 pm
IP Address: n/a

Q1.	**Given name**	Kirsty
Q2.	**Family Name**	Howey
Q3.	**Location**	DARWIN, NT
Q4.	**Stakeholder type**	Non Government Organisation (NGO)
Q5.	**Email address**	kirsty.howey@ecnt.org
Q6.	**Interest area**	Water
Q7.	**Please provide your comments**	Please note that this submission, and the 6 attachments, have been emailed to santos.ep161@nt.gov.au
Q8.	**Add an attachment - Max file size: 5MB**	https://s3-ap-southeast-2.amazonaws.com/ehq-production-australia/036f599ae6213192024478373 19a8ee69f238dc0/original/1766128345/3c5a61d27e1a9aa517495cfaf05305f2_Submission%20on%20Santos%20Tanumbirini%20EMP%20Dec%202025.pdf?1766128345
Q9.	**Tick this box if you wish for your name and contact details to be confidential**	not answered

From:	Kirsty Howey
To:	SantosPetroleum DLPE
Cc:	Bree Ahrens; ntepa epa
Subject:	Comments - STO8-1: EP161 Beetaloo Basin Appraisal Pilot Environment Management Plan
Date:	Friday, 19 December 2025 4:42:03 PM
Attachments:	image001.jpg Submission on Santos Tanumbirini EMP Dec 2025.pdf Henry Stoetzel Independent Report EP161.pdf Professor Grant Hose Independent Report EP161.pdf Professor Matt Currell Independent Report EP161.pdf Ryan Vogwill Independent Report EP161.pdf Protected Matters Report.pdf Professor Penny Sackett Independent Report EP161.pdf

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To Whom it May Concern,

Please find **attached** ECNT's submission on the above draft EMP, together with the following attachments:

a. Report of Professor Grant Hose;
b. Report of Dr Ryan Vogwill;
c. Henry Stoetzel;
d. Report of Professor Matthew Currell;
e. Report of Distinguished Professor Penny Sackett;
f. Protected Matters Report.

Kind regards,

Kirsty Howey – she/her
Executive Director
Environment Centre NT

M 0488 928 811 **E** kirsty.howey@ecnt.org **| W** http://www.ecnt.org.au/
GPO Box 2120, Darwin NT 0801 **|** Unit 3/98 Woods Street, Darwin Northern Territory

We acknowledge the Traditional Owners, the Larrakia people, on whose land we meet, live and work.
We acknowledge Australia's First Nations never ceded sovereignty of their lands, seas and waters.

19 December 2025

Department of Lands, Planning and Environment
Petroleum Regulations Unit
PO Box 3675
Darwin NT 0801

By email: Santos.ep161@nt.gov.au

To Whom it May Concern,

SUBMISSIONS: STO8-1: EP161 Beetaloo Basin Appraisal Pilot Environment Management Plan

1. The Environment Centre NT (**ECNT**) is the peak community sector environment organization in the NT, raising awareness among 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.

2. On 19 November 2025, Santos QNT Pty Ltd (**Santos**) submitted an Environment Management Plan (**EMP**) for assessment, under the *Petroleum (Environment) Regulations* 2016. The EMP was published for comment on 21 November 2025.

3. The EMP proposes a scope of activities on the Exploration Licence EP 161. The scope of works includes the following activities:

   (i) Clearing 87.34 hectares of remnant vegetation and previously disturbed land, along with earthworks for two new well pads;

   (ii) Drilling and hydraulic fracture stimulation for up to 12 appraisal wells;

   (iii) Operating, testing, maintenance and decommissioning;

   (iv) Wastewater management that includes evaporation tank, storage tanks, drilling sumps, cutting pits and any transfer infrastructure within the well pad;

   (v) Infrastructure and activities required to support the appraisal activities ie, water supply bores, groundwater monitoring bores, borrow pits, installation and operation of camps, bulk material transport and storage, office, workshop and storage, traffic management;

   (vi) Incorporation of previously authorized and ongoing regulated activities (including at Inacumba and Tanumbirini well pads).

4. Santos makes clear in the EMP that this project is an appraisal project that could lead to significantly expanded onshore gas development in the Beetaloo Basin at export scale, including for “Asian LNG markets” and that the NT “could be on the cusp of a shale gas boom akin to the coal

seam gas boom". Santos states that "the capital intensity of a greenfield shale gas industry will need to be underpinned by foreign investment and the scale of Asian LNG export markets and customers".[1] The cumulative impacts of a production-scale onshore gas industry in the NT are likely to be very significant and could include:

(a) The construction of up to 6000 wells drilled through complex geological formations, including the 500,000 square kilometre Cambrian Limestone Aquifer, which is the lungs of the Northern Territory and supplies water for communities, as well as the tourism, farming and pastoral industries and discharges into the Roper and Daly Rivers (as well as, potentially, the McArthur and Limmen Bight Rivers);

(b) The extraction of billion of litres of water from the Cambrian Limestone Aquifer; and

(c) The generation of up to 1.2 billion tonnes of greenhouse gas emissions in the 25 years to 2050.[2]

5. ECNT submits that section 50(1) of the *Environment Protection Act 2019* (NT) applies, and you should:

(i) Refer the EMP to the NTEPA under section 50(2)(c) of the *Environment Protection Act 2019* (NT); and

(ii) Refuse to consider the application until the EMP is referred to the NTEPA and a decision is made on the referral, pursuant to s50(2)(a) of that legislation.

6. In addition, the EMP should be referred for assessment under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) as it has the potential to cause significant impacts to matters of national environmental significance, including threatened species and water resources.

7. Alternatively, the Minister should reject the EMP because it does not comply with the *Petroleum (Environment) Regulations 2016* (NT) for the following reasons:

(i) Santos has not managed its environmental risks to be as low as reasonably practicable (ALARP) nor acceptable;

(ii) The EMP is not appropriate for the nature and scale of the regulated activity; and

(iii) The EMP does not contain the information required within Schedule 1.

Non-conformance with the Petroleum Environment Regulations

8. The project does not conform to applicable regulations or requirements, including the *Petroleum (Environment) Regulations* 2016 (NT) (**Regulations**) that were revised in 2025, for the reasons set out below.

Many of Santos' environmental outcomes do not satisfy the "as low as reasonably practicable" or

[1] Santos EMP, Foreword.
[2] Bill Hare and Thomas Houlie, Emissions Impossible Report (2023).

"acceptable" standard required by Section 3 of the Petroleum Environment Regulations.

9. Schedule 1, section 4 of the Regulations requires that an EMP must specify the environmental outcomes of the regulated activity. Section 3 of the Regulations provides a definition of an "environmental outcome" that has two-elements: an environmental outcome is an "outcome that will be achieved if the environmental impacts and environmental risks of a regulated activity are reduced to a level that is:(a) as low as reasonably practicable ["ALARP"] ; and (b) acceptable."

10. A number of environmental outcomes for the EMP do not satisfy both elements of the definition in Section 3 of the Regulations. For example, in relation to greenhouse gases, Santos states "The environmental outcomes of the Activity are:... Maintain greenhouse gas emissions below acceptable levels."[3] Here, this environmental outcome aims for an acceptable level of emissions but does not ensure that emissions are reduced to be as low as reasonably practicable. Even if Santos were to achieve this outcome, the ALARP standard would not necessarily be met. For another example, an environmental outcome related to hydraulic fracturing and aquifers is to "Protect the quality and integrity of surface water and groundwater by preventing contamination and maintaining natural flow regimes where practicable."[4] This environmental outcome neither addresses nor ensures that prevention of contamination of aquifers only "where practicable" will be acceptable. To the contrary, contamination of aquifers when prevention is not practicable may not be acceptable to key stakeholders.[5] Because these outcomes address only the practical reduction of risks, or only set an acceptable level of risk, but not both, they do not satisfy both elements of the definition of an "environmental outcome" in Section 3 of the Regulations.

11. The Minister should not approve the EMP until the environmental outcomes are redefined so that, if achieved, they will ensure that risks are managed to be both ALARP and acceptable.

Santos' measurement criteria cannot be used to determine whether environmental outcomes are met in violation of Section 3 and Schedule 1, Section 4(c) of the Petroleum Environment Regulations

12. Section 4(c) of Schedule 1 of the Regulations states that the EMP "must specify" the "measurement criteria to be used to ensure the environmental outcomes and environmental performance standards are met." Section 3 Part 1 of the Regulations define measurement criteria to mean "the criteria to be used in determining whether an environmental outcome or environmental performance standard has been met." Measurement criteria for the EMP are provided in Table 62.[6] However, many of the EMP measurement criteria provide no objective definitions or measurement that could be used to verify whether environmental outcomes are being met.

    (i) **Water use:** In relation to impacts from the drawdown of aquifers through the use of 750 ML of water, the measurement criteria includes groundwater monitoring that shows water "quality, extraction volumes and water level are relatively unchanged, and water availability is unchanged."[7] This outcome does not define what constitutes "unchanged"

[3] Santos, Beetaloo Appraisal EMP, Executive Summary, *Environmental outcomes*; *id*. at p. 155.
[4] Santos, Beetaloo Appraisal EMP, p. 146.
[5] *See* Santos Beetaloo Appraisal EMP, Appendix N (noting water is a primary concern amongst stakeholders, including associated cultural values).
[6] Santos, Beetaloo Appraisal EMP, p. 141.
[7] Santos, Beetaloo Appraisal EMP, p. 148.

and provides no objective standard to measure water availability, such as ensuring that water levels in bores within a certain distance do not change by more than 1 meter.

(ii) **Aquifer contamination**: The measurement criteria for the environmental outcome of protecting groundwater "where practicable" from contamination due to migration of fluids between geological layers is that "Well control monitoring demonstrates adequate well control."[8] This provides no objective standard by which one can assess whether outcomes or performance standards are being met. For example, Santos does not define whether a single loss of well control would be acceptable, or the kinds of casing failures or losses of annulus pressure that could be considered acceptable. Furthermore, for assessing aquifer contamination, key investigation thresholds are missing. For example, for water level and salinity, temperature, and pH the "Investigation Threshold" is simply "N/A."[9] For BTEX, the investigation is 1 standard deviation beyond baseline,[10] but the EMP does not define what years and locations will be considered baseline. For all other analytes that must be assessed (Table 4 of Appendix I to the EMP), Santos provides no other investigation criteria beyond BTEX chemicals. For example, there is no investigation threshold for metals or radionuclides. Thus, there is neither an investigation threshold for key risks nor measurement criteria that could be used to determine whether performance standards or outcomes are being met.

13. These examples are not exhaustive but illustrative of how the EMP does not use measurement criteria that satisfy the definition in Section 3 of the Regulations because they do not allow one to make a measurement that could ensure performance standards or outcomes are being achieved.

Santos has failed to demonstrate that drilling and hydraulic fracturing fluids comply with the Onshore Code of Practice

14. Schedule 1 Section 10 of the Regulations requires an EMP to (a) specify any legislative requirements applicable that are relevant to the protection of the environment; and (b) "demonstrate how those requirements will be met." In this clause, "legislative requirements" include "the requirement to comply with an approved code of practice."[11] The EMP fails to demonstrate that drilling and hydraulic fracture fluids comply with the *Code of Practice: Onshore Petroleum Activities in the Northern Territory* (**Code of Practice**), an approved code of practice for the purpose of Schedule 1, for reasons detailed below in the body of the submission.

Impacts on hydrological processes, inland water quality and aquatic ecosystems

15. Hydraulic fracturing poses significant risks to surface water and groundwater. Risks to water-based environmental values were a key focus of the Pepper Inquiry. The key risks identified included:

(i) Unsustainable groundwater use;

(ii) The contamination of groundwater with hydraulic fracturing fluids and wastewater from

[8] Santos, Beetaloo Appraisal EMP, p. 146.
[9] Beetaloo Appraisal EMP, Appendix I: Surface Water and Groundwater Management Plan, p 14, Table 5.
[10] Beetaloo Appraisal EMP, Appendix I: Surface Water and Groundwater Management Plan, p 14, Table 5.
[11] *Petroleum (Environment) Regulations 2016*, Schedule 1, S. 10 (2025).

leaky well or from on-site surface spills; and

(iii) The effect of any water contamination on surface and/or groundwater dependent ecosystems.

16. The EMP fails to demonstrate that the possible significant impacts to groundwater, surface water and water-dependent ecosystems would be reduced to an acceptable level. Further, due to the number of risks and potential significant environmental impacts, the EMP should be referred for assessment under the *Environment Protection Act 2019* (NT) and the *Environment Protection and Biodiversity Conservation Act 1999* (Cth).

17. ECNT notes that the information provided by Santos to assess impacts on water resources falls far short of the information requirements for assessment of the impacts of coal seam gas and coal mining on water resources (noting that the guidelines have yet to be updated to include shale gas) under the *Environment Protection and Biodiversity Conservation Act*, including:

(a) Santos has not identified and characterized all relevant water resources;

(b) Santos has not applied appropriate methods to investigate the risks to those water resources, including comprehensive impact pathway diagrams developed from evidence-based conceptualisations;

(c) Santos has not addressed the uncertainties in predictions of potential impacts on water resources through appropriate data collection, analysis and discussion;

(d) Santos has not adequately described appropriate avoidance or mitigation strategies to prevent or reduce potential impacts on water resources;

(e) Santos has not adequately specified and justified rehabilitation strategies for water resources affected by the project;

(f) Santos has not proposed effective monitoring and management procedures to detect and ameliorate the risk of potential impacts on water resources, and to assess the effectiveness of proposed mitigation strategies and other management measures;

(g) Santos has not considered potential cumulative impacts from past, present and reasonably foreseeable actions.

Scientific uncertainty and significant new research

18. There is a high degree of scientific uncertainty regarding the potential impact of hydraulic fracturing on groundwater resources and associated dependencies in the area of the EMP.

(a) New scientific information/research (much of it not yet complete) regarding the Hot Springs Valley spring complex, and possible groundwater flows/discharges from the Cambrian Limestone Aquifer to the east and north-east (Limmen Bight and McArthur River catchments) does not resolve this uncertainty but increases the risk profile of fracking activities significantly through the identification of possible contamination pathways. Furthermore, the research indicates that existing understandings of groundwater flow paths in the region (including

modelling) upon which decisions have been made to date may be fundamentally flawed.

(b) Santos has ignored this research and its implications. Santos only briefly mentions the Hot Springs Valley in the EMP,[12] but makes no further analysis about the significance of this research or its implications for fracking in the region. Santos does not mention at all new GISERA research suggesting that existing modelling of groundwater flows may be flawed. This is curious given that Santos has partly funded both of these research programs.

19. The application of the precautionary principle requires that the EMP be referred under the *Environment Protection Act 2019* (NT) and the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) for a comprehensive assessment of these risks, given these uncertainties.

Strategic Regional Environmental Baseline Assessment – remaining uncertainties

20. In response to Pepper Inquiry recommendations, the NT Government commissioned the Strategic Regional Environmental and Baseline Assessment (**SREBA**) to address key knowledge gaps regarding hydrogeological connectivity in the Beetaloo Basin.

21. Following an independent review of the SREBA, Currell and Ndehedehe[13] found that there are critical data and knowledge gaps remaining, and as a result, there is ongoing uncertainty about the likely impacts of fracking on aquifers, springs and rivers in the NT, including the Mataranka Hot Springs and the Roper River.

22. In summary, Currell and Ndehedehe found that:

> *Considerable uncertainty remains regarding key aspects of the CLA [Cambrian Limestone Aquifer] (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.*[14]

23. They also found that preliminary data indicates areas of substantial connectivity between deep aquifer units and shallow Cambrian Limestone Aquifer and/or springs. Even if separation exists between shale gas layers and aquifers as noted in the EMP, this can change as a result of hydraulic fracturing or associated seismic activity.

24. The report notes there is a lack of groundwater monitoring bore coverage (and thus baseline data) in key areas, including data to characterise the groundwater level behaviour and flow gradients in the aquifer units below the Cambrian Limestone Aquifer. The SREBA area is of considerable size, warranting an extensive bore monitoring network to collect data and improve our understanding of groundwater in the area.[15]

[12] Santos EMP, p 110.
[13] Prof. Matthew Currell and Dr Christopher Ndehedehe, SREBA Expert Review – Groundwater, (2023).
[14] Matthew Currell, Sue Jackson & Christopher Ndehedehe 'Risks in the current groundwater regulation approach in the Beetaloo region, Northern Territory, Australia', Australasian Journal of Water Resources, (2024) DOI: 10.1080/13241583.2023.2297949.
[15] Currell and Ndehedehe (2023), p 1.

25. Currell and Ndehedehe confirm that substantial additional data and analysis is required to fully assess the extent of connectivity and likely behaviour of deep and shallow aquifers, and impact that the extraction of groundwater could have on interconnectivity and groundwater movement. This analysis is built upon further in in the **attached** expert reports and the body of the submission below.

The significance of Hot Springs Valley

26. The SREBA revealed new scientific knowledge involving the existence of a series of springs in Hot Springs Valley on Tanumbirini Station, likely sourced from deeper Mezoproterozoic formations, which has serious implications for hydraulic fracturing activities in the region and risks associated with it. ECNT estimates that this spring complex is less than 50 kilometres from Santos' proposed new well pads at Jiberu and Newcastle South, and is less than 40 kilometres from Santos' Mount Brown well (noting that activities associated with this well are to be incorporated into the EMP).

27. Specifically, while the Cambrian Limestone Aquifer is generally isolated from deeper aquifers by aquitards, the SREBA noted that there is the "potential for active connection between deep (gas-bearing) and shallow formations" including at Hot Springs Valley where "faulting may provide a connection between the Beetaloo Sub-basin to the surface."[16]

28. Hot Springs Valley is located within the catchments of the Limmen Bight River, and the SREBA report stated that this area warranted "further monitoring and investigation".

29. In September 2022, detectable and correlated concentrations of methane and ethane were detected in the air surrounding Hot Springs Valley (including at Clint's Gorge) on Tanumbirini, approximately 30-40 kilometres from the proposed well pads. Methane bubbles were identified near the spring vent indicating possible association with Beetaloo Sub-basin gas exploration targets. The SREBA Regional Report states:

> "the CLA is generally isolated from deeper aquifers by extensive aquitards (basalts and the Cox Formation) but there are restricted areas where it is potentially in contact with deeper aquifers. There are a few areas where there is potential for active connection between deep (gas-bearing) and shallow formations, but one area (Hot Springs Valley, which is not part of the CLA) has been identified where faulting may provide a connection between the Beetaloo Sub-basin to the surface."

30. Hot Springs Valley has the highest recorded water temperature (65C) of any spring in the NT and was identified during the GBA and GISERA programs "as an area of interest". The groundwater source could be from at least 1000 metres below groundwater, suggesting the source as a deeper formation underlying the area, noting that "without further geophysical investigation (eg seismic), the source of these springs remains poorly understood."[17]

31. Another spring nearby (Lagoon Creek Gorge spring) has a lower temperature (42C) suggesting the source could be 200-500m below ground level. The SREBA opined that the source could be the

[16] "Regional Report: Strategic Regional Environmental and Baseline Assessment for the Beetaloo Sub-basin", NT Government, 2023, Page 12.
[17] Ibid, page 86.

Bessie Creek Sandstone.[18]

32. The SREBA also suggested that detectable concentrations of methane and ethane in the air surrounding one of the springs in the complex (Beauty Creek hot spring) indicated a thermogenic source, and GISERA recommended further investigations of the gas source given the likely implications of their findings (ie potential interaction of the deep regional system with surface hydrology and ecosystems). The SREBA stated "until the groundwater source and discharge mechanism are better conceptualized, it is recommended that a monitoring program be implemented. This program would ensure ongoing collection of baseline water quality and quantity data, in addition to relevant ecological and greenhouse gas data."[19]

33. Hot Springs Valley is within the Limmen Bight River catchment. While in September 2022 (the late dry season), streamflow was observed not to reach the Cox River downstream (which becomes part of the Limmen river), it is part of this river system and likely discharges into the river during periods of higher flow and rainfall. Water from the hot springs complex that is not evaporated may be lost "through infiltration into the riverbed of the downstream watercourse" and possibly into the aquifer.[20]

34. There are significant data gaps involving the Cox and Limmen Bight Rivers downstream of Santos' proposed fracking operations (and the Hot Springs Valley). No current or historical gauging data exists for the Cox River, and the only gauging site on the Limmen River is 50 kilometres downstream and has been dormant since 1987. It is unclear whether and to what extent a comprehensive groundwater monitoring program has been implemented.

35. The SREBA concluded that the petroleum industry should prioritise investigations of the Hot Springs Valley area, especially those companies undertaking work within 50 kilometres of the springs.[21] Santos' proposed fracking activities are located within 50 kilometres of the springs and very close to creeks that discharge into the Cox/Limmen River systems.

36. Hot Springs Valley is associated with a large number of geological faults and naturally fractured zones which can create natural pathways for contamination due to pre-existing cracks and weaknesses in the rock. Fracking activities create new fractures, which can then link up with these natural fault networks, creating extensive pathways for contamination of productive groundwater in shallower aquifers (like the Cambrian Limestone Aquifer) and dependencies (like Hot Springs Valley and the Cox/LImmen Rivers). Connected fault systems allow injected fracking fluids, produced gas/brine and/or hypersaline aquifer water to travel upwards towards aquifers.

37. Slow contamination of groundwater can occur along fault zones, and research suggests that "hydraulic fracturing should not be carried out near potentially conductive faults, and impacts should be monitored for long timespans."[22]

[18] Ibid, page 86.
[19] Ibid, page 86.
[20] Ibid, p 102.
[21] Ibid, p 108.
[22] Gassiat et al, "Hydraulic fracturing in faulted sedimentary basins: numerical simulation of potential contamination of shallow aquifers over long time scales", *Water Resources Research,* (2013) 49(12), https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2013WR014287.

38. Frery et al[23] have published peer-reviewed research demonstrating that a number of geological faults/fractures associated with the Hot Springs Valley complex, and underlying Tanumbirini Station, could become pathways for contamination of groundwater and groundwater dependencies (see Table 7 below).

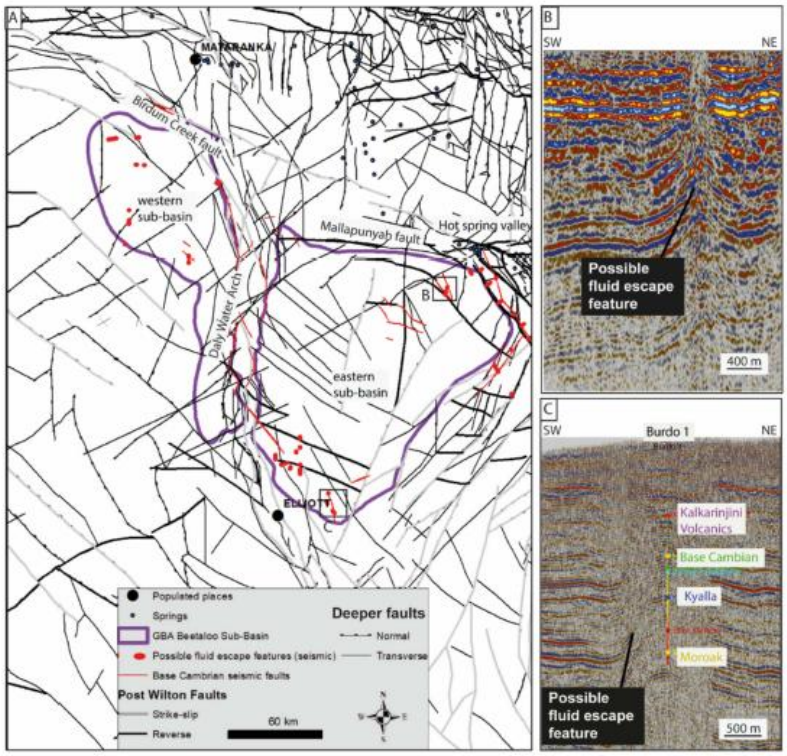

Figure 7. Potential fluid or gas escape features localised on the seismic reflection profiles of the Beetaloo Sub-basin. (**A**) location of the possible fluid escape features on a map view with the interpreted traces of the deep faults reactivated post-Cambrian, the post-Wilton faults [48], and the location of the surface springs. (**B**,**C**). Examples of potential fluid escape features on seismic reflection lines respectively in the northeast and southern parts of the eastern Beetaloo Sub-basin (lines MD92-58 and 89-20).

39. They state, in relation to the Hot Springs Valley complex that the springs suggest "active circulation to at least 650 metres below ground surface along conduits with relatively good permeability."[24]

40. They also state, in relation to the OT Downs fault system underlying the region that "fault segments linked to those systems, especially around fault termination or relay zones, may be triggered and currently openly acting as a conduit for deep fluids and gas leakage directly to the surface".[25]

41. GISERA has been undertaking further research in relation to the Hot Springs Valley complex in order to collect baseline data to comprehensively characterize the springs, stating that "environmental data capture at these springs has been limited to date due to their remote location" and further studies are needed "to provide a baseline prior to any potential development

[23] Frery et al, "Fault-Related Fluid Flow Implications for Unconventional Hydrocarbon Development, Beetaloo Sub-Basin (Northern Territory, Australia)", *Geosciences 2022,* 12(1), https://doi.org/10.3390/geosciences12010037.

[24] Ibid, p 19.
[25] Ibid, p 21.

of gas resources in the nearby Beetaloo Sub-basin."[26] It is noted that this research is incomplete, and the final report is not expected for some months (pers comm, Cindy Ong, CISRO).

42. The available evidence suggests an increased degree of risk to groundwater and groundwater dependent ecosystems arising from hydraulic fracturing activities in this area. However, Santos' EMP contains no analysis of the significance of the faults/fractures associated with the Hot Springs Complex, the risk to groundwater associated with these faults, and there is no contaminant pathway or impact pathway modelling in the EMP. The EMP makes a very brief and misleading reference in an Appendix about the significance of faults: "Faults in the region generally do not extend to shallow formations, reducing the risk of fluid migration. The potential for aquifer connectivity, particularly between the CLA and the Roper Group, is an important consideration for water resource management within the Beetaloo Sub-basin."[27] The EMP refers to a desktop analysis undertaken by AECOM (which has not been published), and does not reference the extensive research outlined above, nor the ongoing GISERA program of work. The Chemical Risk Asessment undertaken for the project (Appendix D), does not address these potential impact pathways.

43. ECNT refers to the expert report of Professor Matthew Currell (**attached**). Professor Currell states that the EMP has the potential to change the permeability and structure of the Velkerri Formation (the shale gas target) during hydraulic fracturing. He notes that this may lead to enhanced connectivity with, and movement of hydrocarbons into, the overlying and underlying sandstone aquifers of the Roper Group. He notes in particular the possible impacts on the Hot Springs Valley complex, which may suffer reduced water quality and/or quantity as a result of the activity.

44. Santos' EMP should not be approved until this research is completed and synthesized as this would constitute development of gas resources prior to a baseline being collected. Contaminant and impact pathway modelling, and a conceptual groundwater model (including connection with deeper aquifers) must be undertaken once an adequate baseline is obtained. This should be undertaken as part of a comprehensive environmental impact assessment under both the *Environment Protection Act 2019* (NT) and the *Environment Protection Biodiversity Conservation Act 1999* (Cth).

NT Government groundwater model possibly flawed

45. The EMP's analysis of impacts on groundwater (and in particular the Cambrian Limestone Aquifer), and groundwater dependent ecosystems rests on an assumption that groundwater flows in a north-westerly direction, discharging at the Mataranka Hot Spring and the Flora River hot spring complexes (and then into the Roper and Daly rivers).

46. This is due to reliance on the NT Government's Daly-Roper (DR) model, which is a coupled numerical surface water—groundwater flow model. The model was developed to assess the hydrogeological system response at basin scale and to predict flow rates within the Daly River and the Roper River drainage systems, including the base flow contribution from the Cambrian

[26] GISERA, Project Order: Environmental baseline characterization of the springs in Hot Springs Valley, NT", https://gisera.csiro.au/research/surface-and-groundwater/environmental-baseline-characterisation-of-the-springs-in-hot-springs-valley-nt/.
[27] Appendix J: Environmental Assessment Report, page 19.

Limestone Aquifer which sustains flow during the dry season. Development of the DR model commenced in 2004 and has undergone multiple extensions.[28]

47. The SREBA Regional report states that the DR model would be "the main scientific tool used for assessing water extraction scenarios for the area that covers the Beetaloo Sub-basin.[29] The model was the tool used to underpin the Georgina Wiso Water Allocation Plan, which allocates water (including to petroleum) from the Georgina and Wiso Basins (part of the Cambrian Limestone Aquifer). Recommendations 7.7 and 7.8 of the Pepper Inquiry required that water allocation plans be declared in the Beetaloo Basin and that they include provision that adequately control both the rate and volume of water extraction by the gas companies.

48. Santos relies on this model and its assumptions in assessing groundwater impacts (including on groundwater dependent ecosystems), stating for example that "the aquifer discharges into the Roper River … north-west of the Beetaloo Basin, supporting important groundwater-dependent ecosystems".[30]

49. New research being undertaken by GISERA suggests that this model (upon which decisions about fracking and its impacts on groundwater have been based) may be fundamentally flawed.[31]

50. The study is in relation to groundwater in the "eastern extension" of the Beetaloo Sub-basin. The area of study includes a large area in the vicinity of Santos' current and proposed operations, with the outer study area including parts of EP161.

51. The project order states:

    (a) "this newly identified eastern extension … was not entirely included in these research programs and the potential impacts on water resources and water dependent ecosystems from unconventional gas exploration and development in this area remains poorly understood";

    (b) "the fault zones within the eastern extension host geological sequences that are folded, faulted and displaced and may host potential pathways for contaminants to leak into the overlying Cambrian Limestone Aquifer (CLA) hosted in the Georgina Basin";

    (c) "the boundary of the McArthur and Georgina Basins coincide with numerous springs and waterholes amongst the headwaters of the Limmen Bight and McArthur Rivers that are known to be ecologically and culturally important but are poorly characterized";

    (d) "the previous work in the region has suggested that there is the potential for connectivity between the CLA and surface features, but the source aquifers of these springs and waterholes have not been previously investigated";

[28] Knapton, A. (2020). Upgrade of the Coupled Model of the Cambrian Limestone Aquifer and Roper River Systems, Technical Report 57/2020. Prepared by CloudGMS for Northern Territory Department of Environment, Parks and Water Security, Northern Territory Government. Palmerston, Northern Territory.
[29] Beetaloo SREBA Regional Report, p 51.
[30] Santos EMP, p 84.
[31] GISERA Project Order 38, "Groundwater connectivity between the CLA and the surface in the Eastern Beetaloo Sub-basin extension", https://gisera.csiro.au/research/surface-and-groundwater/groundwater-connectivity-in-the-eastern-extension-of-the-beetaloo-sub-basin/.

(e) The IESC has given advise emphasizing the "importance of collecting adequate pre-development groundwater and surface water quality data, and local shale investigations of the connectivity from the surface to the gas bearing layers";

(f) The GBA reports assessing the risks of unconventional gas development did not include the eatern extension;

(g) An environmental baseline assessment of springs in Hot Springs Valley, NT, showed that some flow out of the region is to the north east rather than to the Roper River.

52. The project order states that the DR model "used a no flow boundary along this edge of the Cambrian Limestone Aquifer and so forces the model to have a flow direction toward the Roper River." The project order also states that "the assessments conducted on the potential impacts of unconventional gas development have assumed a north-westerly groundwater flow direction to the Roper River and have not considered that there may be a northern or eastern component to the flow."

53. This research program is incomplete, but the findings may reveal that the basis of our understanding of groundwater flows and impacts has been incorrect, including in the region of Santos' operations. It is noted that GISERA notes there are other risks associated with faulting in the region that could "provide a connection between the gas resource and the springs that could be activated by hydraulic stimulation". [32]

54. The consequences of this research are very significant for the entire risk profile of fracking, including in the vicinity of Santos' operations:

> "The Georgina Wiso Water Allocation Plan (Northern Territory Government, 2023) makes the assumption that all water north of the Alexandria-Wonarah basement high flows to the north-west to discharge to the Roper River and that the CLA is isolated from the layers below by the APV (Antrim Plateau Volanics). These assumptions are reasonable at the regional scale of the Georgina Basin but may not be accurate at the local scale of the eastern Beetaloo Sub-basin extension. The risks to water related assets from unconventional gas developments that have been assessed by GBA, SREBA and IESC are based on these same assumptions. If the assumptions are not correct then the risk profile for the eastern Sub-basin may need to be reconsidered." [33]

55. The project order proposes work be undertaken including the "development of an initial conceptual hydrogeological model of the aquifer systems and potential pathways to the surface through integration of multiple lines of evidence (eg geological, hydrogeological, hydrochemical and geophysical data). [34]

56. Santos' EMP should not be approved until this research is completed and synthesized as this would constitute development of gas resources prior to a baseline being collected, in a very high risk context. Contaminant and impact pathway modelling, and a conceptual groundwater model (including connection with deeper aquifers) must be undertaken once an adequate baseline is

[32] Ibid, page 8.
[33] Ibid, page 8.
[34] Ibid, page 8.

obtained. This should be undertaken as part of a comprehensive environmental impact assessment under both the *Environment Protection Act 2019* (NT) and the *Environment Protection Biodiversity Conservation Act 1999* (Cth).

Unsustainable water extraction

57. Santos has a licence to extract 193ML of groundwater per annum, but proposes to apply to increase this entitlement to 750ML per annum (although this increased volume is not yet authorised). Santos proposes to extract up 2.35GL of water per annum in total for the duration of the EMP (approximately 3 years). This is a significant increase in water extraction in an area with episodic and rare recharge.

58. Groundwater extraction is stated to be in accordance with the allocation for petroleum activities in the Georgina Wiso Water Allocation Plan (**WAP**), which allocated a total of 10,000ML/year for petroleum activities across the Basin). Accordingly, Santos' proposed licence would comprise 7.5% of the annual petroleum activity allocation in the plan. Santos should be required to substantiate why it requires such a significant proportion of the available petroleum allocation for the EMP appraisal activities. ECNT notes that, if this appraisal project is successful, Santos proposes significant expansion of its operations in the Beetaloo Basin. Assuming annual water extraction per well (62.5ML), and an eventual export-scale operation of 500 wells on EP161, this could increase water use to approximately 31GL per annum in the area, well in excess of the Georgina Wiso WAP allocation for petroleum.

59. In ECNT's view, the Georgina Wiso WAP is flawed and allocates an unsustainable amount of groundwater from the Cambrian Limestone Aquifer. It relies on very coarse data, particularly regarding recharge rates and mechanisms in the plan area, noting that recharge in the Anthony Lagoon and Gum Ridge Formations varies significantly with precipitation, topography, karstic features, overlying rock and sediment formations. The annual recharge estimate in the WAP appears to be a gross overestimate, noting that recharge for this basin is low and episodic. There was a very significant recharge event in 1974 of over 20,000GL which has skewed the average. If the median is used instead, the annual recharge is actually 0.5GL. Recharge is thus considerably lower than the long-term average in most years (and may be negligible under the current climate), except for rare events where rainfall and recharge far exceeds the long-term average. Accordingly, Santos' proposed annual extraction would exceed the median annual recharge and is likely to be unsustainable.

60. As discussed above, it is possible that the Georgina Wiso WAP is flawed in its reliance on the DR model (which assumes that groundwater flow moves in a north westerly direction towards Mataranka Springs). Accordingly, there is a possibility that extraction in this area could impact other springs and waterways (including the Hot Springs and/or the Cox and Limmen Bight Rivers).

61. Santos inconsistently states any localized drawdown from water extraction would be temporary (in the EMP), and also that the project is "unlikely to cause water drawdown".[35] There is no modelling to support this assertion, on either a local or regional scale. The local impacts of drawdown are glossed over or ignored. This could include impacts on water supply for Tanumbirini Homestead

[35] Appendix J: Environmental Assessment Report.

(located only 3.4km away), livestock water supply (including via bores and turkeys nests), for threatened species (such as the critically endangered northern blue tongue skink, where water drawdown is listed as a risk to that species in the EMP),[36] and local groundwater dependent ecosystems.

62. The EMP does not sufficiently address the impacts of extracting 2.35 billion litres of water over a relatively short timeframe, nor does it explore the water balance, hydrogeology and characterization of groundwater dependent ecosystems to understand the effects of such extraction.

63. There is insufficient exploration of the potential impacts of groundwater extraction at a significantly higher rate and the EMP does not appropriately address the cumulative impacts of the proposed water extraction along with other existing or proposed water extraction in the region.

Impacts on groundwater dependent ecosystems

64. Santos' analysis of impacts on groundwater dependent ecosystems is flawed and inadequate.

65. Groundwater dependent ecosystems have only been identified within a 5 kilometre radius of the well pads. This is a clearly insufficient area, given the possible large area of impact in the case of groundwater or surface water contamination.

66. A number of high value groundwater dependent ecosystems are identified within this 5km radius consistent with the location of the project within a significant floodplain, including melaleuca forests, riparian woodland and *corymbia bella* (ghost gum) woodland. Santos assumed these extensive ecosystems will not be impacted because they are likely accessing a perched groundwater system. The connection between these groundwater dependent ecosystems and deeper aquifers needs to be better characterized to estimate any contribution to shallower/perched aquifers and springs, seeps and surface water. Santos has not undertaken any assessment of the risk to these systems from surface water contamination.

67. Santos states that "there is also a range of small wetlands associated with springs, sinkholes and minor depressions in the generally flat landscape." These are potential groundwater dependent ecosystems, and should be surveyed and assessed.

68. Within a 50 kilometre radius, there is a range of groundwater dependent ecosystems, including the Hot Springs Valley complex. GBA research data suggests these springs (including Clint's Gorge) are very biodiverse in terms of aquatic ecology.[37] A total of two species of freshwater turtle, 17 species of fish, and 27 species of aquatic vertebrates were observed and identified during two field visits by the GBA aquatic ecology team. A total of 61 species was recorded from the site, similar to the species richness near Mataranka Hot Springs (80 species). Santos has not assessed the impacts to these ecologically significant ecosystems. The GBA terrestrial ecology team did not visit the Hot Springs Valley area, so there is a likelihood that there is even greater species diversity at this site, if

[36] Appendix J: Environmental Assessment Report.
[37] Davis, J, Gillespie, G, Cuff, N, Garcia, E, Andersen, A, Young, L, Leiper, I, Ribot, R, Kennard, M, Pintor, A, Bonney, S, and Wedd, D (2021). Beetaloo GBA Region Baseline Survey Program. Research Institute for Environment & Livelihoods, Charles Darwin University, Darwin, Australia.

it were to be surveyed.

69. The EMP does not adequately assess the impacts on stygofauna in the project area, noting that the nearest records are located 17 kilometres away and stating "given the absence of detections and the spatial separation from known occurrences, it is considered unlikely that stygofauna are present within the Project Area." This assumption must be tested by a stygofaunal survey on all current and future groundwater monitoring bores.

70. ECNT refers to the report of Dr Ryan Vogwill (**attached**), which sets out a number of risks associated with impacts to groundwater dependent ecosystems which have not been reduced to ALARP.

71. ECNT makes the following recommendations consistent with Dr Ryan Vogwill's analysis:

    (a) All exploration wells should be drilled to a Category 9 (or above) standard of well construction incorporating cement casing from the shale formation to the surface, as per Pepper Inquiry recommendation 5.3 (NT Government 2018). Current Santos well design does not have cement to surface stipulated around the 5 ½" production casing (see pg. 65 Fig. 11 of EMP);

    (b) Detailed seismic survey across the area to identify the locations of minor fractures and faults that may be activated or act as existing conduits;

    (c) Baseline surface gas survey in all existing bores and oil gas wells, the latter of which need to be also evaluated for current well seal status;

    (d) Installation of groundwater monitoring network in the target aquifers, including aquifer testing, typically this occurs in the context of other development before a water licence approval and also noting the large increase currently not approved as part of the current water licence;

    (e) Extended constant rate aquifer tests (minimum 72hrs) should be carried out on all groundwater abstraction bores, and data should be collected from a comprehensive monitoring bore network that should be installed for all GDE types once a holistic assessment is completed. During testing discharge water should be frequently monitored (e.g. every 30 mins) for water quality parameters such as pH and salinity as this can provide important additional data. Robust estimates of hydraulic conductivity need to be available so a more defensible and preferably precautionary groundwater model can be developed/presented (see item 9 below);

    (f) A network of nested piezometers or a set of monitoring bores (targeting shallower aquifer units at each site ~<1km) should be established. The groundwater monitoring network should include (recommendations 7.1 and 7.3 SERBA) multilevel monitoring bores. This should include one site that covers aquifers likely to be accessed (e.g. Anthony Lagoon Beds, Gum Ridge Formation, Unnamed Sandstone, Bukalara Sandstone) The deeper aquifers (e.g. Bukalara Sandstone, Moroak Sandstone and Bessie Creek Sandstone) may require a more pragmatic approach to monitoring and obtaining deeper groundwater heads via techniques such as drill stem tests conducted over deeper aquifer zones should be employed. Connections between the formations above and below the Cambrian Limestone need to be better established,

including the Bessie Sandstone unit underlying the Velkerri Formation (target gas zone). A hydrograph of groundwater levels at each current monitoring site would be a helpful inclusion;

(g) A bore census for water quality and gas at all pre-existing bores and in exploration/monitoring bores (see above) that should be installed before any approval is given to better understand the current hydrogeological conditions. This should include a methane isotopes sampling program to differentiate between biogenic and thermogenic sources of methane;

(h) A detailed assessment of the distribution and groundwater dependency of GDEs is required. The first stage of the GDE toolkit (Richardson et al., 2011a) needs to be applied at all project locations at a minimum. If GDEs are detected then application of Part 2 of the GDE toolkit (Richardson at al., 2011b). This will ensure the impact assessment will include all possible drawdown receptors. To be explicit all 3 broad groups of GDEs - Aquatic (pools, springs, soaks, seeps etc), Subterranean (stygofauna and troglofauna) and Terrestrial (groundwater dependent vegetation) need to be assessed. These investigations should be completed prior to any further disturbance. Note that this should include a stygofaunal survey on all current and future groundwater monitoring bores and that linked cultural values should also be considered;

(i) A groundwater model (that has undergone a sensitivity analysis, incorporating the data suggested herein) needs presenting, incorporating conceptual mechanisms (i.e. fault/fracture water and gas transport) by which any impacts may manifest. Once this is completed and a more robust impact assessment is presented, the potential impact area may increase, in which case the receptor survey from the dot point above may need to be increased;

(j) The following is a list of recommendations that should also be addressed in the context of the fault seal analysis:

a. Gas logging during all drilling both for water bores and hydrocarbon wells;
b. Water quality needs evaluation in deep aquifers prior to HFS, the area has unexplored water resources that could be impacted;
c. Pressure monitoring in bores screened in the deep aquifer (i.e. the proposed Grant/Poole groundwater monitoring bores) with real time pressure monitoring during hydraulic stimulation should be considered. This type of monitoring is a more reliable way of assessing how the transient pressure during hydraulic fracture stimulation propagates and impacts on deep aquifers located in critical areas, particularly near faults and fractures;
d. Monitoring of breakouts and drilling induced tensile fractures during drilling;
e. Fracture stability assessment should be conducted as a routine. Maximum bounds for stimulation pressure require site specific thresholds based on a consideration of both the stress state and reservoir type;
f. Fracture propagation modelling, G Function analysis and interpretation, stress barriers assessment. Stress barriers, not just geomechanical contrasts, are required for fractures to be contained within the hydraulic stimulation zone. There needs to be more detailed consideration of minimum horizontal stress in the cap rock and this needs to be completed for all areas where hydraulic stimulation is proposed.

Cross-contamination of aquifers

72. ECNT submits that the EMP demonstrates that the risk of cross-contamination of high value groundwater aquifers (eg the Gum Ridge aquifer) with hydrocarbons and other contaminants of potential concern have not been reduced to ALARP.

73. ECNT refers to the report of Professor Matthew Currell (**attached**), which states that the EMP has not sufficiently considered this risk. Professor

74. Professor Currell refers to research indicating that approximately 2 to 20% of wells within a given unconventional gas development region experience well integrity breaches (median rate 13%)[38] and notes that:

> Well integrity breaches are a major issue associated with shale gas development. They are one of the primary pathways by which contaminants (predominantly hydrocarbons) can cross-contaminate aquifers in areas of shale gas development (Vengosh et al., 2014; Lackey et al., 2021). This contamination pathway has been documented to have affected important water supply aquifers with contaminants introduced into wells in multiple cases in the United States (Darrah et al., 2014; Llewellyn et al., 2015; Whyte et al., 2021).

75. ENCT notes media commentary regarding a decision not to prosecute Beetaloo Energy for its failure to appropriately isolate aquifers in the vicinity of Santos' operations, namely the Anthony Lagoon and Gum Ridge Formations.[39] In ECNT's view, the Anthony Lagoon Formation and the Gum Ridge Formation aquifers (while both part of the CLA) should not be considered a single hydrostratigraphic unit, but separate units. It is unclear whether Santos proposes to isolate the Anthony Lagoon and Gum Ridge formations from each other as required by the Code of Practice. This should be clarified/required.

76. Professor Currell (**attached**) notes the difficulty of cementing the gas wells' annular space through the Gum Ridge aquifer – the major water supply for the region, stating:

> This is due to the karstic nature of the aquifer, whereby the rock matrix contains significant fractures and caverns into which fluids flow and are easily 'lost' into the aquifer matrix. This typically results in an inability to maintain fluid circulation during drilling through the unit. In some cases, fluids lost during drilling through the Gum Ridge aquifer have been identified as re-emerging at the surface through sink-holes (Deslandes et al., 2019). This highlights the complex permeability pathways fluids take during the drilling process in the aquifer.
>
> Successful return of fluids to the surface is vital to effective well cementing. Most water bores in the Gum Ridge aquifer are not cemented throughout the aquifer, due to fluid loss. If successful cementing of gas wells through the Gum Ridge Formation is not achieved or is incomplete, this will leave the aquifer vulnerable to contamination. Without a protective cement barrier, any casing deformation events or degradation of production and/or intermediate casings over time may allow hydrocarbons to migrate into the aquifer.
>
> A specific scenario that could lead to contamination of groundwater would be the inflow of pressurized hydrocarbons from the Kyalla Formation (which sits above the target Velkerri Formation) into the wellbore during drilling, which could then migrate upwards and enter the Gum Ridge aquifer. This risk will be of considerable likelihood if continuous cementing to protect

[38] Davies, R.J., et al., 2014. Oil and gas wells and their integrity: Implications for shale and unconventional resource exploitation. Marine and Petroleum Geology 56: 239-254.
[39] https://www.abc.net.au/news/2025-10-14/alleged-environmental-law-breach-nt-beetaloo-basin-gas-company/105854186.

the aquifer is not achieved and could occur either before the wells are completed (i.e., during drilling into the Kyalla Formation) or, after the construction of the intermediate casing around the Kyalla Formation, which is designed to prevent cross contamination."

77. Santos previously notified, under Regulation 23, of the existence of a previously unknown aquifer, the "Inacumba Aquifer", on EP161 which triggered a change in the existing environment. The EMP was modified to address this change to appropriately mitigate risks in accordance with regulatory requirements with respect to the drilling of the Tanumbirini 2H well. Santos amended its relevant EMP, and committed to isolate the Inacumba unit with "cemented 9-5/8 surface casing", among other measures. A schematic diagram illustrating the locations of proposed casing shoes relative to stratiography in the EMP for STO2-S is below.

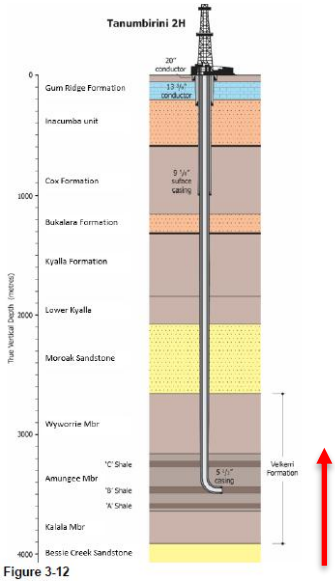

Figure 3-12

78. A Technical Report from the NT Water Resources Division explains the identification of the new Inacumba aquifer at Tanumbirini Station.[40] It states that this significant aquifer is believed to extend over an area of at least 1500 square kilometres (previously thought to be the Bukalara Sandstone). The aquifer is productive, and capable of pumping up to 15 litres per second. Minor water level response was detected from the overlying Gum Ridge Formation. Recharge is likely to be sporadic, only occurring in very wet years. A possible avenue for recharge is downward seepage from the Gum Ridge Formation. The report states that "further investigation is required to determine its recharge and discharge regime."

79. The discovery of a new aquifer should prompt a changed management and regulatory response. The Code of Practice requires all aquifers in the area to be isolated from the surface and each other and any hydrocarbon bearing zones using appropriate barriers. Monitoring of barriers and casing condition must be carried out in accordance with a well operations management plan. Multi-level observation bores must be installed and groundwater monitored in accordance with the *Preliminary Guideline: Groundwater Monitoring Bores for Exploration Petroleum Wells in the Beetaloo Sub-basin*.

80. Santos does not mention the Inacumba Aquifer at all its in EMP, and this absence has not been

[40] Water Resources Division Technical Report 20/2020, "Identification of the new Inacumba aquifer at Tanumbirini Station."

explained. Instead, there is a reference to an "unnamed sandstone" which may correspond with this unit. There is no specific reference to isolation of this aquifer during well construction and it is unclear whether it will be so isolated. Santos has indicated in the EMP that it only considers the Cambrian Limestone Aquifer to constitute an aquifer (and by extension does not propose to monitor the Inacumba aquifer). There is no indication that Santos is proposing to construct and use multi-level observation bores in accordance with the *Preliminary Guideline: Groundwater Monitoring Bores for Exploration Petroleum Wells in the Beetaloo Sub-basin*.

Contaminants and risks to surface water and groundwater

81. If site containment is breached, contaminated water may be mobilised within temporary overland stormwater flow events into surrounding ephemeral waterways and groundwater. This impact pathway was identified as being of low likelihood but high consequence in the Beetaloo by the IESC (2024) who noted that such events could cause significant harm to aquatic ecosystems.

Drilling fluids

82. The 2025 Onshore Code of Practice states that the "protection of aquifers requires the following to be achieved:…(e) drilling fluids must be designed to minimise environmental harm."[41] Additionally, when "drilling through local aquifers and until these aquifers are isolated by a minimum of two verified barriers, then… chemicals or other substances that could leave a residual toxic effect in the aquifer must not be added to the drilling fluid."[42] Santos' measurement criteria for drilling fluids to ensure environmental performance standards and outcomes are met include "Drilling reports include details of all additives…and demonstrate that they were not considered to be ecologically toxic."[43]

83. Santos' drilling reports indicate that some of Santos' drilling fluids may not minimise environmental harm, may leave a residual toxic effect in the aquifer, and are ecologically toxic. The following substances in Santos' proposed drilling fluids show risks of being ecologically toxic:

    (a) Tetrahydro-3,5-dimethyl-1,3,5-thiadiazine-2-thione (Cas No. 533-74-4):[44] This substance was evaluated as one of the existing drilling fluids proposed by Santos,[45] and is listed in Santos' use of the Halliburton Barahib Plus Soup Mix,[46] and the Halliburton "KCl/Polymer Mud System."[47] Santos list of chemical data sheets does not appear to provide an independent toxicity assessment for this substance. However, the same company doing the risk assessment for the EMP, EHS Support, lists a quantitative and qualitative tier 3 assessment for this substance, and notes it is also sometimes called "Dazomet."[48] EHS notes Dazomet degrades rapidly into "Methylisothiocyanate (MITC)" and thus EHS when

[41] Code of Practice: Onshore Petroleum Activities in the Northern Territory ("2025 Onshore Code of Practice"), cl. B.4.2.1.
[42] 2025 Onshore Code of Practice, cl. B.4.10.2.
[43] Santos, Beetaloo Appraisal EMP, p. 144.
[44] Santos, Beetaloo Appraisal EMP, Appendix D, Table 7 Existing Drilling Fluid and Cementing Chemicals.
[45] *Id*.
[46] Santos, Beetaloo Appraisal EMP, Appendix D, Attachment D (Chemical data sheet attached to Appendix D, p. 1541 of 2450).
[47] Santos, Beetaloo Appraisal EMP, Appendix D, Attachment D (Chemical data sheet attached to Appendix D, p. 1726 of 2450).
[48] EHS Support, Qualitative and Quantitative Tier 3 Assessment, p. 1 (Oct. 2020) https://www.santos.com/wp-content/uploads/2021/04/Dazomet_Tier3.pdf ("Tetrahydro-3,5-dimethyl-1,3,5-thiadiazine-2-thione (dazomet) is a component in a drilling fluid product (DEXTRID® LTE) used as a fluid loss additive in the following fluid systems: • KCl/Polymer Mud System" and others).

studying residual drilling fluids assesses both Dazomet and MITC together.[49] EHS concluded that "Dazomet exhibits high acute toxicity to aquatic organism, particularly to fish" and "MITC exhibits a higher acute toxicity to fish compared to dazomet." Concerningly, MITC also "does not degrade in freshwater by hydrolysis and it is also not readily biodegradable."[50] Other EMPs in the NT have also reported on the toxicity of dazomet, finding that the toxicity of Tetrahydro-3,5-dimethyl-1,3,5-thiadiazine-2-thione is "Very high."[51] Given that this substance has a high toxicity and that the substance it degrades into, MITC, is even more toxic to aquatic organisms and is persistent, it could be considered ecologically toxic.

(b) Glutaraldehyde – Santos conducted a tier 2 assessment for Glutaraldehyde for avian receptors and found no unacceptable impacts.[52] Glutaraldehyde is listed as one of the substances in Santos' "Existing Drilling Fluid and Cementing Chemicals."[53] It is used as a "biocide."[54] According to international guidelines, such as the US EPA and International Programme on Chemical Safety, "Glutaraldehyde is considered toxic to fish, aquatic invertebrates, oysters, and shrimp and should not be discharged to water bodies."[55] Australian guidelines note that Glutaraldehyde is "moderately toxic to aquatic animals and moderately to highly toxic to algae," but its impact on the environment may be higher if not broken down by bacteria.[56] Santos appears to provide no data on bacteria degradation of Glutaraldehyde in its groundwater or flowback fluids. A CSIRO report on the toxicity of drilling fluids in hydraulic fracturing operations notes that "degradation products of some biocides have been reported to be more toxic and/or persistent than their parent compounds," and detection of both "parent and transformation products in wastewaters and receiving waters" is needed to understand impact.[57] The same report lists this substance as one that is "very toxic."[58]

Hydraulic fracture fluids

84. Clause B.4.13.1 of the 2025 Onshore Code of Practice state that "Hydraulic fracture stimulation and flowback operations must … ensure protection of aquifers is maintained during all operations phases for hydraulic stimulation and flowback." Clause B.4.13.2 on mandatory requirements states "Hydraulic fracture stimulation activities must be designed to not impact aquifers." Clause B.4.13.3(f) on preferred requirements states "As far as reasonably practicable, fluids with the

[49] EHS Support, Qualitative and Quantitative Tier 3 Assessment, p. 2 (Oct. 2020) https://www.santos.com/wp-content/uploads/2021/04/Dazomet_Tier3.pdf.
[50] *Id*. at p. 6.
[51] Tamboran, Regulation 22 Modification Notice – Tam1-3 – Additional DH Drilling Chemicals and updated Appendices, APPENDIX E Chemical Risk Assessment – AECOM 2024, Beetaloo Exploration and Appraisal Program – Hydraulic Fracturing Chemical Risk Assessment, Appendix E Chemical Risk Assessment – Drilling Fluid p. 1 of 2 (9 Aug. 2024).
[52] Santos, Beetaloo Appraisal EMP, Appendix D, p. 9.
[53] Santos, Beetaloo Appraisal EMP, Appendix D, Table 7.
[54] Santos, Beetaloo Appraisal EMP, Appendix D, Attachment A.
[55] Agency for Toxic Substances and Disease Registry (US), Toxicological Profile for Glutaraldehyde (2017) https://www.ncbi.nlm.nih.gov/books/NBK591667/.
[56] Department of Climate Change, Energy, the Environment and Water, Glutaraldehyde: Sources of emissions, https://www.dcceew.gov.au/environment/protection/npi/substances/fact-sheets/glutaraldehyde-sources-emissions.
[57] Department of Agriculture, Water and the Environment, Bureau of Meteorology, Geoscience Australia, Bioregional Assessments, CSIRO, Qualitative (screening) environmental risk assessment of drilling and hydraulic fracturing chemicals for the Isa GBA region, p. 16 (2020) https://www.bioregionalassessments.gov.au/sites/default/files/gba-isa-stage2-appendix-chemicalscreening-final.pdf.
[58] Department of Agriculture, Water and the Environment, Bureau of Meteorology, Geoscience Australia, Bioregional Assessments, CSIRO, Qualitative (screening) environmental risk assessment of drilling and hydraulic fracturing chemicals for the Isa GBA region, p. 15, Table 7 "Chemicals of 'potentially high concern' that are not persistent (P) or bioaccumulative (B), and very toxic (T)" (2020) https://www.bioregionalassessments.gov.au/sites/default/files/gba-isa-stage2-appendix-chemicalscreening-final.pdf.

lowest toxicity should be used in hydraulic stimulation, and the concentrations used should be the minimum required to facilitate effective operations."

85. The list of proposed chemicals to be used in Santos's hydraulic stimulation activities includes those in Attachment A to Appendix D: Chemical Risk Assessment. These substances carry the following risks to aquifers and may be toxic for the following reasons:

(a) Siloxanes and Silicones, di-Me, reaction products with silica (Cas Nos. 67762-90-7, 63148-62-9, 67762-90-7): Siloxanes are added to hydraulic fracturing fluids as defoaming agents and surfactants.[59] These chemicals have low water solubility, are hydrophobic and, in the case of cyclic siloxanes, are volatile.[60] Siloxanes are of potentially high concern to aquatic organisms due to their persistence and bioaccumulative and highly toxic nature.[61] A joint report by the Australian Government and CSIRO ("**2020 CSIRO Report**") concluded that these chemicals,

> "if used at shale, tight and deep coal gas operations, will require a more detailed quantitative ERA [Environmental Risk Assessment] to be undertaken with realistic exposure scenarios in which the quantitative ERA assesses and models the likelihood and consequence of a risk event occurring, identifies and evaluates control and mitigation measures (e.g. what controls are in place to address the identified risk and how effective are these controls), and monitors to ensure controls and management strategies are adequate to prevent impacts on the environment."[62]

Santos' list of "Standard Hydraulic Fracturing System Chemicals" includes "Siloxanes and Silicones, di-Me, reaction products with silica," and Santos assessed the toxicity of this substance using the safety data sheet for polydimethylsiloxanes ("**PDMS**").[63] Santos' safety data sheet is based on a 2019 NICNAS assessment report that did not find high ecotoxicity associated with PDMS.[64] However, the 2020 CSIRO report lists PDMS as one of the five chemicals of all those studied that are not likely to be "easily degraded (persistent), are bioaccumulative (potentially can accumulate in organisms), and exhibit very high acute toxicity to aquatic organisms (P, B, T chemicals)…Such chemicals are considered a high concern/risk to the environment, as they can pose serious harm to aquatic ecosystems if released and require specific controls to prevent their release into the environment."[65]

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[59] Department of Agriculture, Water and the Environment, Bureau of Meteorology, Geoscience Australia, Bioregional Assessments, CSIRO, Qualitative (screening) environmental risk assessment of drilling and hydraulic fracturing chemicals for the Isa GBA region, p. 16 (2020) https://www.bioregionalassessments.gov.au/sites/default/files/gba-isa-stage2-appendix-chemicalscreening-final.pdf.
[60] *Id*.
[61] *Id*.
[62] *Id*. at p. 16-7.
[63] Santos, Beetaloo Appraisal EMP, Appendix D, Table 1.
[64] Santos, Beetaloo Appraisal EMP, Appendix D, Attachment D (Safety data sheet for Siloxanes And Silicones, Dimethyl, Reaction Products With Silica (Cas Rn 67762-90-7) Dimethyl Siloxanes And Silicones (Cas Rn 63148-62-9)).
[65] Department of Agriculture, Water and the Environment, Bureau of Meteorology, Geoscience Australia, Bioregional Assessments, CSIRO, Qualitative (screening) environmental risk assessment of drilling and hydraulic fracturing chemicals for the Isa GBA region, p. 12 (2020) https://www.bioregionalassessments.gov.au/sites/default/files/gba-isa-stage2-appendix-chemicalscreening-final.pdf. *See also* M. Nendeza, "Hazard assessment of silicone oils (polydimethylsiloxanes, PDMS) used in antifouling-/foul-release-products in the marine environment", *Marine Pollution Bulletin* 54: 1190–1196 (2007) (while soluble fractions of this substance can have low toxicity, at "higher exposures, undissolved silicone oil films or droplets can cause physical–mechanic effects with trapping and suffocation of organisms); D. Feng et al., "The effects of model polysiloxane and fouling-release coatings on embryonic development of a sea urchin

(b) Hydrotreated light petroleum distillate[66] (CAS No. 64742-47-8).[67] Santos plans to use this chemical to "ease chemical addition" at volumes of up to 718 liters per stage, making it the wet chemical constituent with the sixth highest concentration in the hydraulic fracturing injected fluid by volume (.0522% of the total injected).[68] Other EMPs in the Territory have acknowledged that the toxicity of this chemical "Based on Chronic" exposure is "High."[69] The 2020 CSIRO Report also gives this substance its highest toxicity rating of "Toxicity = ≤ 1 mg/L (***)."[70] The 2020 CSIRO Report further notes that this substance is one that "can pose serious harm to aquatic ecosystems if released and require specific controls to prevent their release into the environment."[71] Concerningly, the Santos EMP provides a different conclusion that this chemical "Does not meet the screening criteria for toxicity," and "Ecological Hazard - Low concern"[72] without explaining why this conclusion contradicts the toxicity assessment of the 2020 CSIRO report and other EMPs in the NT. The Santos EMP conducts a Tier 2 analysis for this chemical only "based on the potential for inhalation exposures to workers during hydraulic fracturing activities,"[73] but does not conduct an ecological impact assessment for this substance if released from a surface or subsurface spill.

(c) Alcohols, C6-C12, ethoxylated propoxylated ("**AEP**") :[74] The Santos EMP acknowledges that this chemical has "moderate chronic toxicity to aquatic life."[75] In 2024, CSIRO analysed AEP from the Kyalla 117 well site in the Beetaloo, and found that "for water samples from the Kyalla 117 storage pond, AEP did not completely degrade," with 40% of AEP remaining in the pond after a three month incubation, suggesting AEP "may be resistant to abiotic degradation" even if it is readily catabolised by a diverse range of microorganisms.[76] Thus, AEP can be both moderately toxic and persistent in the environment.

(d) Coco alkyldimethyl oxide (CAS No. 61788-90-7).[77] Santos conducted a Tier 2 assessment for avian exposure and found there were no unacceptable exposures.[78] Santos acknowledges that it is "Moderately toxic to aquatic organisms" and "Does meet the

(*Arbacia punctulata*) and a fish (*Oryzias latipes*)," *Aquatic Toxicology*, Vol. 110-11: 162-9 (2012) (leachate of PDMS from coatings applied to marine vessels associated with mortality to mysid shrimp); S. Sarialtin et al., "Toxicological Evaluation of Siloxanes by *In Silico* Approaches" Istanbul Journal of Pharmacy, 55(2): 233-244 (2025) (evaluating the in-silico toxicological profile of sixteen different siloxanes, commonly regarded as safe, and "questioning their potential risks and the validity of the current safety perception").

[66] Santos, Beetaloo Appraisal EMP, p. 15, Table 5.

[67] Santos, Beetaloo Appraisal EMP, Appendix D, Table 1, p. 61.

[68] Santos, Beetaloo Appraisal EMP, Appendix D, Attachment A.

[69] Tamboran, Shenandoah South EMP, Appendix E, Appendix A, "Chemical Risk Assessment Hydraulic Fracture Stimulation Fluid – HAL Hybrid" (assessment for CAS No. 64742-47-8, Hydrotreated light petroleum Distillate).

[70] Department of Agriculture, Water and the Environment, Bureau of Meteorology, Geoscience Australia, Bioregional Assessments, CSIRO, Qualitative (screening) environmental risk assessment of drilling and hydraulic fracturing chemicals for the Isa GBA region, p. 15, Table 6 (2020) https://www.bioregionalassessments.gov.au/sites/default/files/gba-isa-stage2-appendix-chemicalscreening-final.pdf.

[71] *Id*. at p. 14.

[72] Santos, Beetaloo Appraisal EMP, Appendix D, Table 1, p. 61.

[73] Santos, Beetaloo Appraisal EMP, Appendix D, p. 8.

[74] Santos, Beetaloo Appraisal EMP, p. 15, Table 5.

[75] Santos, Beetaloo Appraisal EMP, Appendix D, Table 2.

[76] CSIRO, *Fate of hydraulic fracturing chemicals and geogenic compounds in surface facilities and in the subsurface*, p. 73 (2024) https://gisera.csiro.au/wp-content/uploads/2024/05/CSIROs-GISERA-final-report-NT-fate-of-HF-chemicals.pdf.

[77] Santos, Beetaloo Appraisal EMP, Appendix D, Table 2 Evaluation of Coil Tubing Hydraulic Fracturing System Chemicals Beetaloo McArthur Basin, Northern Territory Chemical Risk Assessment

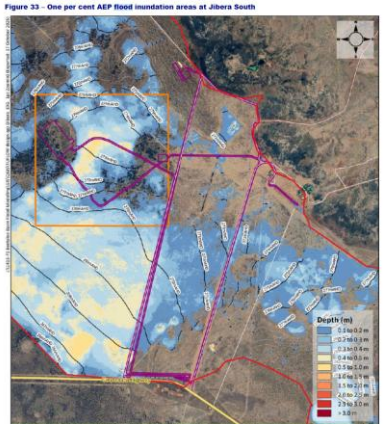
[78] Santos, Beetaloo Appraisal EMP, Appendix D, p. 9.

screening criteria for toxicity."[79] The 2020 CSIRO report ranks this substance to have a "Toxicity = ≤ 1 mg/L," the most toxic ranking.[80] The 2020 CSIRO report also gives this substance its highest bioaccumulation ranking in a list of substances that are persistent or bioaccumulative and harmful to very toxic.[81]

This list is not exhaustive, but illustrative, of how substances in Santos' hydraulic fracturing fluids can potentially be toxic and impact aquifers in contravention of the 2025 Onshore Code of Practice.

Wastewater spills and risks in respect of inter-aquifer connectivity

86. ECNT notes that both of the proposed well pads (and indeed much of EP 161) are located in the middle of a floodplain. Santos has modelled the impacts of 1 in 100 year flooding events in assessing the risk of flooding. ECNT notes that this level of flooding would effectively surround the well pads with floodwaters, some of this water flowing a reasonably high velocities (see image below with respect to Jibera South). This raises serious questions about the ability of Santos to expand fracking operations in this area, and also raises the risk profile regarding spills from the current activities significantly.



87. ECNT notes that 1 in 100 year flood modelling may not be appropriate for this site. It is unclear, for example, how many years of data Santos is relying upon in using this modelling, and it is possible that this data does not contain the largest possible events that could occur in terms of rainfall. Climate change is influencing how often flooding occurs, and rainfall events are expected to become more intense in the future in the Northern Territory. In ECNT's view, Santos should be required to assess flood risk using a 0.1% Annual Exceed Probability (1 in 1000 year) modelling standard.

88. ECNT attaches a report by Dr Grant Hose (**attached**) assessing the environmental impacts and risks (specifically, regarding wastewater spills and risks in respect of inter-aquifer connectivity). Professor Hose's view is that the program poses substantial risk to subterranean aquatic ecosystems, and these have not been adequately characterized and mitigated by the strategies

[79] Santo, Beetaloo Appraisal EMP, Appendix D, Table 1.
[80] Department of Agriculture, Water and the Environment, Bureau of Meteorology, Geoscience Australia, Bioregional Assessments, CSIRO, Qualitative (screening) environmental risk assessment of drilling and hydraulic fracturing chemicals for the Isa GBA region, p. 15, Table 6 (2020) https://www.bioregionalassessments.gov.au/sites/default/files/gba-isa-stage2-appendix-chemicalscreening-final.pdf.
[81] *Id*.

outlined in the EMP, and Santos has not adequately addressed how the requirements of the Code of Practice have been addressed.

89. Professor Hose disagrees with Santos' risk assessment at Appendix O, including because he considers the impacts of aquifer contamination would be "extensive" or 'irreversible" because once contaminated, it is difficult to remediate an aquifer back to its pre-contamination state.

90. Professor Hose that the Chemical Risk Assessment (Appendix D) is deficient in the following key respects:

    (a) The EMP does not consider the risks posed by the release of drilling fluids, hydraulic stimulation fluids, flowback waters, produced waters and other solutions into groundwater that could arise from well failure or leakage;

    (b) The chemical risk assessment does not address the impacts of drilling or other fluids to groundwater ecosystems;

    (c) It is not possible to assess the toxicity of drilling fluids and therefore the risk associated with them because chemicals are only provided in general terms;

    (d) When toxic chemicals are mixed, the effects of the mixture may be greater than the summed toxicity of the constituent parts;

    (e) Mallants et al[82] recommend the use of direct toxicity assessment to characterise the toxicity of flowback waters;

    (f) Golding et al[83] showed that toxicity of flowback water form shale gas wells in the Beetaloo was chronically toxic to eight freshwater species and that a large proportion of that toxicity was due to unidentified chemicals and effects from the mixture of organic and inorganic chemicals and radionuclides (NORMS) in the water;

    (g) The EMP does not consider the ecological risk of the mixtures;

    (h) Salinity is also a considerable risk, and may be acutely toxic to freshwater invertebrates.

91. Professor Hose makes the following recommendations:

    (a) That the chemical risk assessments outlined in Appendix D of the EMP be revised to consider the entry of drilling fluids, hydraulic stimulation fluid and flowback waters into aquifers and the impact of that event on groundwater ecosystems;

    (b) That the effect of relevant mixtures of chemicals used in the Program be tested to

[82] Mallants D, Kirby J, Golding L, Apte S, Williams M. (2022). Modelling the attenuation of flowback chemicals for a soil-groundwater pathway from a hypothetical spill accident. *Sci. Total Environ.*, 806: 150686. https://doi.org/https://doi.org/10.1016/j.scitotenv.2021.150686.

[83] Golding LA, Kumar A, Adams MS, Binet MT, Gregg A, King J, McKnight KS, Nidumolu B, Spadaro DA, Kirby J. K. (2022). The influence of salinity on the chronic toxicity of shale gas flowback wastewater to freshwater organisms. *J. Hazard. Mater.*, 428: 128219. https://doi.org/https://doi.org/10.1016/j.jhazmat.2022.128219.

determine their toxicity to aquatic biota. This should be done using direct toxicity assessment (DTA) and include the various drilling fluids, hydraulic stimulation fluids, flowback waters, produced waters and other solutions;

(c) A survey of groundwater biota be undertaken in the EMP with sampling sites in and close to the development area for the purpose of identifying the presence of any short-range endemic groundwater fauna that may be present in the study area and at risk from the Program.

92. ECNT notes that the EMP and the Chemical Risk Assessment (Appendix D) contains a very limited analysis of Santos' groundwater monitoring and flowback fluid monitoring data. From a brief analysis of the available data:

(a) The Chemical Risk Assessment briefly extracts in table form some of the characteristics of flowback water at Santos' Tanumbirini well paid. This data is selective, but nevertheless demonstrates a high concentration of metals and gross alpha (radioactivity). For example, the gross alpha in flowback water was 2.29 bq/L (compared with the recommended screening value in drinking of 0.5bq/L). The boron level in flowback water was 24,400 ug/L (compared with the recommended removal limit of 900 ug/L);

(b) Santos' "Drilling EMP Annual Groundwater Monitoring Data Review 2023" shows a number of exceedances in heavy metals after exploration activities, including barium. There is a number of analytes with a rising trend.

93. Professor Currell (**attached**) notes that the EMP Wastewater Management Plan (Appendix F) contains "indicative" flowback water quality, containing elevated levels of hydrocarbons, nitrogen, certain metals and radionuclides. Professor Currell states:

> "Without the raw chemical concentration data from flowback samples at the site (covering a full suite of analysed organic and inorganic compounds) and proper documentation of the number and type of samples on which the data in the table are based, it is difficult to verify the full suite of water quality parameters that would be expected in flowback fluid from the project. The contaminants noted above – as well as arsenic, boron and lead, were significantly enriched in flowback water analyses presented in other EMPs in the Beetaloo Basin (such as the Amungee project to the west of EP161; Origin 2022) and should thus be considered likely contaminants of potential concern (CoPC)."

94. Santos should be required to provide an assessment of existing groundwater monitoring and flowback fluid data on EP161.

95. ECNT notes that Santos relies heavily on an unpublished report undertaken by AECOM in 2025 "Groundwater Desktop Self Assessment Technical Report – Santos EP161 McArthur Appraisals". This should be made public.

96. In relation to assessing the risks to groundwater from a hypothetical release from tanks, Santos relies on a report from 2019. This is inadequate, particularly given the significant body of research that has been undertaken since that time (including the SREBA, GBA program, and GISERA program). An updated assessment must be undertaken of the risks to groundwater from tank releases.

97. Santos states that it does not propose to undertake any surface water monitoring because "no permanent or ephemeral surface water bodies are present within two point five kilometres and two point seven kilometres of the two wells pads." This is insufficient and risky, given:

    (a) the two well pads are located within a floodplain and where surface water during flooding or heavy rainfall could discharge into these creeks and into the Cox/Limmen Bight River watershed;

    (b) the close proximity of the well paids to the Tanumbirini homestead (approximately 3.4 kilometres at the closest point);

    (c) the Chemical Risk Assessment states that a catastrophic release from the largest tank could impact an area of up to 220 hectares (or 2.2 kilometres squared) putting the potential zone of impact very close to the nearest waterways;

    (d) the Wastewater Management Plan states that "during exceptionally heavy rainfall, the freeboard [on tanks] may be temporarily exceeded", suggesting a significant spill risk;

    (e) Santos does not propose to cover wastewater tanks during evaporation/treatment (inconsistent with the recommendations of the Pepper Inquiry), creating a significant spill risk;

    (f) Santos does not acknowledge the risk of contamination of groundwater via recharge points at "seasonal creeks". Noting the close proximity of some streams and drainage depressions, it is possible that surface water contamination could seep into the aquifer via these points.

98. Santos should be required to prepare and implement a surface water monitoring plan to detect spills and their risks to sensitive receptors.

99. Professor Currell (**attached**) recommends that Santos should be required to undertake a proper analysis of risks associated with spills and leaks requiring detailed source-pathway-receptor modelling to identify the major impact pathways that likelihood of these being completed during different stages of development, including the implications for ecosystems. Professor Currell notes that there is some scenario modelling in the MEP that looks at the likelihood of complete risk pathways, including infiltration of spilled wastewater into groundwater, and the potential radius of impact that would occur under various spill sizes (eg Appendix D, Attachment B). However this modelling does not involve detailed site-specific soil and shallow aquifer characteristics and hydraulic parameters, or the key sources of potential spill and leak events.

100. The effective protection of groundwater resources from contamination (or drawdown) relating to shale gas development depends on the collection of baseline groundwater data from any potentially impacted aquifers, including multi-level wells monitoring the bottom, middle and top of the aquifer – as outlined in the Preliminary Guideline: Groundwater Monitoring Bores for Exploration Petroleum Wells in the Beetaloo sub-basin (2018).

101. As noted above, Santos' proposed groundwater monitoring regime also appears to be deficient. Santos has not demonstrated it proposes to comply with requirements to install

multilevel monitoring bores for each aquifer, incorrectly stating that the Cambrian Limestone Aquifer (Gum Ridge and Anthony Lagoon Formations) is the only aquifer in the area:

> "At the location of the proposed activities, the CLA is the only aquifer present (Anthony Lagoon and Gum Ridge formations). No other formations in this area are classified as aquifers."

This assertion is incorrect, noting in particular the recently discovered Inacumba Aquifer (see above) and the other aquifers underlying the CLA. Failing to install multilevel monitoring bores for each aquifer would constitute a breach of the Onshore Gas Code of Practice. Santos has previously been advised that aquifer isolation was required when the Inacumba aquifer was discovered.

102. Professor Currell (**attached**) notes other deficiencies with the groundwater monitoring regime:

> Currently, there is one active monitoring bore at the Jibera South site, screening the high-value aquifer of the region – the Gum Ridge aquifer. However, the monitoring bore screens the entire length of the formation from 144 m to 276 m below surface (i.e., a screened interval of more than 120 m). This is a very long screen interval for a monitoring bore, and data from the bore would not provide detailed depth-specific information about water quality changes occurring during hydraulic fracturing and other site activities. This monitoring well is also un-cemented, probably due to the difficulties described above with fluid loss that makes effective cementing of wells difficult. This issue not only creates a high level of risk for cross contamination of the aquifer during drilling and hydraulic fracturing (compared to non-karstic aquifers where cementing is straightforward), but also makes the task of effectively monitoring and early detection of impacts in the aquifer much more challenging, as water samples collected from the well will integrate and average the groundwater input from across the full thickness of the aquifer. Short-screened wells monitoring groundwater level and quality near the base of the formation (the highest risk zone for contaminant input) should be present to enable early detection and mitigation of contamination impacts. This does not appear to be part of the planned monitoring program in the EMP. The monitoring and data collection program in the EMP thus does not align with the following recommendation of the Pepper Inquiry (re-iterated in the Guideline):
>
> "That prior to the grant of any further exploration approvals, in order to minimise the risk of groundwater contamination from leaky gas wells:
>
> - Where a well is hydraulically fractured, monitoring of groundwater be undertaken around each well pad to detect any groundwater contamination using multi-level observation bores to ensure full coverage of the horizon, of any aquifer(s) containing water of sufficient quality to be of value for environmental or consumptive use;
>
> - All existing well pads are to be equipped with multilevel observation bores;
>
> In the monitoring plan of the EMP, it is proposed that the Control Monitoring Bore(s) for the Newcastle South well pad will be constructed less than six months prior to the drilling of gas wells on the pad – in contradiction to the Guideline and Pepper Inquiry recommendations (which cite six months as the minimum period required for baseline data). Santos argue that this is reasonable, as monitoring bore data would still be collected at least six months before the commencement of hydraulic fracturing (as opposed to drilling). However, the risk of contamination incidents taking place may be

just as high during the drilling of the gas wells - for example, via the risk pathway described above and in Figure 1, whereby hydrocarbons enter the wellbore when drilling through the Kyalla Formation and migrate into the Gum Ridge aquifer. In fact, given the highly seasonal rainfall patterns in the NT, at least one year of baseline data should be collected prior to drilling, to capture seasonal variability in groundwater conditions.

Impacts on terrestrial ecosystems and matters of national environmental significance

103. ECNT submits that the project is likely to have a significant impact on a number of threatened species (matters of national environmental significance), necessitating referral under the *Environment Protection and Biodiversity Conservation Act*.

104. Santos' assessment of impacts on matters of national environmental significance is deficient. Santos relies primarily on a desktop species assessment, with a single biodiversity survey being undertaken in December 2024 at the site.

105. Furthermore, the desktop assessment appears only to have assessed populations *within* the project area, rather than within a particular radius (eg 50 kilometres). This has excluded key, ecologically significant, areas that could be impacted by the project (for example, via surface and groundwater contamination) and may be critical habitat for a range of threatened species, such as Hot Springs Valley (and Clint's Gorge), and various creeks and waterways. A Protected Matters Report is **attached** and demonstrates a larger range of threatened species that may be impacted than was assessed by Santos, including the endangered Gulf Snapping Turtle and endangered Freshwater Sawfish. Santos should be required to undertake a more comprehensive assessment of impacts on threatened species within an expanded area (a 50km radius), and undertake comprehensive biodiversity surveys of all relevant species, including of the following species.

Gouldian Finches

106. There are a number of records of Gouldian Finches within, or within a 50km radius of the project area. Many records date recently, from GBA and SREBA studies.

107. Gouldian Finches are listed as endangered under the EPBC Act.

108. According to the Commonwealth Significant Impact Guidelines, a significant impact is one which is important, notable or of consequence in the context of the environment which is impacted and the extent of the impact. For critically endangered and endangered species, the Guidelines provide that an action is likely to have a significant impact on a critically endangered or endangered species if there is a real chance or possibility that it will (amongst other things):

(a) reduce the occupancy of the species;

(b) fragment an existing population into two or more populations;

(c) adversely affect habitat critical to the survival of a species;

(d) modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.

109. The conservation advice for the Gouldian finch states that they feed almost exclusively on grass seed and depend on a relatively small number of grass species which seed at different times of the year. It notes that vegetation change through altered fire regimes and grazing are the most likely causes of past declines in populations and pose a key threat. A 2006 recovery plan also notes climate change is a key potential threat to the Gouldian Finch as it is "likely to affect the timing and amount of wet season rainfall, potentially impacting on Gouldian finch populations by increasing the frequency or intensity of wildfires or by favouring some grass species over others that may not be palatable to Gouldian Finches". Gouldian finches are unique in their nesting habits, as they exclusively nest in tree hollows or holes in termite mounds. They are semi-nomadic, and move through the landscape seeking food and surface water sources.

110. Given the large number of records of Gouldian Finches in the vicinity of the project, and the large amount of suitable habitat such as woodlands and surface water sources (including springs, streams and waterholes), ECNT submits that the Gouldian finch population is likely to be an important population and that the habitat on Tanumbirini is likely to be habitat critical to the survival of the species. Santos has not substantiated its claim that nesting and breeding habitat is unlikely to be found in the project area, and it seems very likely given the number of records of Gouldian Finches that breeding is occurring within the vicinity of the project area. Further surveys should be undertaken of the species to understand its importance, including possible breeding and foraging habitat.

111. Fragmentation of this habitat is possible through land clearing and the construction of roads and tracks. Contamination of surface water and groundwater may pose a significant risk to this Gouldian Finch population. There may also be a significant risk to Gouldian finches from open wastewater tanks on the project area (see further the expert report of Dr Grant Hose regarding the shortcomings of the chemical risk assessment and the significant risk to ecosystems). While Santos claims that the risk to avian species is low, during the dry season when surface water sources are scarce, open wastewater tanks pose an increased risk to birds.[84] These risks would likely be exacerbated by climate change which will change rainfall patterns in this region. These risks need to be comprehensively assessed following more extensive surveys for Gouldian finch populations.

Northern blue-tongued skink

112. The northern blue-tongued skink is listed as critically endangered under the EPBC Act.

113. The EMP incorrectly states that the occurrence of the northern blue-tongued skin is only "possible" within the project area. In fact, according to NT Government records (NR maps) there are two records of northern blue-tongued skinks in the immediate vicinity of the project area (from 1988) and the existence of suitable habitat on the project area suggests they are likely to occur there.

114. The distribution of the Northern Blue-tongued Skink ranges across northern Australia from Eighty Mile Beach WA, across the Kimberley and the Top End of the Northern Territory to approximately the Gregory Downs/Cloncurry area in western Queensland.

[84] Lee, A.T.K, Geary, C., Wright, D.R., Dear, W.R.J. 2019, Vulnerability of birds to contaminated water sources in the Karoo region of South Africa. *Ostrich: Journal of African Ornithology*. DOI: 10.2989/00306525.2019.1638846.

115. The Northern Blue-tongued Skink occurs in a wide variety of ecosystems, including from sandstone plateaus and gorges, limestone ranges, granite, basalt and dolerite hills, glacial shale undulations, sand plains, sandy waterways, swamps, cracking clay floodplains and coastal flats. Vegetation associations include riparian forest, vine scrub, monsoon rainforest, pandanus-lined gorges, melaleuca forest, eucalypt woodland and savanna, sparse and dense shrubland, and spinifex and tussock grassland. Most, but not all, detections have occurred near seasonal or permanent water.

116. Northern Blue-tongued Skink abundance can be high, but locally heterogeneous in areas that are free of cane toads and individuals can be active at any time of the day or night when temperatures are suitable.

117. Northern Blue-tongued Skinks maintain discrete home ranges of 2-12 ha (average 4 ha) containing multiple core habitat patches, and often return to the same sleeping site. The species is more active, transversing across longer distances during the warmer tropical season where food is more abundant than during the cooler dry season.

118. All remnant populations of the Northern Blue-tongued Skink within the distribution of the cane toad are important populations for sustaining this species and providing a source population for dispersing individuals to support recovery.

119. The Northern Blue-tongued Skink Conservation Advice states that areas of dense vegetation that provide cool and moist conditions within otherwise unhospitable landscapes, constitutes habitat critical to the survival of the Northern Blue-tongued Skink. In ECNT's submission, the proposed action area, in part, may contain habitat critical to the survival of the species. It is likely that cool and moist conditions arise, particularly seasonally, within the region given inundation of floodplains and minor streams.

120. The project could impact the Northern Blue-Tongued Skin in a number of ways. Drawdown of the aquifers in the area from groundwater extraction could adversely affect their habitat (ECNT notes that no drawdown analysis has been undertaken by Santos). Contamination of groundwater or surface water could similarly impact this population on or downstream of the project area (particularly in dense vegetation thickets associated with floodplain and riparian habitats. These risks need to be comprehensively assessed following more extensive biodiversity surveys.

Carpentarian Grasswren

121. ECNT refers to the report of Henry Stoetzel, **attached**.

122. In December 2024, fauna surveys undertaken on Tanumbirini Station recorded an individual identified in the survey results as "grass wren" within the family Maluridae. The taxonomic identification was not resolved to species level. However, the authors state that the most plausible candidate species within the genus is the Carpentarian grasswren.

123. If so, this would be a highly significant record. The project area is approximately 100km west of the historically recognized range of the Carpentarian Grasswren and 350km from any known population.

124. The Carpentarian Grasswren is endangered, has a very restricted range, and has been regarded as locally extinct since 2000. The authors state that "a confirmed detection in 2024 would

therefore represent the first record in more than 25 years and would constitute a finding of major conservation importance for the Northern Territory where the species is most threatened".

125. The authors state that "independent verification of this record is essential", and note that habitat characteristics at the site are consistent with those known to support the species elsewhere in its range.

126. The report recommends the implementation of a targeted verification program to resolve the status of the record. Such surveys are necessary to confirm or refute the presence of the Carpentarian Grasswren at the site and to ensure that decisions are informed by robust, evidence-based information.

Mertens Water Monitor

127. The EMP does not mention that there are two records of Mertens Water Monitor (per NR maps) within the vicinity of the project area, nor is there any assessment of the impacts on this endangered species. Surveys must be undertaken, and an assessment of risks to any likely or known population thoroughly assessed.

Impacts on atmospheric processes (greenhouse gas emissions)

128. ECNT submits that the project will have significant climate impacts, and is not consistent with the Northern Territory's policy objective of achieving net zero emissions by 2050.

129. Santos claims that the total anticipated greenhouse gas emissions from the project are 27,741 tonnes of carbon dioxide equivalents in total. This is a very significant under-estimate, taking into account similar sized exploration projects in the Beetaloo Basin. For example, Tamboran's estimated scope 1 emissions from its similar scale Shenandoah Project EMP were 400,000 tonnes of carbon dioxide equivalents over 3 years.

130. ECNT refers to the report of Dr Penny Sackett (**attached**). Dr Sackett's view is that Santos may have significantly under-estimated its greenhouse gas emissions by a factor of 16. Specifically, Dr Sacket states:

(a) Emissions are under-estimated with only values for vegetation clearing, fugitives and non-routine flaring given;

(b) A GWP of 28tCO2e is used in scope 1 estimates, where as an estimate of 29.8 should be used;

(c) A similar exploration and assessment project (Amungee NW Delineation Program) operating on EP98 in the NT, estimated a total of 522,172tCO2-e;

(d) An estimate of the greenhouse gas emissions released on combustion of the EP 161 unrisked 2C contingent gas resource would be equivalent to 92.7 million tonnes (Mt) of carbon dioxide equivalents. This is approximately 4 times the annual emissions of the NT, and these emissions would affect localities in the NT equally through increasingly adverse impacts of resultant climate disruption;

(e) Strong climate change impacts are already being experienced across the Northern Territory, and will be catastrophic if emissions are not curbed;

(f) Every tonne of greenhouse gases emitted into the atmosphere worsens climate change;

(g) It is not the date that net zero is reached that will determine the degree of deterioration of the Territory's future climate, but the total amount of GHG emissions released between now and when net zero is released.

131. Santos must be required to undertake a thorough greenhouse gas assessment and assessment of the climate impacts of the project, including likely and foreseeable cumulative impacts. ECNT submits that this should include the estimate for the combustion of the EP161 unrisked 2C contingent gas resource (92.7 million tonnes), which ECNT says is an activity that may occur in or near the permit area.

132. Santos should be required to offset (via the purchase of ACCUs) all scope 1, 2 and 3 emissions for the project, consistent with Recommendation 9.8 of the Pepper Inquiry. This must be mandatory.

133. The EMP would, based on the above, clearly have a significant impact on atmospheric processes and climate change specifically in the Northern Territory, and should be referred for assessment under the *Environment Protection Act 2019* (NT) and *Environment Protection Biodiversity and Conservation Act 1999* (Cth).

Impacts on human health

134. ECNT notes that the project is located only 3.4km from Tanumbirini homestead, where staff from the station live and work. The project will involve significant, possibly continuous flaring from the wellheads.

135. Significant research has been undertaken since the Pepper Inquiry indicating that there are significant adverse human health impacts associated with shale gas fracking.[85] For example, research suggests that communities within 5 kilometres of flaring experience shorter average length of gestation and a 50% higher chance of having a preterm birth.[86] Flares emit known carcinogens like benzene, which is linked to cancer, anemia, and birth defects, and poses a measurable risk to residents up to five kilometres away. There is a strong association between proximity to flares and respiratory and skin disorders, including worsening asthma in children and other pulmonary problems.

136. Schedule 1, Section 4A(2) of the Regulations requires a "a full human health risk assessment relating to the chemicals or other substances used in the course of hydraulic fracturing." Section 4A of the Regulations states that "a full human health risk assessment is an assessment that takes into account the following instruments": (a) Environmental Health Risk Assessment: Guidelines for Assessing Human Health Risks from Environmental Hazards published by the Environmental Health

[85] Haswell et al, "The risks of oil and gas development for human health and wellbeing: a synthesis of evidence and implications for Australia", 2023.
[86] Cushing LJ, Vavra-Musser K, Chau K, Franklin M, Johnston JE. 2020. Flaring from unconventional oil and gas development and birth outcomes in the Eagle Ford Shale in south Texas. Environ Health Perspect 128(7):77003, PMID: 32673511, 10.1289/EHP6394.

Standing Committee; (b) National Environment Protection (Assessment of Site Contamination) Measure 1999 published by the National Environment Protection Council; (c) National Chemical Risk Assessment Guidance Manual published by the National Environment Protection Council; and (e) any other guideline, measure or document specified by the Minister.

137. Santos' human health risk assessment fails to satisfy the requirements of Schedule 1, Section 4A(2) and the instruments in Section 4A of the Regulations for the following reasons:

(a) The human health risk assessment fails to identify the concentrations of pollutants released into the environment by a surface spill or subsurface release.

The *National Chemical Risk Assessment Guidance Manual* listed in Section 4A requires a risk assessment to estimate the quantity of pollutants released and the predicted environmental concentration in receiving environments.[87] The concentration and distribution of a pollutant, including fluctuations over time, is an "initial requirement for exposure assessment" and one of the "principal determinants of the level of exposure."[88]

Santos assessment of uncontrolled releases fails to predict the concentration of drilling or frack fluid contaminants in the environment, particularly if they are released into subsurface formations or aquifers. Santos primary study of spills or uncontrolled releases is Appendix D, Attachment B that discusses volumes of fluids released and the hectares a spill might cover, but not the concentrations of chemicals released into the environment.[89] Santos also presents a contaminant screening methodology in Appendix F: Wastewater Management's Appendix C, but this study focuses only on risks related to "residual drilling material" for "on-site burial."[90] Lastly, Appendix J provides an environmental impact assessment of project impacts, but its description of operational impacts describes no impacts from drilling or hydraulic fracturing and does not provide concentrations of chemicals from surface or subsurface releases either.[91]

(b) Santos' risk assessment does not assess risks to human health from substances released into drinking water aquifers, which represents an exposure pathway to people.

A full human health risk assessment must assess risks to human health where there is a complete exposure pathway.[92] A pathway "may be considered 'complete' where there is [1] documented evidence of a source (i.e. presence of one or more [chemical of potential concern (**COPC**)] …; [2] there is evidence that the COPCs are actually released from their sources; [3] that there are transport pathways and mechanisms that could convey the

[87] *See, e.g.*, National Environment Protection Council, National Chemical Risk Assessment Guidance Manual, p. 27. *See also*, Environment Protection and Heritage Council, Environmental Risk Assessment Guidance Manual for industrial chemicals, p. 50 (2012) ("An initial requirement for exposure assessment is an understanding of the presence (or absence) of an agent and its concentrations and distribution, including any fluctuations over time") (emphasis added); *id*. at p. 47 (A CSM [conceptual site model] may be based on diagrams or flow charts, but it **must be supplemented with detailed information on COPC concentrations in various media**, transfer characteristics, and receptor characterization") (emphasis added).
[88] *Environmental Health Risk Assessment* (**EHRA**), *Guidelines for Assessing Human Health Risks from Environmental Hazards*, p. 50.
[89] Santos, Beetaloo Appraisal EMP, Appendix D, Attachment B, *Potential Risk to Groundwater from Hypothetical Water Tank Releases*.
[90] Santos, Beetaloo Appraisal EMP, Appendix F, Appendix C, p. 23.
[91] Beetaloo Appraisal EMP, Appendix J, p. 48.
[92] *See, e.g.*, EHRA, *Guidelines for Assessing Human Health Risks from Environmental Hazards*, supra n. 88, p. 46. ("A fundamental concept of risk assessment is that there must be plausible evidence of an exposure pathway linking the source of contamination and the exposed population. Where this linkage exists, an assessment of the nature and significance of the exposure pathway is required to determine the level of risk and the extent to which the proposed pathway is 'complete'").

COPCs from source to the various sites where 'receptors' are located; and that [4] the potential for human contact has been established for contaminated environmental media (air, water, soil food, surfaces) at each point in the transport chain."[93] When surface spills pose a risk to shallow soils and aquifers, then the CSIRO report supporting the *National assessment of chemicals associated with coal seam gas extraction in Australia* concludes that contaminant pathway modelling must be done for the different receiving environments across the project landscape such as wells, wetlands, and creeks.[94]

The EMP found potential complete exposure pathways to humans other than on-site workers only in relation to the burial of residual drilling muds.[95] The "potentially complete exposure pathways that require further consideration could include ingestion of groundwater" contaminated by burial of residual drilling muds if certain conditions are met.[96] The EMP's chemical risk assessment also studied complete exposure pathways, but did so only in relation to surface spills, and found the only complete exposure pathway to be workers' dermal contact and inhalation of chemicals.[97]

The EMP has not completed a full human health impact assessment. This is due to a failure to assess human health impacts from contamination of drinking water aquifers from subsurface events, including loss of fluid circulation during well drilling or well control during fracturing, which represent potentially complete exposure pathways. Professor Hose notes that "the release of drilling fluids to the CLA is likely."[98] Professor Currell similarly notes that the "pathways" by which the activities can "negatively impact water and its dependent users and ecosystems" includes "Well integrity problems, encountered during and following the project, [that] may lead to the cross-contamination of high value groundwater aquifers (e.g. the Gum Ridge aquifer), with hydrocarbons and other contaminants of potential concern (CoPC)."[99] Dr Vogwill also notes that aging wells "can create pathways for contaminants to reach the potable groundwater resources" and that the many different pathways for fracking activities to contaminate aquifers "will vary on a site by site and case by case basis but Reagan et al. (2015) conclude they are all possible. Hence these issues need to be assessed on case by case basis."[100]

Failure to isolate aquifers, which could result in contamination, is not a remote risk. Santos has failed to isolate the Gum Ridge Formation in the past. For example, in 2018, at the Inacumba North Lease Pad, Santos recorded a failure to isolate the drinking water aquifer,

[93] EHRA, *Guidelines for Assessing Human Health Risks from Environmental Hazards*, supra n. 88, p. 46.
[94] CSIRO, *National assessment of chemicals associated with coal seam gas extraction in Australia Technical report number 8 Human and environmental exposure conceptualisation: Soil to shallow groundwater pathways*, p. 115 (2017) (Exposure assessment of chemicals leaking from surface sources into soil and shallow groundwater **requires contaminant pathway modelling from the chemical source (such as low-rate leakage from surface ponds containing flowback and produced water) to different receiving environments (such as water wells, rivers, and wetlands) across the landscape**) (emphasis added).
[95] Santos, Beetaloo Appraisal EMP, Appendix F, Appendix C, p. 28-29.
[96] Santos, Beetaloo Appraisal EMP, Appendix F, Appendix C, p. 29.
[97] Santos, Beetaloo Appraisal EMP, Appendix D, p. 6.
[98] Expert Report of Dr. Hose at p. 6 ("Given that the release of drilling fluids to the CLA is likely, and that the Chemical Risk Assessment does not adequately address the impacts of drilling and other fluids to groundwater ecosystems, the current chemical risk assessment as outlined in Appendix D of the EMP fails to adequately address all risks of the Program to the environment").
[99] Dr. Currell, Analysis of potential water impacts: Santos Beetaloo Basin Appraisal Pilot (EP161) ("**Expert Report of Dr. Currell**"), p. 1 (15 Dec. 2025).
[100] Hydro Geo Enviro Pty Ltd., "Hydrogeological Assessment Of Santos Qnt Beetaloo Basin Appraisal Pilot – Environmental Management Plan," p. 16-7 (17 Dec. 2025).

the Gum Ridge Formation: the "drilling of the groundwater bore RN040931" resulted in "the failure to isolate the Gum Ridge Formation and the Bukulara Sandstone in that bore. This connectivity is potentially inconsistent with the Minimum Construction Requirements for Water Bores in Australia (3rd edition)."[101]

138. The human health impact assessment should be redone by assessing risks to human and ecological receptors in the event of a subsurface event including loss of drilling circulation material, loss of well integrity during or after fracturing, or failure to isolate aquifers.

Conclusion

139. In summary, ECNT submits that the EMP should be rejected.

140. Alternatively, Environment Centre NT submits that the EMP is likely to have a significant environmental impact including on matters of national environmental significance and should be referred for assessment under the *Environment Protection Act 2019* (NT) and the *Environment Protection Biodiversity Conservation Act 1999* (Cth).

Attachments

(a) Report of Professor Grant Hose;

(b) Report of Dr Ryan Vogwill;

(c) Report of Henry Stoetzel;

(d) Report of Professor Matthew Currell;

(e) Report of Distinguished Professor Penny Sackett.

For more information, please contact Kirsty Howey on Kirsty.howey@ecnt.org.

Yours sincerely,

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Executive Director
Environment Centre NT

[101] https://environment.nt.gov.au/media/docs/onshore-gas/emp/reportable-incidents/quarter-3-2018-19/santos-recordable-incident-water-bore-monitoring-q3-2018-19-tanumbirini-south-inacumba-north-south.pdf.

Independent report regarding the possible occurrence of Carpentarian Grasswren (*Amytornis dorotheae*) on Tanumbirini station in the Northern Territory

Prepared by Conservation Partners 17/12/2025

Authors

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1. Introduction

1.1 Context

In December 2024, fauna surveys undertaken on Tanumbirini Station recorded an individual identified in the survey results as “Grass wren” (*Amytornis* sp.) within the family Maluridae. The record was reported as not corresponding to a species listed under either the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) or the *Territory Parks and Wildlife Conservation Act 1976* (NT TPWC Act) (Appendix F: Beetaloo Basin Appraisal Pilot Environment Management Plan). The taxonomic identification was not resolved to species level, and no supporting diagnostic information was provided in the survey documentation.

The genus *Amytornis* comprises 14 species of grasswrens, each characterised by narrow habitat requirements and generally restricted distributions (Christidis 1999, Christidis et al. 2010, Christidis et al. 2013). The EP161 area on Tanumbirini Station is located approximately 100 km west of the historically recognised distribution of the Carpentarian Grasswren (*Amytornis dorotheae*), and more than 350 km from any known population. The only other *Amytornis* species known to occur within several hundred kilometres are the Dusky Grasswren (*A. purnelli*), recorded approximately 180–200 km to the south-west in the arid interior, and the White-throated Grasswren (*A. woodwardi*), which is confined to the sandstone landscapes of the Arnhemland Plateau more than 350 km to the north-west (Birdlife Australia unpublished, Atlas of Living Australia).

The Carpentarian Grasswren was originally described from a specimen collected approximately 160 km east of the record in question (Fleming and Strong 1990). On biogeographic grounds, it therefore represents the most plausible candidate species within the genus *Amytornis* should the Tanumbirini observation correspond to a grasswren. An alternative explanation is that the record represents a superficially similar species, recorded either through misidentification or misclassification within the species list.

Substantial uncertainty surrounds this record. The Carpentarian Grasswren is listed as Endangered, with population declines and local extirpations strongly linked to altered fire regimes (Garnett 2021). The species is widely considered to have been extirpated from the northern extremity of its former range, including areas west of Borroloola. Consequently, while the record warrants careful consideration, it should be treated with caution in the absence of corroborating evidence such as photographic documentation, call recordings, or repeat detections.

1.2 Conservation Significance of the Record

The Carpentarian Grasswren is currently listed as Endangered at both federal and territory levels, in part due to the apparent loss of its northern population, which includes the region east of Tanumbirini Station. The species was last reliably recorded in this north-western area between 1990 and 2000 and has since been regarded as locally extinct (Perry et al. 2011, Harrington and Murphy 2015). A confirmed detection in 2024 would therefore represent the first record in more than 25 years and would constitute a finding of major conservation importance for the Northern Territory where the species is most threatened.

In the Northern Territory, the Carpentarian Grasswren is currently known from only two distinct locations on Calvert Hills Station and Wollogorang Station (Perry et al. 2011, Harrington and Murphy 2015). These locations are natural wildfire refugia, exhibiting steep sided escarpments with an abundance of crevices and vegetation patches that are naturally protected from fire, owing to the complex rocky nature of the landscape (Perry et al. 2011, Harrington and Murphy 2015, Stoetzel et al. 2020, H. Stoetzel unpublished). Despite the protective qualities of these refugia, wildfire impacts are ongoing and the species occurs in very low numbers at these locations (BirdLife Australia unpublished, H. Stoetzel unpublished). Only two neighbouring territories are known to persist on Calvert Hills and no more than five have been recently recorded on Wollogorang.

The species exhibits cryptic behaviour and low detectability without targeted survey methods, and there is potential for misidentification with other small passerines. Given the substantial conservation implications associated with a putative re-discovery well beyond the northern limit of its historical range and more than 350 km from known populations, independent verification of this record is essential (Leseberg et al. 2020).

1.3 Purpose and Scope of This Independent Assessment

This report synthesises published literature, ecological knowledge, and spatial analysis to evaluate the likelihood of occurrence of Carpentarian Grasswren at the proposed sites on EP161. The assessment draws on biogeographic context, species-specific ecological requirements, and habitat characteristics of the survey site including vegetation, geology and fire history. The potential for a misidentification with other similar species is also discussed.

1.4 Data Sources and Methods

This assessment draws on a combination of peer-reviewed literature, regulatory documentation, unpublished expert datasets, targeted field investigations, and spatial datasets. Together, these sources provide the best available evidence for evaluating the likelihood of Carpentarian Grasswren (*Amytornis dorotheae*) occurrence and habitat suitability at Tanumbirini Station. Likelihood terminology used in this report follows a precautionary framework in which ‘possible’ indicates that occurrence cannot be excluded based on ecological evidence, while recognising substantial uncertainty in the absence of diagnostic confirmation.

Project-specific information was sourced from Appendices J–K of the Beetaloo Basin Appraisal Pilot Environmental Management Plan (EMP). These documents provided site-specific vegetation descriptions, fauna survey results, and contextual information relevant to potential impacts, and were used as a baseline for comparison with known habitat characteristics of the species.

Unpublished expert datasets formed a key evidentiary component of this assessment, including long-term research from H. Stoetzel’s PhD project (unpublished), targeted Carpentarian Grasswren monitoring surveys conducted by BirdLife Northern Queensland (unpublished), and field investigations undertaken on Chidna Station, Queensland, under a Threatened Species Grant (Conservation Partners unpublished). These datasets comprise

verified occurrence records, quantitative and qualitative habitat measurements, and behavioural observations collected by experienced personnel using standardised field methods.

Analysis undertaken as part of these projects included desktop assessment of vegetation mapping, occurrence records and published literature to identify potentially suitable habitat. Broad-scale National Vegetation Information System (NVIS) mapping for the Northern Territory was used, recognising its limited accuracy, while higher-quality Queensland Regional Ecosystem mapping was used in Queensland.

Species distribution modelling initially published in Stoetzel et al. (2020) was tested and refined using extensive field survey data prior to recalibration of subsequent models. Although the Tanumbirini record lies marginally outside the modelled extent, habitat suitability was inferred based on site context and the presence of key environmental attributes associated with the species' persistence, including the continuity of suitable lithology and topographic complexity.

Habitat characteristics influencing Carpentarian Grasswren persistence—including vegetation composition, *Triodia* height and cover, lithology, topographic complexity, and fire history—were assessed using field-based methods and post-fire monitoring of known sites, including colour-banded populations. These analyses informed interpretation of habitat quality and resilience in relation to known ecological requirements of the species.

Spatial datasets were used to visualise and contextualise key habitat attributes, including fire history from the North Australian Fire Information (NAFI) database, geological and geomorphological datasets (Raymond et al. 2012, Amatulli et al. 2018, Amatulli et al. 2019), and species occurrence data from BirdData, eBird, the Atlas of Living Australia (ALA). Publicly available occurrence records were interpreted cautiously and primarily for contextual purposes, with greater evidentiary weight afforded to verified expert datasets.

1.5 Key findings

The occurrence of the Carpentarian Grasswren at Tanumbirini Station cannot be excluded on ecological grounds, based on current information, as habitat characteristics at the site are consistent with those known to support the species elsewhere within its range. However, substantial uncertainty surrounds the December 2024 record. In the absence of corroborating evidence, there is a high risk of misidentification, particularly given that the presence of several superficially similar species likely to occur at the site are not accounted for in the EMP.

Accordingly, this report recommends the implementation of a targeted verification program to resolve the status of the record. This should include call-playback surveys conducted by experienced observers familiar with the species' vocalisations and habitat use, and undertaken under appropriate seasonal and weather conditions. Such surveys are necessary to confirm or refute the presence of the Carpentarian Grasswren at Tanumbirini Station and to ensure that land management and regulatory decisions are informed by robust, evidence-based information.

2. Background information

2.1 Relevant Ecological Knowledge

The Carpentarian Grasswren (*Amytornis dorotheae*) is a rare, cryptic passerine endemic to the Gulf of Carpentaria region of northern Australia. The species is a highly specialised *Triodia* obligate species, occurring in open eucalypt woodlands with a ground layer dominated by spiny, hummock-forming perennial grasses of the genus *Triodia*. These habitats are most commonly associated with rocky, silica-rich lithologies and occur in a discontinuous arc extending from the Mount Isa region of north-western Queensland to the Borroloola region of the Northern Territory (Stoetzel et al. 2020). Siliciclastic lithologies, namely sandstone and meta-sandstone, combined with medium to high topographic complexity are apparently the best predictors of suitable habitat in addition to fire history (Perry et al. 2011, Stoetzel et al. 2020).

Suitable habitat is characterised by a sparse to moderately open tree canopy, typically dominated by one or more of *Eucalyptus leucophloia subsp. euroa*, *Corymbia dichromophloia* (syn. *C. capricornia*), *Eucalyptus herbertiana*, and *Eucalyptus miniata* (Harris and Stewart 2009, Perry et al. 2011, H. Stoetzel unpublished). Additional tree species may occur locally, particularly in areas influenced by riparian processes, fire refugia, run-on zones, or ecotonal transitions associated with changes in lithology (H. Stoetzel unpublished). A low to mid-storey shrub layer, frequently dominated by *Acacia* species, is also a common structural component of occupied sites (Harris and Stewart 2009, H. Stoetzel unpublished).

The Carpentarian Grasswren is strongly dependent on *Triodia* for foraging, nesting, and shelter from predators and environmental extremes (McKean and Martin 1989, Harris and Stewart 2009, Perry et al. 2011, Harrington and Murphy 2015, H. Stoetzel unpublished). Consequently, vegetation post-fire age is a key determinant of habitat suitability. Mature *Triodia* hummocks provide dense, structurally complex cover, and their consistent availability within territories appears necessary for sustained occupancy. Rates of *Triodia* growth and the development of protective structure may vary spatially in response to *Triodia* species composition, fire history, soil properties, hydrology, and climatic conditions (Rice and Westoby 1999, Armstrong and Garnett 2011, Armstrong 2012). As a result, precise age-class thresholds are difficult to define; however, habitat is generally considered to regain functional suitability approximately three years or more following fire, once sufficient hummock structure has redeveloped (Harrington and Murphy 2015). Older hummocks appear particularly important for concealing dependent juveniles during the period immediately following fledging, when vulnerability to predation is highest (H. Stoetzel unpublished).

Despite this dependence on mature *Triodia*, the species occurs in landscapes shaped by spatially heterogeneous fire regimes and is capable of utilising younger post-fire age classes for foraging and, in some cases, nesting, provided that patches of mature *Triodia* persist within territories (BirdLife Australia; H. Stoetzel unpublished). Accordingly, while *Triodia* age is an important factor, the spatial configuration and patchiness of fire history, and the resulting persistence of fine-scale refuges of long-unburnt vegetation, are likely to be more critical determinants of habitat quality than the most commonly observed post-fire age alone (Stoetzel et al. 2020).

Rocky substrates, including rock piles and outcrops containing deep crevices, provide an additional and critical refuge, particularly following extensive or high-intensity fire events (H. Stoetzel unpublished). Grasswren groups may persist within rocky refugia immediately post-fire; however, the retention and subsequent recovery of mature *Triodia* within surrounding habitat appears essential for longer-term population persistence (Conservation Partners unpublished). Thermoregulation is also likely to be an important component of the species' ecology in extreme heat conditions. Individuals utilise cooler microhabitats associated with trees, mature *Triodia* hummocks, and rocky features (e.g. shaded crevices and areas of late-afternoon shade), and have been observed drinking at waterholes, likely as a behavioural mechanism to mitigate heat stress (H. Stoetzel unpublished).

2.2 Detection and Survey Considerations

Detection probability is a critical consideration when interpreting both historical and contemporary records of the Carpentarian Grasswren. The Carpentarian Grasswren is inherently difficult to detect without the use of call playback. Individuals typically remain quiet and concealed within spinifex hummocks in the presence of observers. Detection without playback generally requires familiarity with the species' song and contact calls, as individuals often communicate vocally from within dense ground cover.

Home range mapping using colour-banding and radio-telemetry on Calton Hills Station, Queensland, recorded an average home range size of approximately 10.5 ha. Smaller ranges were observed during the wet-season breeding period (approximately 5–10 ha), followed by expansion to larger ranges (approximately 10–20 ha) once dependent young become mobile (H. Stoetzel unpublished).

Current monitoring programs employ a standardised survey protocol involving playback locations spaced at 200 m intervals along box-shaped transects with 600 m sides. Even under optimal conditions and in areas with high territory density, this method detects the species in approximately 72% of surveys, indicating that false absences are likely without repeat visits (BirdLife Australia unpublished).

The species is typically encountered in pairs or small family groups with up to six members. It is likely socially monogamous and may engage in cooperative breeding, consistent with patterns documented in other grasswren species (Karubian 2001; Gibson Vega 2022). The vocal repertoire is complex, comprising squeaks, whistles, and trills, as well as insect-like single-syllable contact calls. Vocal activity plays a central role in territory defence and is thought to peak during the breeding season, which follows sufficient rainfall and typically occurs during the November–March wet season.

Brief visual observations or short vocalisations may lead to misidentification, particularly by observers inexperienced with the species. Several sympatric species can superficially resemble the Carpentarian Grasswren, including the Kalkadoon Grasswren (*Amytornis ballarae*), Spinifexbird (*Poodytes carteri*), Purple-backed Fairywren (*Malurus assimilis*), and Red-backed Fairywren (*Malurus melanocephalus*). However, the Carpentarian Grasswren can be distinguished by its white throat, black sub-moustachial stripe, and strongly patterned upper-body plumage. Additional diagnostic features include coloured flank feathers and undertail coverts, which are yellow-buff in males and rich red-brown in females.

2.3 Threats

Inappropriate fire regimes represent the primary threatening process for the Carpentarian Grasswren, particularly large-scale, homogeneous wildfires that remove extensive areas of mature spinifex without leaving sufficient unburnt refuges. Predation impacts are likely to be most severe in the immediate post-fire period, when birds are displaced into smaller habitat patches and cover is reduced. Feral cats (*Felis catus*) are also present within grasswren habitat and are potential predators, especially of dependent young (Conservation Partners unpublished). Feral cats preferentially move along linear features such as tracks, creek lines, and fire scar boundaries, increasing predation risk in disturbed landscapes (Conservation Partners unpublished).

Land clearing and other human activities may directly remove critical habitat features and indirectly increase predation pressure and weed invasion at a local scale. The naturalisation of buffel grass (*Cenchrus ciliaris*), represents an additional emerging threat, due to its capacity to invade spaces between spinifex hummocks and promote more frequent, hotter, and more contiguous fires (Garnett 2021). Pollution and sedimentation of waterways potentially impact Carpentarian Grasswren if impacted watercourses are important for hydration-mediated thermoregulation (i.e. drinking behaviour associated with heat stress) as observed in Queensland (H. Stoetzel unpublished).

Natural wildfire refugia are often scarce and spatially limited within the landscape. These areas, buffered from fire impacts by topography or other environmental factors (e.g. rocky outcrops, drainage lines, and water sources), may have a disproportionate importance for population persistence (Perry et al. 2011, Stoetzel et al. 2020). Such locations may function as source populations following large-scale fire events and play a critical role in recolonisation of the broader landscape once conditions become suitable. Impacts to these refugial nodes are therefore likely to have consequences beyond their immediate footprint, and are therefore likely to warrant a higher level of protection under precautionary management frameworks.

Collectively, these ecological characteristics underscore the species' vulnerability to landscape-scale disturbance and the importance of fine-scale habitat structure and fire refugia in determining persistence.

3. Assessment of the 2024 Tanumbirini Record

3.1 Biogeographic Context of the Record

Based on published literature and verified occurrence datasets, the 2024 record in question is located approximately 100 km west of the historical Extent of Occurrence (EOO) of the most northern sub-population (Figure 1), commonly referred to as the Borroloola population (Harrington and Murphy 2015). Prior to the species' decline and apparent extirpation across much of its northern range, it is plausible that suitable habitat on Tanumbirini Station supported the species. Typical dissected sandstone-*Triodia* habitats occur on the property and are akin to, and partially contiguous with, habitat associated with proximal verified historical records from the Borroloola population (Figure 1).

A historical record dated 21 May 1999 from October Creek is listed in the Atlas of Living Australia database and associated coordinates place this record approximately 30 km southeast along the Carpentaria Highway from the 2024 record in question (Figure 1 & 2). However, the veracity and spatial accuracy of the October Creek record are uncertain. It is plausible that the observation originated 15-20 km downstream along October Creek, which would place it within more typical Carpentarian Grasswren habitat associated with more appropriate geology. This uncertainty likely explains its exclusion from verified datasets.

The 2024 record in question is also spatially separated from the more substantial ranges northeast on Tanumbirini Station, which are geomorphologically similar to the dissected sandstone habitats the species is known from in the NT. Nevertheless, low sandstone derived protrusions occur at the location of the record. These features form part of a distinct rocky breakaway following the margin of an elevated plateau. These landscapes support some vegetation communities with *Triodia*-dominated understories and are connected to the more substantial sandstone features to the north west where grasswrens would be more expected (Figures 1 & 2).

Such gentler, more undulating landscapes are not characteristic of habitats currently or historically occupied elsewhere in the Northern Territory, likely reflecting the combined effects of altered fire regimes and limited availability of fire refugia. However, such geomorphic and lithological configurations are consistent with known Carpentarian Grasswren habitat near Mount Isa in Queensland, where fire impacts are less. Close to Mount Isa they have been recorded 8-10km from significant exposed sandstone protrusions on more undulating habitats with rocky drainage lines (Beruldsen 1992).

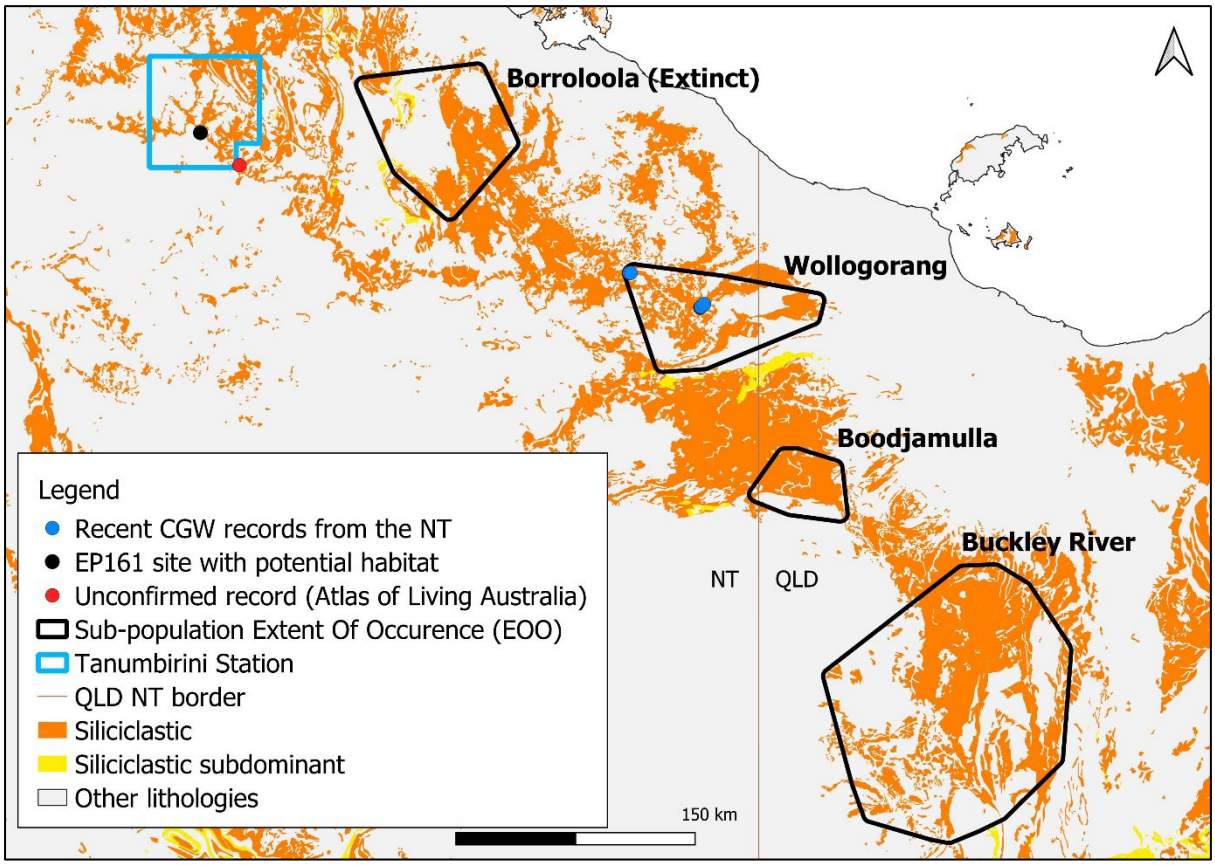

Figure 1: Map showing the distribution of silica rich lithologies (i.e., siliciclastic), a key determinant of suitable habitat for Carpentarian Grasswren. These habitats are present at the site and connected to formerly occupied habitats to the west. Lithology data were sourced from (Raymond et al. 2012).

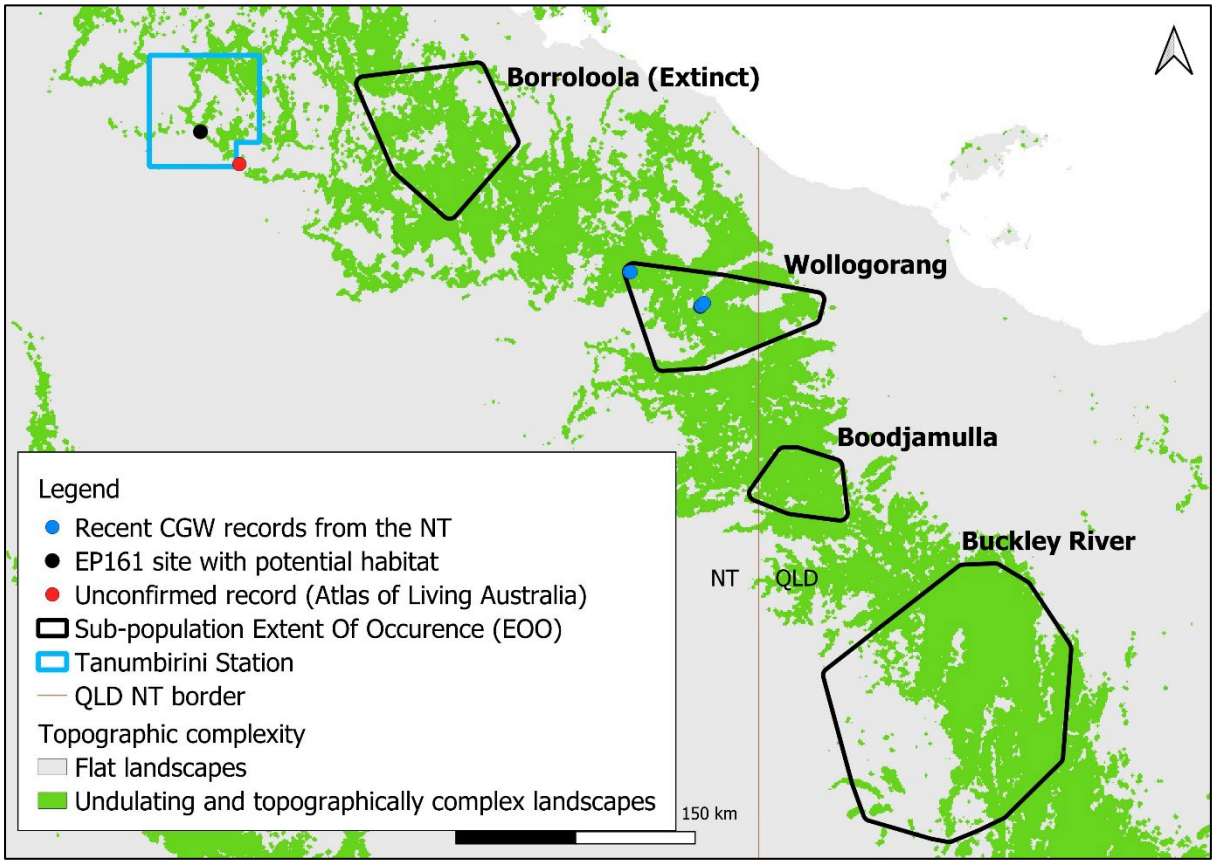

Figure 2: Map showing undulating and topographically complex habitats associated with Carpentarian Grasswren habitat. These habitats were defined according to the presence of landforms other than flat as detailed in (Amatulli et al. 2018). These landforms include peaks, ridges, shoulders, spurs, slopes, hollows, foot slopes, valleys, and pits.

3.2 Vegetation at the Site

The Environmental Management Plan (EMP) identified two vegetation communities at the site that align closely with known Carpentarian Grasswren habitat. Community 1a: *Corymbia dichromophloia*, *Eucalyptus leucophloia*, *Erythrophleum chlorostachys* mid–high open woodland. Community 1b: *Corymbia dichromophloia*, *Eucalyptus leucophloia*, *Erythrophleum chlorostachys* mid–high open woodland over *Acacia calligera* low shrubland.

Field data reported in the EMP indicate that the understory within both communities is dominated by *Triodia bitextura*, a species recognised as a nesting and foraging substrate for the grasswren (Harris and Stewart 2009, H. Stoetzel, unpublished). The overstorey is dominated by tree species commonly associated with the species' habitat, including *Eucalyptus leucophloia* and *Corymbia dichromophloia*, while the presence of sparse acacias

(*A. cowleana and A. calligera*) in the shrub layer represents another characteristic structural feature of suitable habitat. *Petalostigma pubescens* and *Terminalia canescens* were also recorded in the mid-story and are a known component of the species habitat elsewhere in their range (H. Stoetzel unpublished).

Importantly, *Triodia*-dominated communities at the site are interspersed with lancewood stands and rocky, sandstone-derived protrusions. This mosaic closely resembles habitat configurations documented in Queensland, where the species occurs in relatively narrow swathes associated with geological features of comparable form and lithology, including but not limited to monitoring sites on Flora Downs Station, Split Rock Station and Thorntonia Station (Harris and Stewart 2009, H. Stoetzel unpublished, BirdLife Australia unpublished).

Collectively, these vegetation characteristics are consistent with those documented at verified Carpentarian Grasswren sites elsewhere in its range.

3.3 Fire History at the Site

Fire history is a critical factor in assessing the likelihood that a remnant of the Borroloola population may have persisted at this location despite widespread declines elsewhere across the northern range. The only readily available fire history dataset for the area is derived from the North Australian Fire Information (NAFI) database. These data do not capture the fine-scale fire critical to Carpentarian Grasswrens persistence; however, they are suitable for assessing the broader landscape scale fire regimes. Conditions that would indicate suitability for Carpentarian Grasswren include infrequent fire and patchy fire as opposed to large-scale homogeneous fire. Another key indicator would be the presence of mature *Triodia* (i.e., >3-5 years since fire).

To assess fire regime suitability, NAFI data layers, including time since last fire, fire frequency, and late dry season fire frequency, were analysed in QGIS 3 and compared against habitat within the Borroloola population Extent of Occurrence (Figures 4, 5 & 6). In addition, vegetation structure measurements reported in the EMP were used as a proxy for post-fire age, given the strong relationship between *Triodia* height and time since fire.

The average *Triodia* height reported in the EMP was 50 cm and is consistent with habitat age classes known to be suitable for the species elsewhere (BirdLife Australia, H. Stoetzel, unpublished). This result also aligns with the NAFI-derived estimate of 7-9 years since fire at the site. The time since fire mapped within the Borroloola population was generally lower and less patchy than fire on Tanumbirini and the EP161 site, which contained a diversity of age classes including areas unburnt for more than 24 years. If these mature age classes and refuges indeed correspond with suitable *Triodia* habitats it is possible that the fire regime at this location is more conducive to Carpentarian Grasswren persistence than the habitats closer to Borroloola for example.

The presence of rocky features capable of acting as fire refugia would further increase the likelihood of persistence; however, detailed information on the availability and configuration of such refuges was not provided in the EMP and therefore cannot be assessed with confidence. Furthermore, fire frequency at the site, and the frequency of late season fires,

appears to be generally lower than at many historical locations across the Northern Territory especially sites close to Borroloola (Figures 4, 5 & 6).

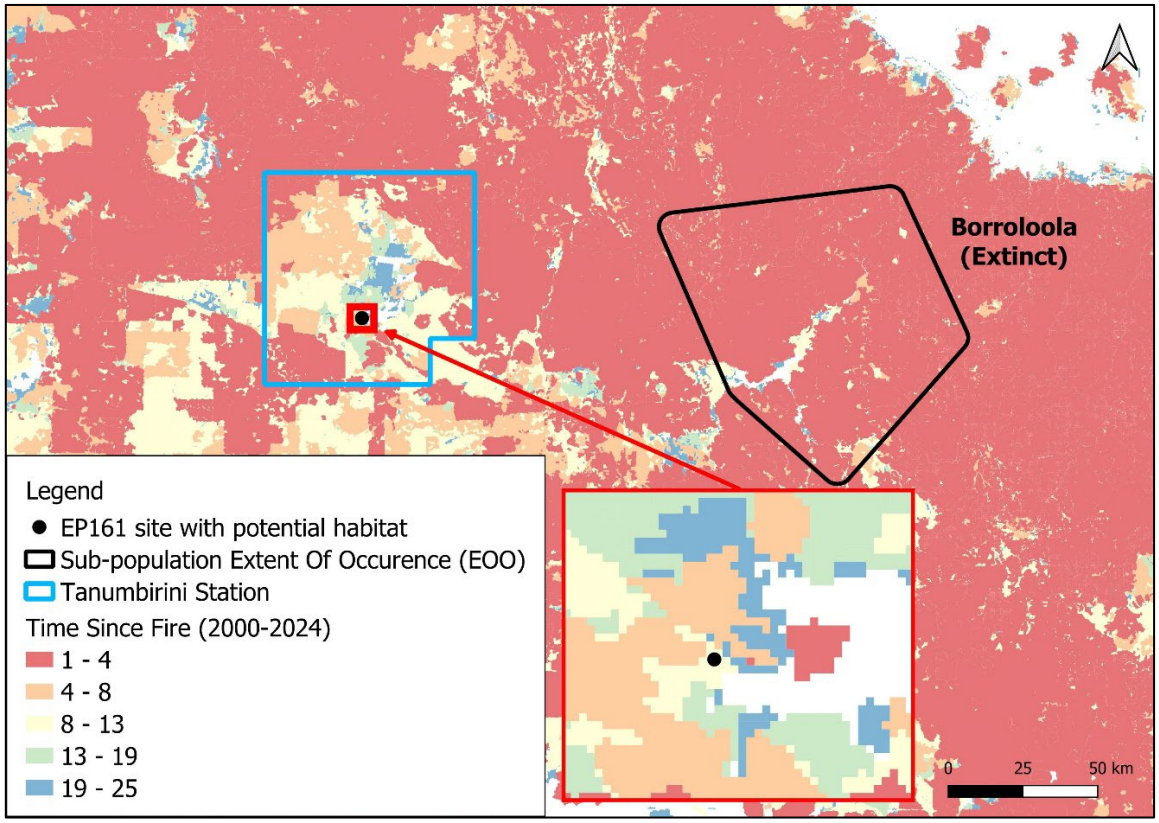

Figure 4: Time since fire layer downloaded from NAFI shows that the Tanumbirini has sufficiently mature age classes, and a diversity of age classes in a patchy configuration. This contrasts with conditions within the Borroloola sub-population Extent of Occurrence which are mostly 1-4 years since burnt.

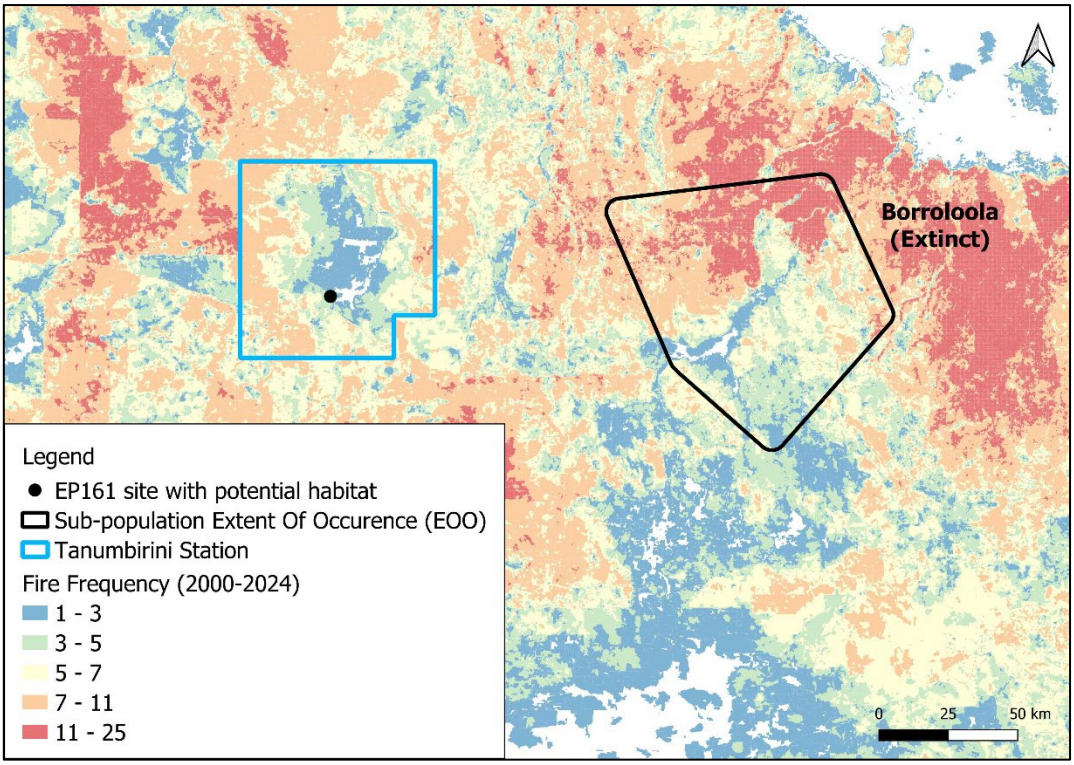

Figure 5: Fire frequency layer downloaded from NAFI shows a generally lower fire frequency at the Tanumbirini site as opposed to higher fire frequencies observed within the Borroloola population.

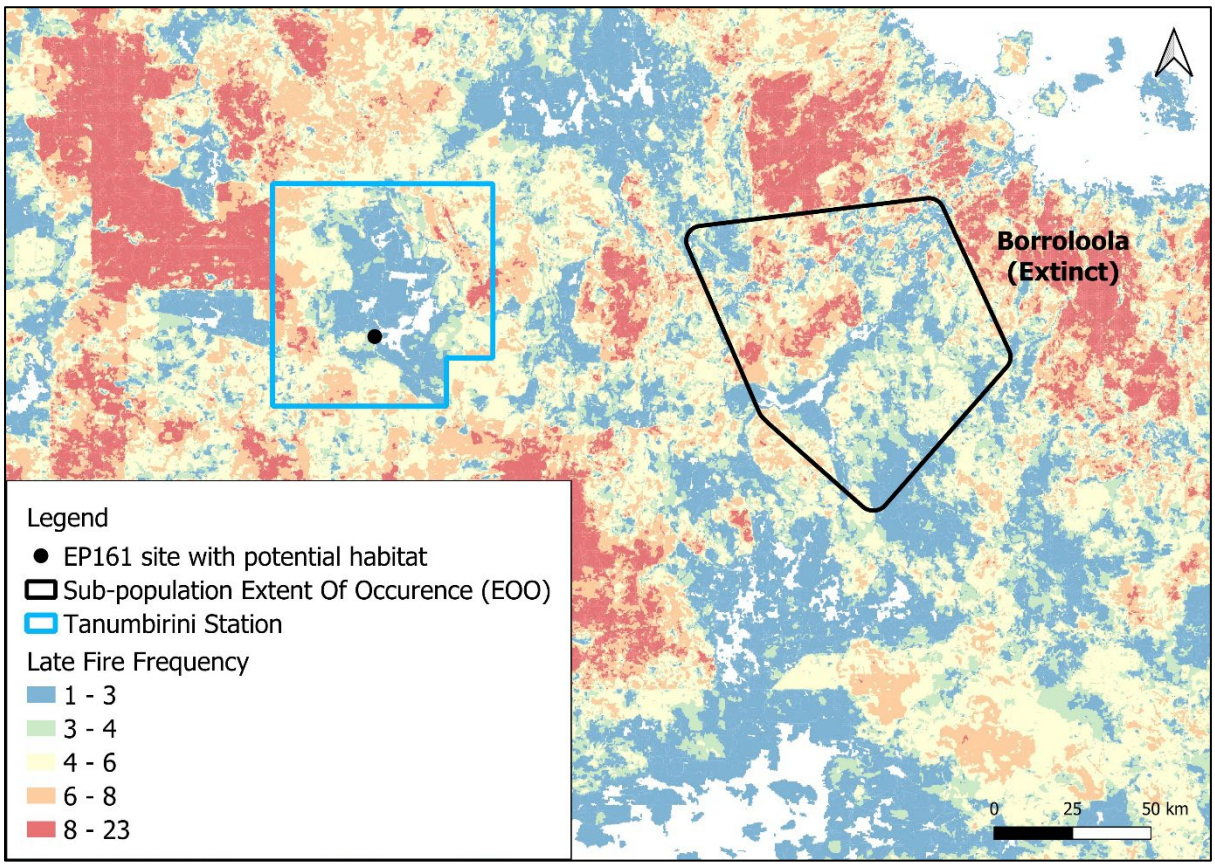

Figure 6: Late fire frequency layer downloaded from NAFI depicts the number of fires that occurred in the late half of the year between 2000 and 2024 and suggests the Tanumbirini site is also associated with relatively few late season fires.

In combination, biogeographic context, vegetation structure, and fire history indicate that suitable habitat is present at the site, while substantial uncertainty remains regarding current species occupancy.

4. Conclusions and Recommendations

4.1 Likelihood of Occurrence

Based on the available evidence, the occurrence of the Carpentarian Grasswren (*Amytornis dorotheae*) at Tanumbirini Station remains possible but unconfirmed. Analysis of the site's location, habitat characteristics, and fire history indicates that conditions are broadly consistent with those known to support the species elsewhere within its range. However, confirmation of the species at this location would be unexpected given it is approximately 100 km from any known historical records, the species' apparent extirpation from the surrounding region since the 1990s, and the absence of recent verified records from the northern extent of its former range.

The conservation implications of a confirmed occurrence would be significant. If present, the Tanumbirini population could represent a remnant of an otherwise extirpated northern population and may function as a critical wildfire refuge. Conversely, it remains possible, and perhaps more likely, that the December 2024 record reflects a misidentification, particularly in the absence of high-veracity supporting evidence. No detailed description of the observation, photographic documentation, audio recordings, or diagnostic field notes was provided, limiting the capacity to assess the reliability of the record.

Several species may be confused with the Carpentarian Grasswren under brief or suboptimal observation conditions. Superficially similar species do not appear in the Environmental Management Plan (EMP) species list, and fairywrens of the genus *Malurus* almost certainly occur at the site. In particular, Red-backed Fairywren (*Malurus melanocephalus*) and Purple-backed Fairywren (*M. assimilis*) are both regionally common and to the untrained observer can be difficult to distinguish when not in breeding plumage, or when identification is based on call. Given that fairywrens are also members of the family Maluridae and are far more likely to be encountered during standard fauna surveys than the highly cryptic Carpentarian Grasswren, it is plausible that a fairywren species was observed and incorrectly attributed to the genus *Amytornis*.

4.2 Conservation Significance

Before impact assessment and mitigation strategies can be meaningfully developed, it is essential to determine whether the Carpentarian Grasswren is present and, if so, whether additional groups persist within the surrounding landscape. Should the species be confirmed within EP161, this occurrence would likely meet the definition of a "critical occurrence of a threatened species" under Section 8.4.1 of the Scientific Inquiry into Hydraulic Fracturing in

the Northern Territory (Pepper Inquiry) Final Report. This designation would be justified on the basis that the population would represent a remnant of an apparently extirpated northern population and may constitute an important refuge from wildfire impacts. In such circumstances, identifying the spatial extent of occupancy and the location of additional groups would be critical to informing tailored, population-level management.

4.3 Implications for impact Assessment

The proposed works have the potential to impact the Carpentarian Grasswren, if present, through direct and indirect mechanisms including clearing of suitable habitat, disturbance from noise and activity, degradation of water quality, increased predation pressure from feral cats, and the introduction or spread of invasive weeds. Fire also represents a substantial risk; accidental ignitions or inappropriate fire regimes could result in extensive loss of mature spinifex habitat.

The species has also been observed drinking from water sources, likely as part of hydration-mediated thermoregulation during periods of extreme heat. While the extent to which reliance on local water sources influences population viability remains uncertain, project activities that modify or degrade natural water sources could represent an additional impact if the species occurs at the site. This potential impact pathway remains poorly understood and would require further investigation should the species be confirmed.

4.4 Recommended Next Steps

The primary recommendation of this report is the implementation of a targeted verification program. This should comprise call-playback surveys conducted by experienced observers, using a standardised protocol and repeated site visits under appropriate seasonal and weather conditions. Such surveys are necessary to confirm or refute the presence of the Carpentarian Grasswren and to determine the appropriate next steps for impact assessment, mitigation planning, and regulatory decision-making.

If the species is confirmed, a site-specific fire management program designed to retain suitably sized patches of mature *Triodia* across the landscape would be required to buffer the effects of wildfire. The extent to which the proposed works may impact the species cannot be determined with confidence until targeted verification surveys are undertaken.

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6. Expert Witness Declaration and Statement of Compliance

I, Henry J. Stoetzel, of Conservation Partners, 98 Landry Road, Malanda, Queensland 4885, Australia, state as follows.

I am the primary author of this report and the expert witness responsible for the opinions expressed herein. As part of Conservation Partners policy, a final peer review was conducted by colleague Nick Leseberg. The opinions contained in this report are my own and are based on my professional expertise, experience, and analysis of the available evidence.

I acknowledge that I have read the relevant Expert Evidence Code of Conduct and agree to be bound by it. I understand that my paramount duty is to the Court, not to any party to the proceedings.

I am a conservation ecologist specialising in threatened avifauna, fire ecology, and habitat assessment in northern Australia. I have extensive experience researching the Carpentarian Grasswren (Amytornis dorotheae), including long-term field studies, spatial habitat modelling, and post-fire monitoring across Queensland and the Northern Territory. I completed a Bachelor of Science majoring in ecology and zoology followed by an Honours in geographical sciences. Now PhD candidate I began work on Carpentarian Grasswren in 2017 and have been conducting intensive research on the species since 2019.

The opinions expressed in this report are based on the assumptions and material facts set out in the report, including information contained in the Environmental Management Plan, published scientific literature, spatial datasets, and unpublished expert datasets. Where information was incomplete or unavailable, this has been explicitly identified and considered in a precautionary manner.

The reasons for my opinions are provided throughout the report and are supported by peer-reviewed scientific literature, government datasets, spatial analyses, and unpublished expert research, all of which are cited in the References section.

Where questions fall outside my field of expertise, including legal interpretation, regulatory decision-making, or engineering assessments, no opinion is offered.

This report relies on desktop analyses, review of existing survey data, spatial analyses, and prior field investigations undertaken by qualified ecologists, including myself. No new field surveys were conducted specifically for this report unless stated otherwise.

Where I have relied on the opinions or data of other experts, including unpublished datasets from BirdLife Australia and collaborative research with other ecologists, this reliance is identified and acknowledged in the report.

I declare that I have made all inquiries that I believe are desirable and appropriate for the purposes of this report which are detailed in the Expert Brief included as an annexure at the end of this report, and that no matters of significance which I regard as relevant have, to my knowledge, been withheld from the Court.

The opinions expressed in this report are subject to the qualifications, limitations, and uncertainties identified within the report, particularly in relation to the absence of diagnostic evidence confirming species identification.

Where opinions are not concluded, this is due to insufficient data, including the absence of photographic, acoustic, or repeat-detection evidence. These limitations are clearly stated in the report.

Given the length and complexity of the report, a brief summary of key findings is provided at the beginning of the report.

I confirm that this declaration is true and correct to the best of my knowledge and belief.

Signed:

Henry J. Stoetzel

Date: 19 December 2025

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EXPERT BRIEF

CONFIDENTIAL AND LEGALLY PRIVILEGED

Date: 12 December 2025

To: Henry Stoetzel
Conservation Partners
University of Queensland

By e-mail only: henry.stoetzel@conservationpartners.org.au; h.stoetzel@uq.net.au

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ENVIRONMENT CENTRE NT

SANTOS – BEETALOO BASIN APPRAISAL PILOT EMP

From: Johnson Legal
Level 21, 8 Chifley Square
SYDNEY NSW 2000

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THE LAW SOCIETY OF NEW SOUTH WALES PRO BONO SCHEME SUPPORTER 2025

THE LAW SOCIETY OF NSW PROFESSIONAL STANDARDS SCHEME

Dear Henry

Environment Centre NT (ECNT) – Santos QNT Pty Ltd Beetaloo Basin Appraisal Pilot Environment Management Plan (EMP)

1. We confirm that we act for ECNT in the above matter, who wish to provide submissions in relation to the EMP currently under assessment with the Northern Territory Government.

2. We wish to brief you to provide a preliminary expert report for ECNT in relation to the likely environment impacts and risks associated with the carrying out of the Project, within your scope of expertise.

The EMP

3. As part of the assessment process, the EMP was published for comment on 21 November 2025.

4. Comments on the EMP will close on **19 December 2025.**

5. The key documents subject to assessment are linked below:

    a. EMP currently open to comment and relevant appendices, including:

    - Appendix A-K - Summary of Approved Regulated Activities
    - Appendix L – Cultural Heritage Assessment
    - Appendix M - Emergency Response Plan – Mcarthur and Ameadeus Basins

The Project

6. Santos is an Interest Holder and operator of Exploration Permit (**EP**) 161 located in the Beetaloo Basin, approximately 350 kilometres south-east of Katherine in the Northern Territory.

7. Santos proposes to drill and test petroleum appraisal wells across two locations within EP 161, collectively referred to as the Beetaloo Appraisal Pilot.

8. The subject EMP covers the installation of up to twelve new petroleum appraisal wells at two separate well pads within EP 161. Some of the proposed activities include:

    a. Clearing and earthworks for 2 new well pad locations – The clearing and construction to create two new well pads and ancillary infrastructure at well pad locations referred;

    b. Drilling up to 12 appraisal wells, either vertical or horizontal well types;

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c. Operating, testing, maintenance and decommissioning and hydraulic fracture stimulation of up to 12 appraisal wells;

d. Wastewater management – each well pad will include evaporation tanks, storage tanks, drilling sumps, cutting pits and any transfer infrastructure within the well pad. This also includes transportation onsite and disposal of these wastes (unless otherwise approved for reuse or burial).

9. The approval criteria are set out in reg 9 of the *Petroleum (Environment) Regulations 2016* (**the Regulations**) and include that the EMP must demonstrate that the Project will be carried out in a manner by which the environmental impacts and environmental risks will be reduced to a level that is 'as low as reasonably practicable' (ALARP) and 'acceptable'.

10. In determining whether or not to approve the EMP, the Minister must consider whether the EMP for the Project should be approved pursuant to the *Petroleum Act 1984* and the Regulations and if so, on what conditions.

Your brief

11. We request that you:

a. Provide an expert report for ECNT by **16 December 2025** in relation to:

i. The likelihood of occurrence for the Carpentaria Grasswren (identified in site surveys as *Amytornis sp.* as found in Appendix J to the EMP) at the proposed site on EP161 and significance of this habitat. This would include your assessment of the likelihood of any risks identified and the impacts and consequences if those risks crystallise;

ii. Whether the species in the area is likely to be impacted by relying on local water sources;

iii. Whether there is potential for the occurrence of the Carpentaria Grasswren on the EP161 site to represent a "critical occurrence of threatened species" as per section 8.4.1 of the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (Pepper Inquiry) Final Report in the context of species population trends;

iv. Any recommended conditions or recommended amended conditions for the EMP to ameliorate the impacts and risks you have identified above. This aspect should address the degree to which the EMP and proposed works meet the standards set by legislation and the standards recommended by the Pepper Inquiry.

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12. We ask that you prepare your opinion in accordance with the NT Supreme Court's Practice Direction No. 6 of 2015 – Expert Reports.

13. We note that under the Practice Direction, 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.

Your fees

12. Please provide us with an estimate of your fees for carrying out this work at your earliest convenience.

Yours faithfully
Johnson Legal Pty Ltd

Matt Floro
Principal Lawyer

Encl.

INDEX TO BRIEF

An index to the materials briefed is below. A copy of the annexures is contained at this Dropbox link.

No.	Document	Date
1	Beetaloo Basin Appraisal Pilot Environmental Management Plan	November 2025
2	Appendix A-K	November 2025
3	Appendix L	November 2025
4	Appendix M-P	November 2025

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Expert Report

Professor Grant Hose

School of Natural Sciences

Faculty of Science and Engineering

MACQUARIE UNIVERSITY NSW 2109

Australia

19 December 2025

Qualification and Experience

1. I hold a PhD from the University of Technology Sydney ('UTS'), for studies on the impacts of pesticides to stream invertebrate communities.
2. I hold a Bachelor of Science (Honours 1st Class) from UTS. My honours thesis investigated impacts of motor vehicle emissions on spider populations in Jenolan, Abercrombie and Wombeyan Caves, NSW.
3. A copy of my curriculum vitae is annexed as Appendix A.
4. I am currently employed as a Professor in the School of Natural Sciences and Faculty of Sciences and Engineering at Macquarie University.
5. Prior to my employment at Macquarie University, I was employed as a Postdoctoral Research Fellow in the Department of Environmental Sciences and Institute for Water and Environmental Resource Management at UTS.
6. Prior to my employment with UTS I was employed by the New South Wales Environment Protection Authority between January 2000 and October 2002. During this time, I was employed as an Environmental Scientist working on the research and development of Australian River Assessment System ('AUSRIVAS') river health program.
7. I have been author or co-author on over 150 scientific publications in peer-reviewed journals and more than 20 consultancy reports and assessments.
8. I have experience in ecotoxicological assessments of mine waters, pesticides and metals, including complex chemical mixtures, on freshwater ecosystems.
9. My current research focus is to understand the structure and functioning of surface water and groundwater ecosystems and their response to environmental change, including contamination and groundwater drawdown.

Expert Witness Code of Conduct

10. Prior to the preparation of this report I have read NT Supreme Court's Practice Direction No. 6 of 2015 – Expert Reports (Practice Direction). I have prepared this report in accordance with those Rules and agree to be bound by those Rules in relation to my evidence.

Background

11. On 12 December 2025, I was engaged by Johnson Legal, on behalf of Environment Centre NT (ECNT), to provide an expert report on the Environment Management Plan

(EMP) that has been prepared as part of the Santos – Beetaloo Basin Appraisal Pilot Program (Program).

Scope of work

12. I was engaged by Johnson Legal, on behalf of Environment Centre NT (ECNT), to provide an expert report in relation to the environmental impacts and risks (specifically, regarding ecotoxicological impacts and risks) associated with the Program and the carrying out of the Program.

13. I was engaged by Johnson Legal to provide an expert report in relation to:
    13.1. The environmental impacts and risks (specifically, regarding wastewater spills and risks in respect of inter-aquifer connectivity) associated with the Project and the carrying out of the Project. This would include your assessment of the likelihood of any risks identified and the environmental impacts and consequences if those risks crystallise; and
    13.2. Any recommended conditions or recommended amended conditions for the EMP to ameliorate the environmental impacts and risks you have identified in (i). This aspect should address the degree to which the EMP and proposed works meet the standards set by the legislation and the standards recommended by the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (Pepper Inquiry).
14. A copy of the letter of engagement dated 12 December 2025 is provided in Appendix B.
15. I have been provided with documents that are detailed in the attached letter of engagement.

My opinion

16. The proposed Program poses substantial risk to subterranean aquatic ecosystems in the vicinity of the development and these risks have not been adequately characterised and mitigated by the strategies outlined in the EMP.
17. The *Petroleum (Environment) Regulations 2016* (NT) Reg 9 (1) requires that the Environment Management 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'

18. I do not consider that the EMP demonstrates that the environmental impacts and risks of the Program will be reduced to a level that is acceptable. I consider this because the EMP does not adequately address how the requirements of Code of Practice: Onshore Petroleum Activities in the Northern Territory (NT Government 2025) are met.
19. The EMP does not adequately assess the risks to groundwater ecosystems because 1) the groundwater ecosystems at the development location have not been adequately characterised and 2) the risk to the environment from contamination due to leakage and/or spillage of chemicals and chemical mixtures both above and below ground have not been adequately assessed and mitigated.
20. The EMP risk assessment (Appendix O) does not explicitly address the impacts of well failure.
21. The EMP risk assessment (Appendix O), based on the risk matrix (EMP p133), assesses the risk of contamination arising from abandoned or suspended wells.
22. Risks #13 and #14 of Appendix O relate to contamination of aquifers.
23. The initial assessment of Risks #13 and #14 of Appendix O identifies those risks as being Low (L) and (M), respectively.
24. The residual risk for Risks #13 and #14 of Appendix O following the implementation of control measures is considered Very Low (VL).
25. I disagree with the initial assessment of risk of activities that could cause aquifer contamination as being ‘Low’ (EMP Appendix O p2).
26. Assessing the risk of the development requires analysis of the likelihood of an event and the consequences of that event (as per the risk matrix of the EMP (p133)).
27. Based on the risk matrix of the EMP (p133), activities with consequences that cause ‘Extensive’ or ‘Irreversible’ impacts to the environment must have a risk rating of ‘High’ or ‘Very High’ based on the likelihood of those events being ‘Occasional’ or ‘Possible’ (Appendix O p2).
28. In my opinion, the consequences of leaks and/or spills arising from the Program, where those leaks and/or spillages enter surface or subsurface waterbodies (aquifers) could be ‘Extensive’ or ‘Irreversible’, as defined in the risk matrix (EMP, p133).
29. I consider that the impacts of aquifer contamination would be ‘Extensive’ or ‘Irreversible’ because once contaminated, it is difficult to remediate an aquifer back to its pre-contamination state. The removal of chemical contaminants from aquifers can be costly, slow, cause further environmental harm and be difficult to achieve completely. The ecological restoration of aquifers following clean-up is challenging. I am not aware of projects that have successfully restored groundwater ecosystems following groundwater remediation.

30. In my opinion, contamination of an aquifer could be ‘extensive’, and cause ‘long-term’ to ’permanent’ or ‘partially reversible’ damage to the environment. The consequences of the contamination would be considered ‘Very High’.
31. I consider that the consequences could be ‘Catastrophic’ because:
    31.1. The remoteness of the activities and the extremes of weather in the region may mean there is a delay in response to major spills and/or leakages.
    31.2. The large volumes of the chemicals used.
    31.3. The high toxicity of the chemicals to humans and to the environment.
    31.4. The dependence on remote communities on the Cambrian Limestone Aquifer (CLA) and Gum Ridge Formation (GRF) Aquifer as a water supply. The GRF is a limestone aquifer that is part of the CLA.
    31.5. The dependence of surface and subsurface ecological communities on surface and subsurface environmental waters, in particular the CLA, in the arid zone.
    31.6. The impacts could be extensive. The location of the proposed development in the top portion of the CLA in terms of its environmental flow path, meaning that there is a large area of the aquifer ‘downstream’ that could be contaminated by leakages and/or spillages.
    31.7. The impacts could be long-term or permanent. Remediating contaminated aquifers takes a long period of time (years to decades) to reduce contaminant concentrations to guideline concentration levels, and even longer to remove contaminants to pre-contamination levels (e.g., Jain, 2023, Yuan et al., 2024). The process of remediation may cause further environmental impacts.
    31.8. The impacts could be irreversible. It is unlikely that a contaminated aquifer can be returned to pre-contamination state in terms of its water quality, biodiversity and ecological function.
    31.9. The costs of groundwater remediation could exceed $100 million (as per V of the risk matrix of the EMP (p133)).
    31.10. The current risk assessment for the project has underestimated the risks of its activities. Consequently, the residual risks of those activities may also be underestimated and must be reassessed.

Adequacy of the Environmental Management Plan (EMP)

32. Appendix D of the EMP relates to chemical risk assessment.
33. The chemical risk assessments consider the risks of individual chemicals on receiving waters.

34. The EMP does not consider the risks posed by the release of drilling fluids, hydraulic stimulation fluids, flowback waters, produced waters and other solutions into groundwater that could arise from well failure or leakage.
35. It is common during drilling that there is partial or total loss of drilling fluid to the surrounding aquifer due to high permeability conduits, fractures and cavernous zones expected in karstic formations (Tamboran Resources 2024). This means that it is 'common' that the surrounding aquifers may be contaminated by drilling fluids.
36. The chemical risk assessment (Appendix D) does not specifically address the impacts of drilling or other fluids to groundwater ecosystems.
37. Given that the release of drilling fluids to the CLA is likely, and that the Chemical Risk Assessment does not adequately address the impacts of drilling and other fluids to groundwater ecosystems, the current chemical risk assessment as outlined in Appendix D of the EMP fails to adequately address all risks of the Program to the environment.

Recommendation 1: That the chemical risk assessments outlined in Appendix D of the EMP be revised to consider the entry of drilling fluids, hydraulic stimulation fluid and flowback waters into aquifers and the impact of that event on groundwater ecosystems.

Risk posed by chemicals used in Program

38. The risk for chemicals used in the proposed development are assessed in Appendix D of the EMP.
39. The environmental risk posed by chemicals used and stored on site has been assessed for each chemical individually and has not considered the combined effects of those chemicals.
40. The drilling fluids, hydraulic stimulation fluids, flowback waters, produced waters and other solutions used on site are complex mixtures that contain many different chemicals, including metals, organics, and naturally occurring radioactive materials (NORMs) derived from the shale formation itself.
41. Flowback and produced waters are often highly saline and have a composition that is influenced by the chemicals added, the operating conditions, location, geology and hydrocarbon type (Chang et al., 2019).
42. Detailed information about the chemicals used during drilling is provided in the Chemical Risk Assessment (Appendix D) which includes the Safety Data Sheets (SDS) and relevant hazard assessment as required by CoP– Well Integrity. The report states that it is not necessary to use all these additives for every hole and specific additives are selected for each well.

43. This suggests that the fluids used in each well may differ. The likely solutions to be used in each well are not provided. Therefore, the toxicity of those solutions cannot be assessed. The EMP is therefore deficient in identifying and assessing the risks of all chemicals.
44. When toxic chemicals are mixed, the effects of the mixture may be greater than, less than or equal to the summed toxicity of the constituent parts.
45. Mallants et al. (2022) state that flowback waters from shale gas wells in the Beetaloo Basin are complex mixtures and that assessing the hazards of such waters by considering only the individual chemicals will likely underestimate the risks associated with a potential leak or spill of those waters.
46. Mallants et al. (2022) recommend the use of direct toxicity assessment (DTA) to characterise the toxicity of flowback waters. They showed that the dilutions required to achieve safe environmental concentrations in the event of a spill or leakage of flowback water from a storage were at least 1.8 times greater when informed by DTA than when based on individual chemicals.
47. Golding et al. (2022) showed that the toxicity of flowback water from shale gas wells in the Beetaloo sub-basin was chronically toxic to eight freshwater species and that a large part of the toxicity was due to unidentified chemicals and interactive effects from the mixture of organic and inorganic chemicals and radionuclides (NORMs) in the water.
48. Golding et al. (2022) cite a number of studies that demonstrate cellular, whole-organism, behavioural and/or developmental impacts of shale gas flowback waters on aquatic biota.
49. Willems et al. (2023) showed that chemicals used in shale gas operations were more toxic as a mixture than when used alone.
50. Warne and Hawker (1995) demonstrated experimentally that the toxicity of a mixture approaches additivity (i.e., is more likely to reflect the summed toxicity of the parts), as the number of chemicals in a mixture increases.
51. In my opinion, it is reasonable to expect that the toxicity of solutions that are complex mixtures, such as the hydraulic stimulation fluids, flowback waters, produced waters and other solutions used in or generated by the Program, will reflect the sum of the toxicities of the constituent parts (i.e., the toxicity will be additive). This means that the toxicity of those solutions may be far greater than the toxicity of the individual components.
52. The EMP shows that many of the individual chemicals used in hydraulic stimulation fluids, flowback waters, produced waters and other solutions are present at concentrations greater than the predicted no effect concentration (PNEC) and therefore have potential to cause harm to the environment if spilled or otherwise released.

53. Currently the EMP does not consider the ecological risk of the mixtures. This means that the ecotoxicological risk posed by the hydraulic stimulation fluids, flowback waters, produced waters and other solutions is likely underestimated and has not been adequately characterised.
54. In addition to the toxicity of the mixture components, the salinity of the hydraulic stimulation fluids, flowback waters, produced waters and other solutions is likely to cause harm to groundwater and surface water ecosystems.
55. Flowback and produced waters are often highly saline (Chang et al., 2019) and the salinity of these solutions may increase where those solutions are stored in evaporation ponds (Willems et al., 2022).
56. Salinity is a measure of the quantity of dissolved salts in a solution. Salinity may be measured as the total amount of dissolved solids (salts) dissolved in a solution. This is referred to as the concentration of total dissolved solids (TDS).
57. The salinity of the hydraulic stimulation fluids, flowback waters, produced waters and other solutions is likely to exceed the levels that are toxic to aquatic fauna.
58. Willems et al. (2022) reviewed international studies and concluded that saline produced waters from onshore unconventional gas activities are acutely toxic to freshwater invertebrates.
59. Willems et al. (2024) have shown that saline produced waters from onshore unconventional gas activities are toxic to freshwater invertebrates and may cause intergenerational effects even when diluted 800-fold.
60. Golding et al. (2022) showed that saline flowback water from shale gas wells in the Beetaloo Basin was chronically toxic to eight freshwater species from surface waters.
61. Laboratory studies have shown that salinity is acutely toxic to groundwater invertebrates (stygofauna). The concentrations of salt (NaCl) that killed 50% of the test populations within 96 h ranged between 1670 and 7350 mg/L (Castano-Sanchez et al., 2020). The concentrations of NaCl in that study are a slight underestimate of the concentrations of total dissolved solids.
62. In Queensland, unidentified species of stygofauna have been reported living at salinities of 22500–32500 mg/L of dissolved solids (Schulz et al., 2013) suggesting considerable variation in the sensitivity of stygofauna to salinity.
63. Studies referred to in paragraphs 61 and 62 are based on saline waters in which NaCl is the dominant salt. It is well established that the ionic composition of saline waters is critical to their toxicity (Zalizniak et al., 2006), and NaCl mixtures are typically less toxic than other salts (Hills et al., 2019; Rath et al., 2016).

64. Given the uncertainty in the sensitivity of stygofauna to salinity in general and to the complex saline flowback water, it is advisable that the toxicity of those waters be tested to inform risk assessment.
65. The Code of Practice: Onshore Petroleum Activities in the Northern Territory, Section B.5.1 (p72) lists the maximum concentrations of BTEX compounds in drilling and stimulation fluids. There are limited data available on the toxicity of BTEX to subterranean ecosystems. Available data suggest that the proposed limits of individual components are of the magnitude that would be unlikely to cause acute effects to groundwater biota (Avramov et al., 2013). However, the combined toxicity of BTEX mixtures to groundwater organisms is uncertain.

Recommendation 2: That the effect of relevant mixtures of chemicals used in the Program be tested in the EMP to determine their toxicity to aquatic biota. This should be done using direct toxicity assessment (DTA) and include the various drilling fluids, hydraulic stimulation fluids, flowback waters, produced waters and other solutions.

Knowledge and assessment of subterranean aquatic ecosystems

66. The Pepper Inquiry Report Recommendation 7.20 (p165) that *'the Beetaloo Sub-basin SREBA must identify and characterise all subterranean aquatic ecosystems',* emphasises the importance of identifying and characterising the subterranean ecosystems in the project area. While this recommendation places the emphasis for knowledge generation on the SREBA, there remains an obligation on the proponent to ensure that the knowledge of subterranean aquatic ecosystems at the project area is sufficient to adequately assess the risk to those ecosystems.
67. It is my opinion that current knowledge of subterranean aquatic ecosystems at and close to the project area is insufficient to adequately assess the risks posed by the Program.
68. The EMP rightly acknowledged the SREBA (Humphreys et al., 2022) and GISERA (Rees et al., 2020) reports that identified stygofauna and/or their DNA in the shallow aquifers of the region.
69. These reports did not specifically identify stygofauna in the study region, although did report the presence of the blind shrimp *Parisia unguis* in well RN006329, which is located 17 km from the project area. The surveys did not detect fauna in well RN029025, which is less than 1 km from Jibera South.
70. The proponents dismiss the importance of stygofauna, citing the absence of fauna in the closest a lack of suitable habitat for stygofauna in the study area (EMP p110).

71. The previous studies highlight the presence of stygofauna within 20 km of the project area. It is likely, based on previous studies (Oberprieler et al 2021), that *Parisia unguis* is distributed across the aquifer in areas beyond the wells in which it has been found.
72. In my opinion, it is likely that *Parisia unguis* occurs in the areas of the CLA that overlap with the project area.
73. The limited spatial and temporal sampling of stygofauna within or closer to the project area may miss unique or narrowly distributed taxa. If those taxa are limited to areas close to the project area, they could be significantly impacted by the Program.
74. Stygofauna typically have a patchy distribution and low abundance within an aquifer, which means that it may take several sampling occasions to detect stygofauna in a given bore (Hose & Lategan, 2012). My understanding from the EMP is that limited stygofauna sampling has been undertaken in the Project area, and that this level of sampling effort is not sufficient to reliably conclude the absence of stygofauna.
75. Current knowledge of subterranean GDEs and the sampling regime used to inform this EMP in relation to stygofauna is insufficient to characterise and hence protect subterranean ecosystems at the project site. In doing so, the EMP does not align with the intent of the Pepper Inquiry report to characterise and protect subterranean aquatic ecosystems.

Recommendation 3: A survey of groundwater biota be undertaken in the EMP with sampling sites in and close to the development area for the purpose of identifying the presence of any short-range endemic groundwater fauna that may be present in the study area and at risk from the Program.

Assessment of chemical risks to subterranean aquatic ecosystems

76. Currently, the chemical risk assessments are based on ecotoxicological data for surface water species. For example, the PNEC values for Hydrotreated Light Petroleum Distillate are based on data for *Daphnia magna* which is a small crustacean that typically lives in freshwater lakes in the northern hemisphere (Appendix D, Table 1 p10).
77. The use of surface water data for risk assessments that are applied to groundwaters assumes that surface water and groundwater species have similar sensitivities to chemicals.
78. Groundwater invertebrates may be more sensitive, less sensitive, or similarly sensitive to chemicals as surface water species depending on the chemical to which they are exposed (e.g., Hose, 2005, Di Lorenzo et al., 2019, 2023). This means there is

uncertainty as to whether data for surface water fauna are protective of groundwater fauna.

79. Given that well failure and leakage can reasonably be expected to provide a complete exposure pathway (i.e., a direct connection) for hydraulic stimulation fluids and flowback waters to enter aquifers, including the CLA, risk assessments that specifically consider groundwater fauna are needed, and these risk assessments should recognise the limitations of using surface water data to represent groundwater species where this is the case.

Recommendation 4: The risks of chemicals to subterranean fauna be considered in chemical risk assessments in the EMP, acknowledging the challenges of using ecotoxicological data for surface water species, and undertaking direct toxicity assessments of drilling fluids, hydraulic stimulation fluids and flowback waters to subterranean fauna as part of more robust chemical risk assessments.

Monitoring and protection of aquifers

80. In 2020, Santos identified the existence of the Inacumba Aquifer during the McArthur Basin 2019 Drilling Program (EMP ID No. STO2-5). This discovery is documented in the EMP modification documentation (https://environment.nt.gov.au/media/docs/onshore-gas/emp/pdf/ep161-santos-mcathur-basin/sto2-5-modification-1-regulation-23-new-inacumba-aquifer.pdf)
81. The Inacumba Aquifer is a water-bearing geological formation that sits below the Gum Ridge Formation. At the time of the EMP modification referred to in Paragraph 80, there was "*limited information available regarding the regional and stratigraphic extent of the Inacumba unit.*"
82. The Inacumba Aquifer is not identified in the geological stratigraphies provided in Figures 13 and 14, and Tables 19 and 20 of the Santos – Beetaloo Basin Appraisal Pilot Program EMP.
83. The Inacumba Aquifer is not considered in the description of well design and casing (EMP Section 3.7.2, Figure 12) in the Santos – Beetaloo Basin Appraisal Pilot Program EMP.

Recommendation 5: The presence or absence of the Inacumba unit at the study site must be thoroughly investigated. If present, measures to protect, manage and monitor the Inacumba Aquifer must be incorporated into the EMP prior to the commencement of any works.

84. Section 5.3.1 of Appendix I of the EMP (Surface Water and Groundwater Management Plan) outlines the plans for installing Control and Impact monitoring bores at the project site.
85. The Plan states that "*Control Monitoring Bores on Newcastle South will be constructed prior to well drilling, but may not be in place for a full six months before the well is drilled, but will be in place for at least six months prior to the first HFS activity at that location. This deviation from the guideline is deemed reasonable because weekly samples will be collected to accelerate the establishment of baseline conditions in the bore prior to drilling*." (EMP Appendix I p10).
86. This deviation from the guideline is not acceptable because reducing the duration of sampling prior to drilling will mean that sufficient baseline data are not collected. Collecting more samples over a shorter period (i.e., <6 months) means that important temporal; variation in groundwater conditions may be missed and that the baseline data collected may not be fully representative of conditions during that period.

Recommendation 6: The commencement of drilling on Newcastle South should be delayed until Control monitoring bores have been constructed and monitored for 6 months as per the Department of Natural Resources (2018) Preliminary Guideline: Groundwater Monitoring Bores for Exploration Petroleum Wells in the Beetaloo Sub-basin.

87. The Management plan indicates that one *Impact Monitoring Bore and Control Monitoring Bore will be installed for each discrete aquifer unit, which is screened near the top, middle and bottom of the vertical extent of that unit (or continuously as appropriate)* (EMP Appendix I p9).
88. The Management plan indicates that "*The monitoring bore array for each well pad will consist of a single Impact Monitoring Bore and Control Monitoring Bore for the Gum Ridge Formation and the Anthony Lagoon Beds, respectively*." (EMP Appendix I p9).
89. While this array of monitoring wells may align with the requirements of the relevant guidelines, it would be desirable to have a greater number of impact monitoring bores to have greater certainty that any impacts are not being missed. A single impact monitoring bore has the risk that changes in groundwater quality as a result of the Program activities are not identified because of complex groundwater flow paths that may bypass the monitoring bores.

90. Regarding Paragraphs 80-83 above, the groundwater monitoring program should be expanded to include the Inacumba Aquifer if this aquifer is identified as being present within the project area.

Recommendation 7: That multiple Impact Monitoring bores be constructed in each aquifer to increase the reliability of the monitoring program. Following further investigation, that the Inacumba Aquifer be included in the management plan and monitored if present within the project area.

91. Based on the observations outlined above, it is my opinion that the EMP does not align with the recommendations of the Scientific Inquiry into Hydraulic Fracturing in the NT final report (2018).
92. In my opinion, the EMP does not address the risks posed by the Program to the extent that the environmental impacts and risks of activities are reduced to a level that is as low as reasonably practicable or acceptable, as required by the *Petroleum (Environment) Regulations 2016* (NT).
93. The EMP has not adequately assessed the presence of stygofauna in and close to the project area.
94. The EMP does not adequately consider the risks to subterranean ecosystems and fauna caused by contamination that may occur as a consequence of the Program.
95. The EMP fails to recognise that well failure would lead to contamination of the surrounding aquifer(s). The chemical risk assessments do not consider the risks posed by such a scenario and as a result do not adequately characterise the environmental risks of the Program.
96. The EMP does not meet the Preliminary Guideline: Groundwater Monitoring Bores for Exploration Petroleum Wells in the Beetaloo Sub-basin, which requires monitoring of wells for six months prior to drilling.

I declare that this report represents my independent and impartial expert opinion, on matters relevant to my professional expertise, in line with the NT Supreme Court's Practice Direction No 6 of 2015 – Expert Reports and the expert witness code of conduct contained therein.

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Education

Mar 1996 – Mar 2000

Doctor of Philosophy
Centre for Ecotoxicology, University of Technology Sydney
Project Title: "*The effect of endosulfan on macroinvertebrate communities in artificial streams*". Supported by a LWRRDC Postgraduate Research Scholarship.

1990 – 1994

Bachelor of Science (Honours - 1st Class)
University of Technology Sydney
Thesis Title: "*The distribution of heavy metals, dust and other pollutants in the habitats of two species of cave spider*".

2006 – 2007

Graduate Certificate – Higher Education Teaching and Learning
University of Technology Sydney

2014

Certificate III in Business
Scouts Australia Institute of Training

Research and Professional Experience

Jan 2019 – (FT)

Professor
Head of School, School of Natural Sciences (Mar 2025- Dec 2025)
MQU Executive Sponsor, IATD (2021-2025)
Associate Dean, Innovation (2022-2025)
A/Deputy Dean, Research & Innovation (Aug-Nov 2022, Sept-Nov 2024, Feb 2025)
Associate Dean, Industry & Corporate Engagement (2019-2021)
Deputy Head, Department of Biological Sciences, (2018-2019)
Macquarie University

Oct 2013 – Dec 2018 (FT)

Associate Professor
Deputy Head of Department (2018-2019)
Program Director for Master of Research (2013-2019)
Department of Biological Sciences, Macquarie University

Jan 2008 – Oct 2013 (FT)

Senior Lecturer
Departments of Biological Sciences & Environment and Geography
Macquarie University
Teaching and research on invertebrate biology, river and groundwater ecology, ecotoxicology and management. Includes postgraduate supervision.

Aug 2005 –

Chancellor's Postdoctoral Research Fellow

Jan 2008 (FT) Institute for Water and Environmental Resource Management,
University of Technology Sydney
Research focus to value the ecosystem services of groundwater ecosystems.
Includes postgraduate supervision and lecturing within the Faculty of Science.

Oct 2002 – Aug 2005 (FT)

Research Fellow in Ecotoxicology
Institute for Water and Environmental Resource Management,
University of Technology Sydney
Conducting research in ecotoxicology and freshwater ecology, supervising research students, lecturing on freshwater ecology, ecotoxicology & data analysis.

Jan 2002 – Oct 2002 (FT)

Senior Project Officer (Monitoring and Reporting)
Beachwatch Programs, NSW Environment Protection Authority
Project Manager for the Beachwatch water-quality monitoring program including staff management and training, QA audits, data analysis and reporting, and community liaison.

Jan 2000 – Dec 2001 (FT)

Environmental Scientist
Water Science Section, NSW Environment Protection Authority
Research and development of AUSRIVAS for monitoring river health using macroinvertebrates. Involved designing, conducting and analysing ecological studies, use of spatial databases and GIS, and developing predictive models.

Mar 1999 – Dec 2001 (PT)

Lecturer
School of Mathematics and Sciences, Australian Catholic University
1st year Biology, Ecology and Data analysis

May 1996 – Jul 2006

Biologist/Ecologist
Jenolan Caves Scientific and Environmental Advisory Committee
Contracted to advise the management of Jenolan Caves on issues related to water quality and visitor impacts on cave and aquatic ecosystems.

Apr 1995 – Apr 1996 (FT) Apr 1996 – Dec 1999 (Cas)

Aquatic Ecologist
The Ecology Lab Pty Ltd
Project manager for research projects in marine, estuarine and freshwater ecosystems, requiring fieldwork, data analysis and report writing.

May 1999

Freshwater Ecologist
Assisting NSW Fisheries with artificial stream studies on cold-water impacts.

Feb – Mar 1998

Research Assistant
NSW EPA - Reviewing data for inclusion in ANZECC water quality guidelines.

Expert Witness Experience

Jan 2025

Environment Centre NT v Minister for Environment, Climate Change & Water Security
Expert advice relating to Shale Gas activities in the Beetaloo Basin, NT.

Jun 2018

North West Alliance Vs Santos
Expert advice relating to the Narrabri Gas Project Environmental Impact Statement (EIS) and Response to Submissions. For NSW EDO.

Nov 2015 - Mar 2017

4Nature Vs Springvale Colliery
Provision of expert evidence pertaining to the impacts of mining activity on upland swamps. For NSW EDO.

Nov 2015

NSW EPA Vs Clarence Colliery

-Mar 2017 Provision of expert evidence pertaining to the toxicity and ecological effects of coal fines in freshwater ecosystems.

Nov 2011 **Eurobodalla Shire Council Vs Minister for Planning and Infrastructure and**
May 2012 **Big Island Mining Pty Ltd**
Dec 2015 Provision of expert evidence pertaining to the toxicity and ecological effects of mine tailings water. Including review of modifications. For NSW EDO.

Nov 2009 **Stoneco P/L & Upper Hunter Shire Council Vs Newcastle & Hunter Valley Speleological Society**
Review of expert evidence pertaining to karst management and presence and significance of groundwater ecosystems.

Nov 2006 **DECC vs Cleary Bros.**
Technical confirmation of invertebrate identifications. Preparation of Affidavit
Expert advice on ecological effects of waste spill into streams.

Apr 2006 **Warringah Council vs Severino**
Preparation of Affidavit, attendance at court, response to Statement of Evidence of defence expert, relating to ecological effects of sediment pollution of streams.

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Book chapters and contributions

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Reports (since 2005)

Hose GC, Dabovic J, Korbel K (2025) Application of the Groundwater Health Index (GHI) as Water Monitoring Tool: Benchmarking and assessing groundwater ecosystems within the Darling-Baaka River catchment. Report to NSW DCCEEW. Macquarie University, Sydney.

Hose GC, McKnight K, Greenfield P, Chariton A, Korbel K. 2024. Bioassessment of groundwater ecosystems. III. A comparison of eDNA metabarcoding and metagenomics for assessing microbial communities. Report prepared for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development through the Department of Climate Change, Energy, the Environment and Water, Commonwealth of Australia

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Adams MA, McKnight K, Spadaro DA, **Hose GC,** Simpson SL 2020. Barrow Island stygofauna Risk Assessment: Site-specific guidelines for groundwater contaminants: Year 1 report – method development. CSIRO Land and Water, Lucas Heights, NSW, Australia.

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Davies P, Corkery L, Nipperess, D, Barnett G, Bishop M, Hochuli D, **Hose G**, Joei LC, Lin B, Keane A, Osmond P, Pelleri N, Staas L, Threlfall C, Van den Berg F, Wilkinson S 2017. Blueprint for Living Cities: Policy to Practice. National Green Infrastructure Network

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Hose GC, Sreekanth J, Barron O, Pollino C 2015. Stygofauna in Australian Groundwater Systems: Extent of knowledge. Report to Australian Coal Association Research Program. Macquarie University and CSIRO**.**

Hose G 2015. Stream health in Tarban and Brickmakers Creeks, Hunters Hill LGA. Spring 2014. Report to Hunters Hill Council.

Hose G 2012. Assessment of stream health in the Hunters Hill LGA. Autumn 2011. Report to Hunters Hill Council.

Hose GC, Lategan MJ 2012. Sampling strategies for biological assessment of groundwater ecosystems, CRC CARE Technical Report no. 21, CRC for Contamination Assessment and Remediation of the Environment, Adelaide, Australia.

Hose G 2011. Assessment of stream health in the Hunters Hill LGA. Autumn 2010. Report to Hunters Hill Council.

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Cardno Ecology Lab & **Hose GC** 2010. Effects of Mine Water Salinity on Freshwater Biota: Investigations of Coal Mine Water Discharge in NSW. Project C15016 Final report. Australian Coal Association Research Program, Brisbane.

Hose GC 2009. An assessment of the biological values of caves in the Mt Sebastopol karst area. Report to NSW DECCW. Macquarie University, Sydney.

Hose GC 2009 Stygofauna baseline assessment for Kangaloon Borefield Investigations- Southern Highlands, NSW. Supplementary Report – Stygofauna molecular studies. Report to Sydney Catchment Authority, Access Macquarie Ltd, North Ryde.

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Hose G, Stephenson S 2008. Assessment of stream health using macroinvertebrates in the Lane Cove River and Middle Harbour Catchments. Autumn 2008. Report to Hunters Hill, Lane Cove, North Sydney, Ku-ring-gai and Willoughby Councils.

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Hose G 2007. Blue Lake Biodiversity Study. Report to Jenolan Caves Reserve Trust.

Stephenson S, **Hose G** 2007. Assessment of stream health using macroinvertebrates in the Lane Cove River and Middle Harbour Catchments. Autumn 2007. Report to Hunters Hill & Lane Cove Councils.

Hose G, Stephenson S 2007. Assessment of stream health using macroinvertebrates in the Lane Cove River and Middle Harbour Catchments. Spring 2006. Report to Hunters Hill, Lane Cove, North Sydney, Ryde and Willoughby Councils.

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Plenary, keynote & invited presentations

Keynote Speaker, 10th International Conference on Marine Pollution and Ecotoxicology, Hong Kong, 2024.

Keynote Speaker, IESC Stakeholder workshop, Brisbane, 2023.

Plenary Speaker, New Zealand Hydrological Sciences Conference, Dunedin, 2022

Plenary Speaker, Australasian Groundwater conference, Brisbane, 2019

Plenary Speaker, International Conference on Subterranean Biology, Aviero Portugal, 2018.

Research Grants

Korbel & Hose. Estuaries and Catchment Team Inland River research collaboration. Collaboration with NSW DCCEEW. May 2025.	**$172239**
Hose. Groundwater levels, chemistry and health survey for the Darling-Baaka River health monitoring project. Collaboration with NSW DCCEEW Jun 2024.	**$199031**
Hose, Korbel, Dabovic. Predicting the ecological responses of groundwater ecosystems to groundwater extraction during drought. Collaboration with NSW DCCEEW. Jun 2024.	**$100000**
Hose, Korbel, Dabovic. Monitoring long term impacts of changes in groundwater levels. Collaboration with NSW DCCEEW. Jun 2024.	**$160000**
Chariton, Leishman**, Hose,** Doyle. Role of contaminants and altered flow regimes in dieback of Dwarf Mountain Pine in the Blue Mountains WHA. Collaboration with NSW DCCEEW. Jun 2024.	**$130000**
Hose, Korbel, Chariton. Riparian and groundwater dependent vegetation condition project for Coastal WSPs. Industry collaboration grant with NSW DPIE. Dec 2023.	**$49000**
Hose, Korbel. Reanalysis of groundwater health in alluvial aquifers in the Murray-Darling Basin and associated thresholds for GDEs. Industry collaboration grant with NSW DPE. December 2023.	**$90000**
Hose, Korbel, Dabovic. Establishing the links between groundwater ecosystem health, and Groundwater dependent vegetation and wetland health. Collaboration with NSW DPE. Dec 2023.	**$90000**
Hose, Simpson, Adams, Korbel. Barrow Island stygofauna risk assessment: Site-specific guidelines for groundwater toxicity testing with stygofauna. Stage 3. Industry funded Research. Chevron. CSIRO. 2023.	**$150000**
Maselko et al (**Hose**). Opportunities for insecticide resistant honeybees for pollination security. Horticulture Innovation Australia Ltd. January 2023.	**$769174**
Hose, Korbel, Dabovic. Establishing the links between groundwater ecosystem health, and Groundwater dependent vegetation and wetland health. Collaboration with NSW DPE. Nov 2022.	**$180000**
Hose, Korbel, Chariton. Reanalysis of groundwater health in alluvial aquifers in the Murray-Darling Basin and associated thresholds for GDEs. Industry collaboration grant with NSW DPE. March 2022.	**$170000**
Hose, Korbel, Chariton, Greenfield, McKnight. Using environmental DNA (eDNA) to identify microbes in alluvial aquifers and compare shot-gun and metabarcoding approaches to determine the more effective methodology. Department of Agriculture, Water and the Environment. Jan 2022.	**$87120**
Hose, Korbel, Chariton, McKnight, Greenfield, Angel. Using metagenomic approaches to assess phreatic assemblages within a sandstone rock aquifer that may potentially be affected by coal mining and coal seam gas development. Department of Agriculture, Water and the Environment. Dec 2021.	**$87672**
Chariton, Boyer, **Hose**, Allen. Development of a predictive ecological response model for the Wet Weather Overflow Monitoring Program. Industry collaboration grant with Sydney Water Corporation: Sept 2021.	**$499919**
Hose, Korbel, Chariton. Establishing a groundwater health index for aquifers in coastal WSP areas and associated thresholds for GDEs. Industry collaboration grant with NSW DPIE. June 2021.	**$200000**
Hose, Korbel, Chariton. Riparian and groundwater dependent vegetation condition project for northern Basin MER. Industry collaboration grant with NSW DPIE. June 2021.	**$280000**
Davies, **Hose.** Memorandum of Understanding Partner Grants Project. Industry collaboration grant with NSW DPIE. June 2021.	**$150000**
Simpson, Adams, **Hose.** Barrow Island Stygofauna Risk Assessment: Site-Specific Guidelines for Groundwater Toxicity testing with stygofauna. Stage 2. Industry funded Research. Chevron. CSIRO. 2021.	**$200000**
Hose, Korbel, Chariton, McKnight, Adams. Using metagenomic approaches to understand impacts of coal seam gas and coal mining to stygofaunal assemblages. Department of Agriculture, Water and the Environment. March 2021.	**$168414**
Hose, Korbel, Chariton. Riparian and groundwater dependent vegetation condition project for Coastal WSPs. Industry collaboration grant with NSW DPIE. March 2021.	**$150000**
Hose, Korbel, Chariton, A DNA database for groundwater dependent vegetation. Industry collaboration grant with NSW DPIE. November 2020.	**$30000**
Hose, Chariton, An environmental DNA (eDNA) metabarcoding survey of Lake Macquarie's sedimentary environments. June 2020.	**$48092**

Hose, Fryirs, Chariton. Monitoring program for the upland swamps in the Blue Mountains World Heritage Area. Blue Mtns World Heritage Institute. June 2020. **$40000**

Hose, Chariton, Andersen, Stumpp, Landis, Dabovic, Baker. Predicting the impacts of groundwater abstraction on groundwater ecosystems. ARC Linkage Grant. May 2020. **$366244**

Simpson, **Hose.** Barrow Island Stygofauna Risk Assessment: Site-Specific Guidelines for Groundwater Toxicity testing with stygofauna. Industry funded Research. Chevron. CSIRO. 2020. **$100000**

Hose, Korbel, Chariton, Andersen. Predicting the impacts of groundwater abstraction on groundwater ecosystems. NSW Environmental Trust. December 2019. **$198162**

Hose, Korbel & Chariton. Predicting the response of groundwater ecosystems to groundwater abstraction. Industry collaboration grant with NSW Dept of Industry - Water. July 2019. **$150000**

Hose, Korbel & Chariton. Determining groundwater use by vegetation using environmental DNA. Industry collaboration grant with NSW Dept of Industry - Water. July 2019. **$220000**

Hose, Korbel & Chariton. Establishing a groundwater health index for the alluvial aquifers in the Murray-Darling Basin and associated thresholds for GDEs. Industry collaboration grant with NSW Dept of Industry - Water. Jan 2019 **$40000**

Dudaniec, Stow, Hose, Chariton, Fryirs. Building the resilience of swamp communities to environmental change in the Sydney Basin. NSW Environmental Trust. December 2018. **$150000**

Dudaniec, Stow, Hose, Chariton. Building the resilience of swamp communities to environmental change in the Sydney Basin. NSW Saving our Species Science & Research Program. August 2018. **$70000**

Hose, Korbel & Chariton. Establishing a groundwater health index for the alluvial aquifers in the Murray-Darling Basin and associated thresholds for GDEs. Industry collaboration grant with NSW Dept of Industry - Water. July 2018. **$150000**

Chariton & Hose. A high-resolution molecular database for aquatic invertebrate sampling. Industry collaboration grant with Environmental Research Institute of the Supervising Scientist. 2018 **$140000**

Hose, Korbel, Chariton. Incorporating traits into groundwater ecology. Macquarie University Species Spectrum Research Centre Grant. 2018 **$10000**

Hose et al. High throughput system for the preparation of genomic samples. Macquarie University Infrastructure Grant. 2017 **$89688**

French, Bull, Hose et al. Impacts of locust control pesticides on arid-zone fauna. ARC Linkage Grant. 2016 **$410000**

Davies et al (Hose). Urban Ecology Renewal Program. NSW Environmental Trust. Feb 2016. **$250000**

Hose. Stygofauna in Australian Groundwater Systems: Extent of knowledge. Contract research to CSIRO June 2015 **$36000**

Hose & Korbel. Developing the groundwater health index (GHI) as an industry-wide monitoring tool. Cotton Research & Development Corporation 2014 **$381408**

Mitchell, Hose et al. Quantitative metrics for determining aquifer ecosystem state. ARC Linkage Grant. 2013 **$447000**

Fryirs, Hose et al. Upland swamps and chains-of-ponds as unique and rare Australian river types: understanding their function to improve conservation and rehabilitation. ARC Linkage Grant. 2013 **$179945**

Hughes et al (Hose) New South Wales Office of Environment and Heritage Climate Change Biodiversity Research Hub. NSW OEH. February 2013. **$900000**

Hose, et al. Residual toxicity and risk assessment of petroleum hydrocarbons in Antarctic and sub-Antarctic. Australian Antarctic Science Program. Aug. 2012. **$149500**

Hose, Fryirs, Keith A framework and toolbox for assessing and monitoring swamp condition and ecosystem health. SEWPAC/ ANU Fenner School Temperate Highland Peat Swamps research program. May 2012. **$199154**

Fryirs & Hose. Spatial distribution and landscape attributes of upland swamps in Eastern NSW with a focus on Temperate Highland Peatlands on Sandstone. SEWPAC/ANU Fenner School Temperate Highland Peat Swamps research program. May 2012. **$40106**

French, Bull, Hose et al. The effect of aerial spraying of two pesticides on semi-arid grasslands. ARC Linkage Grant. 2011 **$296000**

Hose et al (Faculty of Science). State of the art teaching microscopy for state of the art teaching laboratories. Macquarie University Teaching Infrastructure grant December 2011. **$350000**

Stumpp & Hose. Impact of groundwater fluctuations on groundwater ecosystems. Bilateral Cooperation Grant. German Research Foundation. 2011.	**$14625**
Fryirs & Hose. Upland Swamps as sponges and filters. Macquarie University Safety Net Grants Scheme. 2011	**$20000**
Fryirs et al (Hose) Small, track-driven drill rig for sediment coring at remote and difficult to access sites. Macquarie University Research Infrastructure Grant. Nov 2011.	**$93540**
Fryirs & Hose. Sediment dating. AINSE Grant. 2011	**$18000**
Hose. Microanalysis of groundwater invertebrates to determine Cr tolerance and its mechanism. AINSE Grant. 2011	**$19800**
Hose et al. Environmental molecular (DNA) analysis facility. Macquarie University Research Infrastructure Grant. Oct 2010.	**$46994**
Bishop (Hose) et al. PHYTO-PAM: an in situ assessment of the functional diversity and photosynthetic health of aquatic primary producers Macquarie University Research Infrastructure Grant. Oct 2010.	**$41360**
Lategan, Hose et al. Assessing groundwater fungi as novel bioindicators of contamination. NSW Environmental Trust. 2010	**$19800**
Fryirs & Hose The spatial distribution, geomorphic evolution and genetic biodiversity of upland swamps in Eastern Australia: Implications for protecting these endangered ecosystems. Macq Uni Research & Development Grant. May 2010.	**$49956**
Hose, Stow & Nipperess. Biodiversity investigation of aquifers in the Gosford LGA. Gosford Council Ecological Research Grants. May 2010.	**$10795**
Hose. Microanalysis of groundwater invertebrates to determine As tolerance and its mechanism. AINSE Grant. 2010	**$19200**
Hose, Ellis et al. Testing the biodiversity-function paradigm for the provision of clean water in aquifers ARC Discovery. 2010 DP1095200	**$170389**
Hose. Microanalysis of stygofauna to identify the mechanism of tolerance to metal toxicity. AINSE Grant. 2009	**$25650**
Hose & Stow Investigating the evolutionary and ecological basis of groundwater biodiversity in eastern Australia. Macquarie University Safety Net Grants Scheme. 2009	**$14491**
Sorrell et al (Hose) Inter-university Elemental and Structural Analytical Facility. ARC LIEF 2009	**$300000**
Brown & Hose. Macquarie University Infrastructure Grant: Freshwater ecology research facility. Nov 2008.	**$80000**
Hose. Sydney Catchment Authority. Groundwater biodiversity study. 2008-09	**$40000**
Hose. Lane Cove River Catchment Councils. Urban stream bioassessment. Australia. Autumn 2008.	**$15000**
Gore & Hose. Macquarie University External collaborative grant. 2008	**$43000**
Palmer, Lim, Hose et al. Mechanistic and probabilistic approaches to assessing the impact of pesticide mixtures in Australian waterways. ARC Linkage Grant 2007. LP0775468	**$174100**
Hose et al. Contamination Assessment and Remediation of the Environment CRC. Assessment and management of groundwater ecosystems at contaminated sites. December 2006.	**$173551**
Hose. Lane Cove River Catchment Councils. Urban stream bioassessment. Australia. July 2006.	**$5500**
Hose et al. NSW Environmental Trust. Assessment and management of groundwater fauna at contaminated sites. January 2006.	**$148522**
Hose et al. Cotton, Catchments, Communities CRC. Robust and sensitive indicators of groundwater ecosystem health and biodiversity. November 2005.	**$111000**
Palmer et al (Hose) UTS Challenge Grant. Developing a trans-disciplinary team and approach to integrated catchment management, using visual communication design and cooperative decision-making model. Nov 2005	**$50000**
Hose & Murray. Warringah Council Manly Dam Research Program. Assessment of urban development and exotic plant impacts on terrestrial and stream fauna. November 2005.	**$10000**
Lincoln-Smith & Hose. Australian Coal Association Research Program. Effects of saline mine water discharge on aquatic biota. December 2005.	**$226186**
Eamus et al (Hose) Australian Technology Network Research Challenge Grant. Land-Use Change and Ecosystem Services: An integrated, transdisciplinary study across environmental, social and economic sciences. January 2005.	**$40000**

Eamus et al. (Hose). Waste Services NSW. Revegetation of Castlereagh Waste Management Facility. June 2004.	**$24000**
Hose. Jenolan Caves Research Program. Project title: The impacts of exotic plants on cave and karst ecosystems. July 2005.	**$10100**
Hose. UTS Early Career Research Grant. Project title: Water quality protection for groundwater ecosystems. November 2003.	**$20000**
Eamus et al. (Hose). UTS Large Infrastructure Grant. A gas chromatograph, AAS, image analysis system and technical support to build water resource management capabilities. November 2003.	**$200000**
Hose & Lim. Bettersafe Weed Management. Project title: Assessing the biodiversity of golf course wetlands. November 2003.	**$4000**
Hose & Turak. NSW Dept Mineral Resources. Project title: Assessing impacts of derelict mines on stream invertebrate communities. January 2003.	**$6138**
Hose & Turak. Gosford City Council. Project title: Assessing impacts of urban development on stream invertebrate communities. January 2003.	**$5016**
Hose et al. Wakehurst Golf Club. Project title: Water quality and toxicity assessment of Wakehurst golf course and surrounds. July 2003.	**$10000**
Hose. Institute for Water and Environmental Resource Management (UTS). Research Support Grant. October 2002.	**$8000**
Hose. UTS Faculty of Science. Research Support Grant. November 2002.	**$6000**
Turak & Hose. Department of Land and Water Conservation Project title: River Health in the Hunter, Karuah, Tuggerah and Manning Catchments. July 2001.	**$6000**
Turak & Hose. Community Access to Natural Resource Information (CANRI). Linkages to Macroinvertebrate data for Rivers. July 2001.	**$10000**
Turak et al (Hose) Sydney Catchment Authority Project title: Biodiversity Synoptic Study Task 2d, Project 1. February 2001.	**$75052**

Awards

ESR (New Zealand) VISION International Fellowship. Sept 2022.

IEAM Exceptional Reviewers of 2022

Society for Environmental Toxicology and Chemistry – Australasia, Mid-Career Medal Oct 2016

Contributions and Creativity in Teaching Award – Dept Biological Sciences Dec 2014

Faculty of Science Teaching Award November 2011

Vice Chancellor's Learning and Teaching Awards. Genes to Geoscience Research Enrichment Program. Oct 2011.

Runner-up best poster, Communicate 10 Conference. CRC CARE. Adelaide, July 2010.

Australian Academy of Technological Sciences and Engineering Early Career Symposium Fellowship, September 2003.

Award for Best Student Oral Presentation (Ecotoxicology Section), Australian Marine Science Association Conference, University of NSW, July 2000.

Land and Water Resources Research and Development Corporation Postgraduate Research Scholarship 1996-1999.

Dean's Merit List for Academic Excellence 1994.

Current Professional Activities

Guest Editor, Special issue on Groundwater health and ecosystem safety, Ecotoxicology and Environmental Safety 2025.

Guest Editor, Special issue on Groundwater Ecotoxicology and Chemistry, *Environmental Toxicology and Chemistry*, 2023-24.

Independent Expert - Karst Ecology. NSW Karst Management Advisory Committee (by Ministerial Appt) 2020-2025.

Councillor, Macquarie University Senate 2019-2024

Editorial Board, SETAC Journal, *Integrated Environmental Monitoring and Assessment* 2015 - 2025

Reviewer for Australian Research Council

Reviewer for Scientific Journals and international grant programs

Guest Editor, Special issue on Assessment of different contaminants in freshwater: origin, fate, and ecological impact, *Water,* 2019-2020

Professional Affiliations

Society for Environmental Toxicology and Chemistry

International Society for Subterranean Biology (Council member 2018-2022)

International Association of Hydrogeologists

Other Qualifications and Training

Defence Security Clearance (Baseline) (2021)

Provide First Aid Certificate (Sept 2023)

Remote Area First Aid certificate (2015)

NSW Drivers Licence

NSW Boat Drivers Licence

Accredited Instructor for AUSRIVAS in NSW

Work Safety in the Construction Industry (White Card) 2014

Quarantine Approved Premises Training (2017)

Manawari Staff Aboriginal Cultural Safety Training (2022).

NASA 4-Dimensional Leadership training (2022).

Shaping Sustainability Cross-Industry Collaboration Program (2022)

Foundations in AI Microskill. Institute of Applied Technology (2023).

Recent media

Dangers to the Antarctic ecosystems. Radio interview. 2SER FM. Nov 2021.
https://2ser.com/dangers-to-the-antarctic-ecosystems/

Protecting our swamps. Sustainability Podcast. 2SER FM. Nov 2021.
https://2ser.com/podcasts/think-sustainability/

In Underground Waterways, an Endangered Ecosystem. UNDARK Magazine.
https://undark.org/2022/02/07/in-underground-waterways-an-endangered-ecosystem/

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EXPERT BRIEF

CONFIDENTIAL AND LEGALLY PRIVILEGED

Date: 12 December 2025

To: Professor Grant Hose
Acting Deputy Dean, Research and Innovation
Faculty of Science and Engineering
Macquarie University

By e-mail only: grant.hose@mq.edu.au

ENVIRONMENT CENTRE NT

SANTOS – BEETALOO BASIN APPRAISAL PILOT EMP

From: Johnson Legal
Level 21, 8 Chifley Square
SYDNEY NSW 2000

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THE LAW SOCIETY OF NEW SOUTH WALES PRO BONO SCHEME SUPPORTER 2025

THE LAW SOCIETY OF NSW PROFESSIONAL STANDARDS SCHEME

Dear Prof Hose

Environment Centre NT (ECNT) – Santos QNT Pty Ltd Beetaloo Basin Appraisal Pilot Environment Management Plan (EMP)

1. We confirm that we act for ECNT in the above matter, who wish to provide submissions in relation to the EMP currently under assessment with the Northern Territory Government.

2. We wish to brief you to provide a preliminary expert report for ECNT in relation to the likely environmental impacts and risks (specifically, regarding ecotoxicological impacts and risks) associated with the carrying out of the Project, within your scope of expertise.

The EMP

3. As part of the assessment process, the EMP was published for comment on 21 November 2025.

4. Comments on the EMP will close on **19 December 2025.**

5. The key documents subject to assessment are linked below:

    a. EMP currently open to comment and relevant appendices, including:

    - Appendix A-K - Summary of Approved Regulated Activities
    - Appendix L – Cultural Heritage Assessment
    - Appendix M - Emergency Response Plan – Mcarthur and Ameadeus Basins

The Project

6. Santos is an Interest Holder and operator of Exploration Permit (**EP**) 161 located in the Beetaloo Basin, approximately 350 kilometres south-east of Katherine in the Northern Territory.

7. Santos proposes to drill and test petroleum appraisal wells across two locations within EP 161, collectively referred to as the Beetaloo Appraisal Pilot.

8. The subject EMP covers the installation of up to twelve new petroleum appraisal wells at two separate well pads within EP 161. Some of the proposed activities include:

    a. Clearing and earthworks for 2 new well pad locations – The clearing and construction to create two new well pads and ancillary infrastructure at well pad locations referred;

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b. Drilling up to 12 appraisal wells, either vertical or horizontal well types;

c. Operating, testing, maintenance and decommissioning and hydraulic fracture stimulation of up to 12 appraisal wells;

d. Wastewater management – each well pad will include evaporation tanks, storage tanks, drilling sumps, cutting pits and any transfer infrastructure within the well pad. This also includes transportation onsite and disposal of these wastes (unless otherwise approved for reuse or burial).

9. The approval criteria are set out in reg 9 of the *Petroleum (Environment) Regulations 2016* (**the Regulations**) and include that the EMP must demonstrate that the Project will be carried out in a manner by which the environmental impacts and environmental risks will be reduced to a level that is 'as low as reasonably practicable' (ALARP) and 'acceptable'.

10. In determining whether or not to approve the EMP, the Minister must consider whether the EMP for the Project should be approved pursuant to the *Petroleum Act 1984* and the Regulations and if so, on what conditions.

Your brief

11. We request that you:

    a. Provide an expert report for ECNT by **16 December 2025** in relation to:

        i. The environmental impacts and risks (specifically, regarding wastewater spills and risks in respect of inter-aquifer connectivity) associated with the Project and the carrying out of the Project. This would include your assessment of the likelihood of any risks identified and the environmental impacts and consequences if those risks crystallise; and

        ii. Any recommended conditions or recommended amended conditions for the EMP to ameliorate the environmental impacts and risks you have identified in (i). This aspect should address the degree to which the EMP and proposed works meet the standards set by the legislation and the standards recommended by the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (Pepper Inquiry).

12. We ask that you prepare your opinion in accordance with the NT Supreme Court's Practice Direction No. 6 of 2015 – Expert Reports.

13. We note that under the Practice Direction, an expert witness is not an advocate for a party and has a paramount duty, overriding any duty to the

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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.

Your fees

12. Please provide us with an estimate of your fees for carrying out this work at your earliest convenience.

Yours faithfully
Johnson Legal Pty Ltd

Matt Floro
Principal Lawyer

Encl.

INDEX TO BRIEF

An index to the materials briefed is below. A copy of the annexures is contained at this Dropbox link.

No.	Document	Date
1	Beetaloo Basin Appraisal Pilot Environmental Management Plan	November 2025
2	Appendix A-K	November 2025
3	Appendix L	November 2025
4	Appendix M-P	November 2025

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Analysis of potential water impacts: Santos Beetaloo Basin Appraisal Pilot (EP161)

Professor Matthew Currell
Griffith University
Nathan, Qld 4111
19th December 2025

Introduction: I was requested by Johnson Legal to provide my opinion regarding the likely impacts and potential risks to groundwater, surface water and connected ecosystems from Santos' Beetaloo Basin Appraisal Pilot Environmental Management Plan (November 2025). My report has been prepared in accordance with the NT Supreme Court's *Practice Direction No 6 of 2015 – Expert Reports* and the expert witness code of conduct contained therein.

My Expertise: I am a professor of hydrogeology, and the Head of Civil and Environmental Engineering at Griffith University. I completed my PhD at Monash University, on the use of environmental tracers to understand impacts of human activities on groundwater. I am a member of the Commonwealth government's Great Artesian Basin Stakeholder Advisory Committee (GABSAC) and chaired the technical committee for the 2025 International Association of Hydrogeologists Congress. I have been the lead researcher on more than 20 grants awarded from competitive and industry sources over the past 15 years. In 2025 I was awarded a Future Fellowship from the Australian Research Council, valued at $1.28 million, to conduct research into novel methods to understand sources and pathways of groundwater contamination for high-value aquifers. I have published more than 100 peer-reviewed academic works including an edited book and I am a past associate editor for the *Hydrogeology Journal*. My academic works have been cited more than 5500 times. I have been engaged as an expert hydrogeology witness to provide evidence to government inquiries and court proceedings, including those relevant to unconventional gas extraction and mining.

Summary of my opinion

The Beetaloo Basin appraisal pilot proposed by Santos has the potential to negatively impact water and its dependent users and ecosystems through the following pathways:

- Changes to the permeability and structure of the Velkerri Formation (the shale gas target) will occur due to hydraulic fracturing. This may lead to enhanced connectivity with, and movement of hydrocarbons into, the overlying and underlying sandstone aquifers of the Roper Group. These aquifers are identified as being potential/likely sources of water sustaining culturally and ecologically significant springs in the Hot Springs Valley complex, approximately 50 km north of the project area, which may suffer reduced water quality and/or quantity as a result of the activity.

- Well integrity problems, encountered during and following the project, may lead to the cross-contamination of high value groundwater aquifers (e.g. the Gum Ridge aquifer), with hydrocarbons and other contaminants of potential concern (CoPC)

- Spills and leaks of hydraulic fracturing chemical mixtures and/or flowback fluids, drilling fluids, stormwater and other wastes, generated during the project, may contaminate the surface and shallow sub-surface environments surrounding the site.

The current Environmental Management Plan has not sufficiently or conservatively considered these risks, and there are insufficient baseline data and scientific studies completed to comprehensively

assess and mitigate these risks. As such, residual risk levels for the abovementioned water-related impact pathways, should be considered high.

Project activities

The Beetaloo Basin Appraisal project is located within exploration permit 161, on Tanumbirini Station, between Daly Waters and MacArthur. Santos proposes to construct two well pads, on which a total of twelve shale gas wells (targeting the Velkerri Formation shale) and up to 20 water supply bores (targeting the Gum Ridge aquifer), plan to be drilled. The shale gas wells would first be drilled vertically to a depth of approximately 3 km, then continue horizontally within the target shale for up to 3.5 km in different directions. Each shale gas well would then undergo an average of 60 hydraulic fracturing events, during which groundwater extracted from the Gum Ridge aquifer would be mixed with sand and a wide array of chemicals (described in Appendix D of the EMP), and pumped at high pressure into the wells to fracture the gas-bearing shale and liberate hydrocarbons for extraction.

It is estimated that the total groundwater extraction for the project would be approximately 2.35 billion litres (GL) and that between 14 and 28 million litres of flowback fluid would be generated at each well. Flowback fluid would be stored in up to 16 tanks constructed on the well pads, each with 14 ML capacity. Wastewater (including flowback fluid) would be stored temporarily in open tanks for evaporation and solid/liquid waste residues transported for off-site disposal. Some drilling waste is also proposed to be buried at the site.

Potential risks of the project

Impacts on groundwater dependent ecosystems (GDEs)

As discussed in the Northern Territory government's Strategic Regional Environmental Baseline Assessment (SREBA) for the Beetaloo Basin (DEPWS, 2023), there is a significant cluster of thermal springs located on Tanumbirini station - Hot Springs Valley. These springs are located less than 50 km from the project site, to the north. Due to the high temperature of the spring waters (e.g., Beauty Creek spring has a recorded temperature of 65 degrees Celsius), and the detection of hydrocarbon gases in bubbles emanating from the springs (DEPWS, 2023), it is considered likely that the spring waters are sourced from deep in the Beetaloo Basin, within the Roper Group, and reach the surface via fracturing and faulting.

> "Hot Springs Valley is likely sourced from Mesoproterozoic formations that have been uplifted due to faulting along the Lagoon Creek Fault Zone and Mallapunyah Fault Zone, and this includes some of the same formations targeted for petroleum exploration in the Beetaloo Sub-basin." (DEPWS, 2023).

The EMP suggests that the most likely aquifers from which the springs are sourced are the Bessie Creek Sandstone and/or Moroak Sandstone. These sandstone units sit directly below and above the Velkerri Formation (see Table 1), which is the target layer for shale gas extraction, via hydraulic fracturing. The EMP suggests that because these units occur at 'substantial depth' beneath the proposed well pads, the hot springs are not at any risk of impact from the project.

However, this overlooks an important impact pathway. Horizontal drilling and hydraulic fracturing directly above or below the sandstone aquifers may significantly affect the water quality in these

aquifers, through enhanced connectivity with the hydrocarbon-bearing shales. Hydrocarbons that migrate into the sandstone units following hydraulic fracturing, may then migrate laterally and vertically to the springs- the natural discharge area for groundwater from these units. Thus, the proposed hydraulic fracturing may create new pathways for gas and other hydrocarbon fluids to contaminate the springs. An increase in hydrocarbon migration to the springs could result in a significant change in their water quality, and negative impact to these culturally and ecologically significant receiving environments.

Hydraulic fracturing may also alter the rates of groundwater flow discharging from the Roper Group sandstone aquifer(s) to the springs. The major increase in permeability within the shales may result in leakage of groundwater from the underlying and/or overlying aquifers, re-directing groundwater that would otherwise flow to the springs.

Both of these pathways are major risks that have not been considered or assessed in the EMP. Comprehensive modelling of these impact pathways, drawing on an array of baseline field data collected from the region, is a critical aspect of effective risk analysis and mitigation.

PROVINCE	PERIOD / AGE	FORMATION		AQUIFER STATUS	THICKNESS (m)	YIELD (l/s)	AVE. EC (µs/cm)
CARPENTARIA BASIN	CRETACEOUS 145 – 66 Ma	Undifferentiated		*Local Aquifer*	0 - 130	0.3 - 4	1800
GEORGINA BASIN	CAMBRIAN 497-630 Ma	Cambrian Limestone Aquifer (CLA)	Anthony Lagoon Beds	REGIONAL AQUIFER	0 – 200	1 - 10	1600
			Gum Ridge Formation	REGIONAL AQUIFER	0 – 300	0.3 - >20	1400
		Antrim Plateau Volcanics		REGIONAL AQUITARD *Local Aquifer*	0 – 440	0.3 - 5	900
		Bukalara Sandstone		*Local Aquifer*	0 – 75	0.3 - 5	1000
BEETALOO BASIN (ROPER GROUP)	NOT KNOWN	Hayfield Mudstone		REGIONAL AQUITARD *Local Aquifer*	0 – 450	-	32000
		Jamison Sandstone		*Local Aquifer*	0 – 150	-	138000
	MESO-PROTEROZOIC 1430-1500 Ma	Kyalla Formation		REGIONAL AQUITARD	0 – 800	-	-
		Moroak Sandstone		*Local Aquifer*	0 – 500	0.5 - 5	131000
		Velkerri Formation		REGIONAL AQUITARD	700 – 900	-	-
		Bessie Ck Sandstone		*Local Aquifer*	450	0.5 - 5	-

Table 1 – Stratigraphy of the Beetaloo, Georgina and Carpentaria basins, showing relationship between the Velkerri Formation (shale gas target) and Bessie Creek / Moroak Sandstones, considered likely source aquifers for springs. Alteration of permeability, connectivity and water quality in these units is a likely consequence of hydraulic fracturing and may affect the springs at the regional discharge area at Hot Springs Valley (Source: Fulton and Knapton, 2015).

Following the SREBA studies, the CSIRO were commissioned to conduct further isotope tracing work and geological, geochemical and geophysical studies of the Hot Springs Valley. This work is currently underway. Until the outcomes of this assessment are available, the risk of impact to the springs cannot be confidently assigned, and should (conservatively) be considered high. A detailed monitoring program is required to establish baseline groundwater chemistry and flow rates from the

springs, and groundwater quality and level data between the project area and these high value groundwater dependent ecosystems. This was highlighted as a key task to ensure protection of GDEs from shale gas exploration and appraisal activity by the IESC in 2024:

> "To better understand the connectivity and hydrological pathways between groundwater and surface water systems, data are needed to develop a range of suitable trigger values for maintaining groundwater discharge to the surface at major springs such as those in Hot Springs Valley. This needs to be done in conjunction with geophysical studies and tracers (e.g. Campbell et al. 2025) to ensure that potential contamination pathways are identified and incorporated into environmental risk assessments." (IESC, 2024).

At the current time, in the absence of such work it is not possible to:

A) Properly assess the risk to the springs from the project (or rule out such risks, as Santos has done in the EMP)
B) Develop appropriate mitigation measures to minimize the impact on the springs as part of the EMP.

Stygofauna

Stygofauna sampling results from the SREBA studies of the Cambrian Limestone Aquifer are referred to in the EMP (Table 51) as a potential GDE in the region. One sample in the proposed project area was taken during 2020-22 baseline studies, from a bore in the Anthony Lagoon Formation (RN029025). No stygofauna were detected in this bore. Other bore sites located 17 km and 44 km away from the project site, screening the Gum Ridge aquifer, did record the presence of endemic stygofauna - the blind shrimp Parisia unguis. This species has been detected across many bore and spring sites within the Georgina and Daly basins and is thought to be a significant stygofauna community adapted to the conditions of the Cambrian Limestone Aquifer (Oberprierler et al., 2021). Given the frequent detection of stygofauna in other bores in the Gum Ridge aquifer throughout the Beetaloo Basin, a single sample from the overlying unit (Anthony Lagoon Formation), which did not detect any organisms is not sufficient evidence to rule out their presence within the project area. A site-specific survey of the existing monitoring and production bores from the Gum Ridge aquifer is required to properly characterize the groundwater ecosystem that may be impacted by the project.

Stygofauna are at risk of impact primarily due to the potential for well integrity failures (which may create pathways for hydrocarbon contamination in the Gum Ridge aquifer) and wastewater spills and leaks, which may ultimately infiltrate into shallow groundwater. These impact pathways are further discussed below with respect to the specific hydrogeological setting and project activities/characteristics.

Well integrity risks

Well integrity breaches are a major issue associated with shale gas development. They are one of the primary pathways by which contaminants (predominantly hydrocarbons) can cross-contaminate aquifers in areas of shale gas development (Vengosh et al., 2014; Lackey et al., 2021). This contamination pathway has been documented to have affected important water supply aquifers

with contaminants introduced into wells in multiple cases in the United States (Darrah et al., 2014; Llewellyn et al., 2015; Whyte et al., 2021).

A global survey of well databases by Davies et al., (2014) identified that typically, approximately 2 to 20% of wells within a given unconventional gas development region experience well integrity breaches (median rate = 13%). According to Davies et al., older wells typically experience higher rates of failure compared to newer wells (due to issues such as long-term corrosion). However, unconventional oil and gas wells of all ages and types are documented to experience well integrity issues, and none of the databases surveyed report successful shale gas development with zero integrity breaches. Based on the global data, there is a significant likelihood of at least one well integrity breach occurring during the drilling and hydraulic fracturing of the twelve wells in EP161[1].

Due to the Beetaloo Basin having undergone relatively limited exploration to date, and limited geophysical, geological and geochemical characterisation (in comparison to much more extensively characterised gas resources in the US), the risk of failure is arguably greater than the typical rates reported by Davies et al (2014) for major US shale basins. The difficulty that is experienced with effectively cementing and isolating the aquifers above the shale gas target in the Beetaloo Basin is an additional major challenge that will increase the risk of groundwater contamination during the project:

Difficulty cementing wells through the Gum Ridge limestone aquifer

The well designs outlined in the EMP include the use of surface and intermediate casings as a method to isolate the aquifer units above the hydrocarbon reservoirs from contamination. This is standard industry practice, and part of the 2025 Well Integrity Code that applies in the NT.

However, effective cementing of the gas wells' annular space throughout the Gum Ridge aquifer – the major water supply for the region - will be extremely difficult. This is due to the karstic nature of the aquifer, whereby the rock matrix contains significant fractures and caverns into which fluids flow and are easily 'lost' into the aquifer matrix. This typically results in an inability to maintain fluid circulation during drilling through the unit. In some cases, fluids lost during drilling through the Gum Ridge aquifer have been identified as re-emerging at the surface through sink-holes (Deslandes et al., 2019). This highlights the complex permeability pathways fluids take during the drilling process in the aquifer.

Successful return of fluids to the surface is vital to effective well cementing. Most water bores in the Gum Ridge aquifer are not cemented throughout the aquifer, due to fluid loss. If successful cementing of gas wells through the Gum Ridge Formation is not achieved or is incomplete, this will leave the aquifer vulnerable to contamination. Without a protective cement barrier, any casing deformation events or degradation of production and/or intermediate casings over time may allow hydrocarbons to migrate into the aquifer.

A specific scenario that could lead to contamination of groundwater would be the inflow of pressurized hydrocarbons from the Kyalla Formation (which sits above the target Velkerri Formation)

[1] The expected value for well integrity failure for a 12 shale-gas well development would be between 0.24 to 2.4, depending on the adopted rate (ranging from 2% to 20%).

into the wellbore during drilling, which could then migrate upwards and enter the Gum Ridge aquifer. This risk will be of considerable likelihood if continuous cementing to protect the aquifer is not achieved and could occur either before the wells are completed (i.e., during drilling into the Kyalla Formation) or, after the construction of the intermediate casing around the Kyalla Formation, which is designed to prevent cross contamination (e.g., Fig. 1):

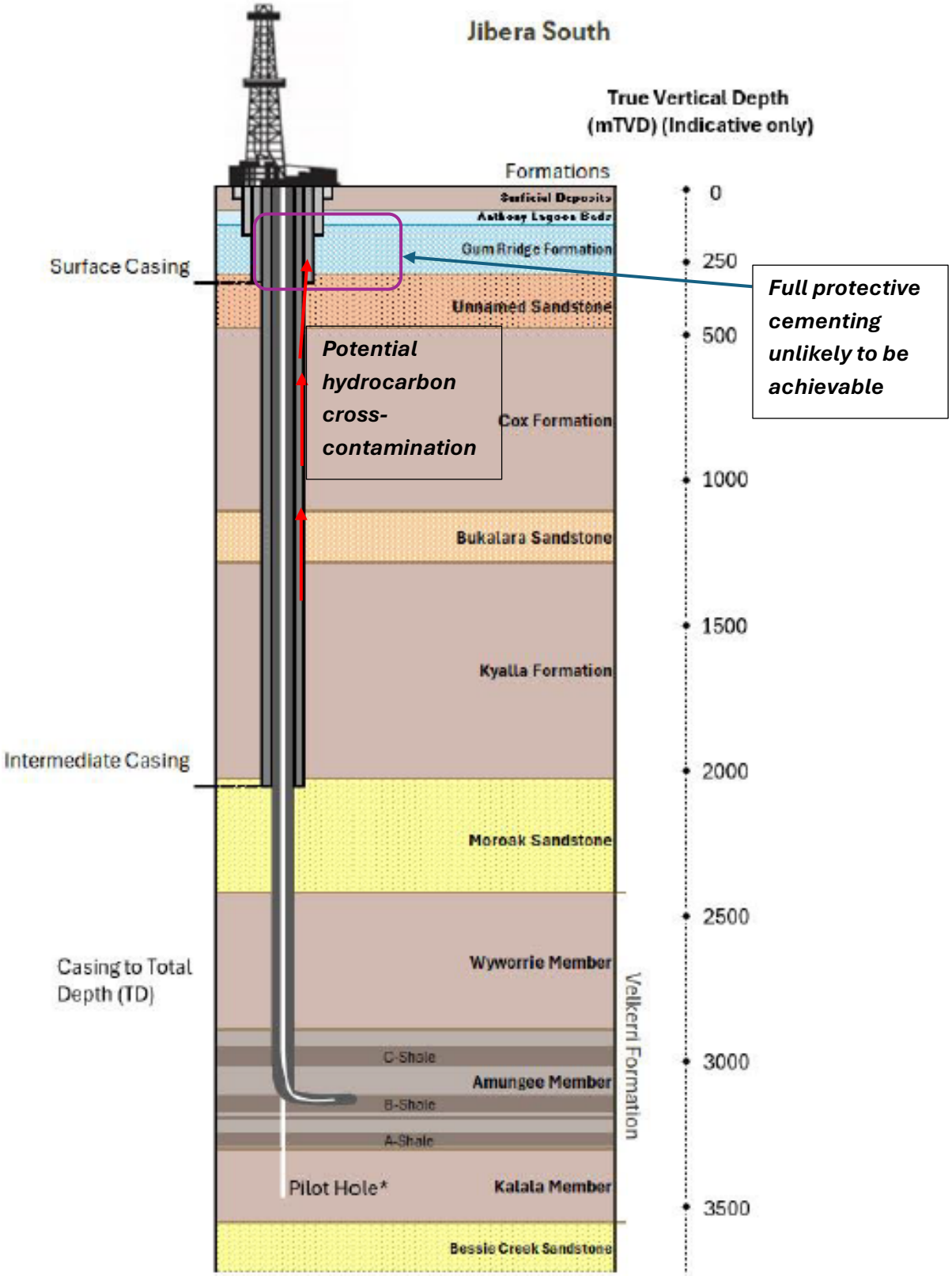


Figure 1 – Conceptual diagram showing impact pathway for cross contamination of Gum Ridge aquifer with hydrocarbons (modified from EMP figure 12).

The Gum Ridge Formation aquifer is a very important regional water supply, containing water suitable for stock and domestic water supply, and it is a habitat for endemic stygofauna in the Beetaloo region (Oberprierler et al., 2021). The EMP notes that there are 21 bores within five kilometers of the proposed well pads, and these will be at risk of contamination, particularly with hydrocarbons, carbon dioxide and hydrogen sulfide (often components of hydrocarbon reservoirs), if well integrity is not maintained. These potential risk pathways are not considered or described in the EMP with relevant data or modelling provided.

Spills, leaks and discharges of contaminated water

A further impact pathway associated with the unconventional gas industry is the release of poor-quality fluids generated during the shale gas drilling, hydraulic fracturing and gas production process, to the surrounding environment. In particular, significant water quality risks are associated with the generation of flowback fluid, which returns to the surface following hydraulic fracturing events. Flowback is generally highly saline, containing a large number of contaminants of potential concern (both organic and inorganic). Flowback fluid contains a mixture of two primary types of water:

1. The hydraulic fracturing fluid that was injected into the gas wells, which returns (in some proportion) back to the wellhead, containing chemicals used in the fracturing process;

2. The native water present within the shale. In most cases (including the Beetaloo Basin), this water is saline brine, concentrated in salts, organic carbon, most metals and other inorganic ions, and radio-nuclides.

Based on review of global shale gas flowback water quality data, Vengosh (2021) summarised the most important water quality parameters that are released into surface water and/or shallow groundwater as a result of unintentional (and intentional) discharge of shale gas flowback water. These include:

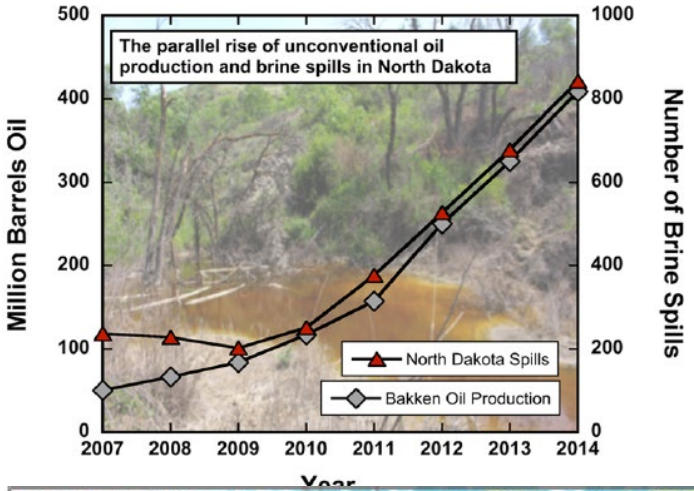
- Chloride, Barium, Strontium, Ammonium, Bromide, Radium (^{226}Ra and ^{228}Ra) and other radio-active nuclides, known as NORM (Vengosh, 2021).

Table 7 of the EMP Wastewater management plan (Appendix F) contains 'indicative' flowback water quality, containing elevated levels of hydrocarbons, nitrogen, certain metals and radionuclides. Without the raw chemical concentration data from flowback samples at the site (covering a full suite of analysed organic and inorganic compounds) and proper documentation of the number and type of samples on which the data in the table are based, it is difficult to verify the full suite of water quality parameters that would be expected in flowback fluid from the project. The contaminants noted above – as well as arsenic, boron and lead, were significantly enriched in flowback water analyses presented in other EMPs in the Beetaloo Basin (such as the Amungee project to the west of EP161; Origin 2022) and should thus be considered likely contaminants of potential concern (CoPC).

Research by Vengosh, Lauer and Patterson in the US have documented that wastewater spills are a considerable environmental risk, which frequently accompany the expansion of shale gas development into new basins. The best available empirical datasets to estimate the frequency of spill and leak events are from the United States, where there has been two decades of drilling and hydraulically fracturing shale gas resources across multiple states. Patterson et al., (2017) identified a yearly spill rate (expressed as the percentage of unconventional gas wells where an incident was recorded and reported to the regulator) ranging between 2% and 16%, with a median of 6.5%:

> "We assessed spill data from 2005 to 2014 at 31,481 UOG (unconventional oil and gas) wells in Colorado, New Mexico, North Dakota, and Pennsylvania. We found 2−16% of wells reported a spill each year." (Patterson et al., 2017).

Data compiled by Lauer et al., (2016) show that there is a clear and direct correlation between the number of unconventional oil and gas wells drilled, and the number and size of spills of brine (hyper-saline water produced as flowback from the formation), based on data from North Dakota:



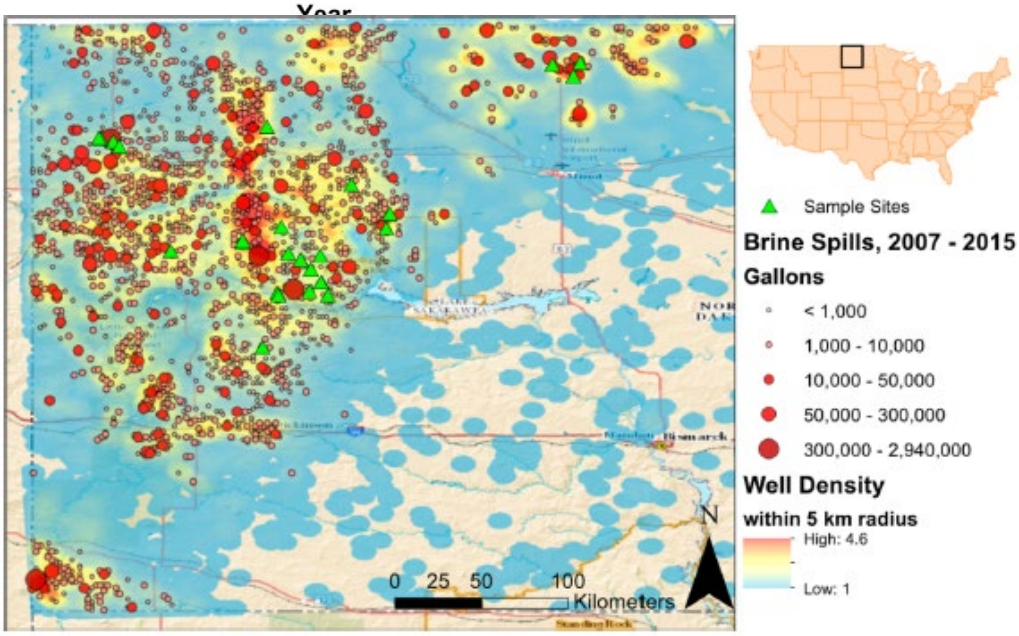


Figure 2 - Corrsepondence between unconventional oil production and spills of produced formation water (brine) and map of brine spills showing location and size of spills, corresponding to well density (Lauer et al., 2016)

Proper analysis of risks associated with spills and leaks requires detailed source-pathway-receptor modelling to identify the major impact pathways and likelihood of these being completed during different stages of development. There is some scenario modelling in the EMP that looks at the likelihood of complete risk pathways, including infiltration of spilled wastewater into groundwater, and the potential radius of impact that would occur under various spill sizes (e.g. Appendix D, Attachment B). However, this modeling does not involve detailed analysis of site-specific soil and shallow aquifer characteristics and hydraulic parameters, or the key sources of potential spill and leak events – which Patterson et al. (2017) examined in detail (e.g. Figure 3):

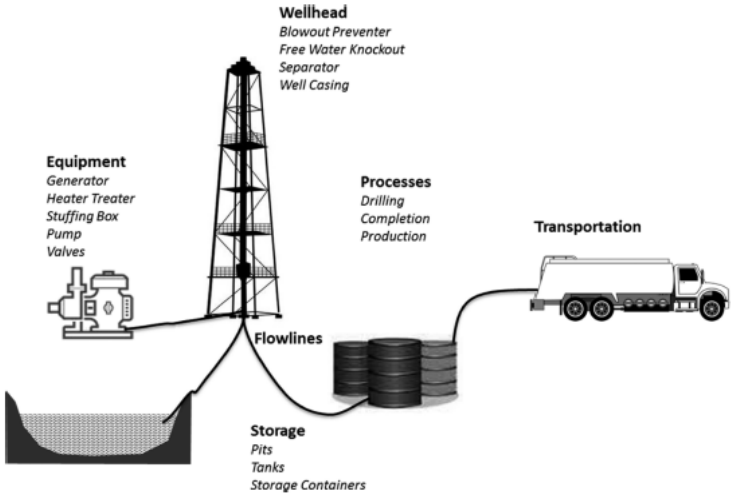


Figure 3 – Common pathways for unconventional gas flowback water spills (Patterson et al., 2017).

Spills, leaks or discharge of wastewater may also occur (in addition to the pathways shown above) particularly during major rainfall/runoff events, in the Northern Territory's highly seasonal climate. If site containment is breached, contaminated water may be mobilised within temporary overland stormwater flow events into surrounding ephemeral waterways. This impact pathway was identified as being of low likelihood but high consequence in the Beetaloo by the IESC (2024) who noted that such events could cause significant harm to aquatic ecosystems. The wastewater management plan for the EMP (Appendix E) notes that:

"Spills to surface have the potential to migrate to surface waters such as ephemeral watercourses. This has the potential to effect surface water quality and ecological values of that habitat."

The spills and wastewater management plans of the EMP contain some analysis of the likelihood of the overtopping of flowback storage tanks and other breaches of containment; however it is still not clear how wastewater containment would be achieved in the event of damage to infrastructure or equipment failure – a major cause of unconventional gas wastewater spills identified by Patterson et al, (2017). The flow of contaminated water into Tanumbirini Creek or Newcastle Creek from the Jibera South and Newcastle South well-pads (respectively) and harm to the associated aquatic ecosystems is thus a potential complete risk pathway for the project.

Incidents of contaminated wastewater discharge to the surface during unexpected high rainfall events have already affected soils and vegetation at other nearby shale gas exploration and appraisal sites elsewhere in the Beetaloo[2] (such as the Carpentaria site within EP187, to the east of EP161), despite a similar level of planning and risk mitigation in the two projects' wastewater and spills management plans and effectively the same controls and risk mitigation strategies put forward in the respective EMPs (e.g., Imperial Oil & Gas, 2024, Appendix 7).

The EP161 wastewater management plan involves the storage and transport of flowback and other wastewater within a combination of covered and uncovered tanks. Similar to other Beetaloo basin exploration and appraisal projects, Santos plans to reduce the volumes of wastewater requiring management using evaporation in open tanks. This presents particular environmental risks due to:

A) The evaporative enrichment will increase concentrations of contaminants of potential concern in the residual wastewater, meaning the impact of any spills or discharges will be greater than un-evaporated wastewater

B) Leaving tanks open to enable the evaporation will potentially increase the likelihood of spilling/over-topping during major storms.

For these reasons, the Pepper Inquiry (Scientific Inquiry into Hydraulic Fracturing in the NT) in 2018 recommended that the storage of unconventional gas wastewaters in open tanks not be permitted.

In terms of monitoring spill and leak events from tanks and other site infrastructure, the spills management plan (Appendix E) outlines detection/monitoring measures which include only weekly visual inspections (in person or remotely) of secondary containment during the dry season, and daily inspections during the wet season when the sites are in use. During a major storm event, it is possible that significant loss of containment could take place and not be detected for many hours (or days, if it occurs during the dry season unexpectedly). This could potentially lead to a significant amount of wastewater being released to the environment before it is detected and effectively contained.

Stormwater management

The EMP also includes measures to manage the stormwater generated on the well-pads during rainfall events. Such water may become contaminated as it interacts with exposed areas containing drilling waste and other contaminated material on-site. One of the management measures for stormwater proposed in the EMP is to discharge the water into the surrounding environment.

The EMP outlines 'stormwater release limits' which are water quality parameters below which stormwater may be discharged (in unlimited amounts) into the surrounding environment. The proposed limits include salinity (measured as electrical conductivity) of up to 1300 µS/cm, pH values between 5.2 and 9 and 'no visible hydrocarbons, foams or abnormal discoloration'. These visible assessment criteria are not an appropriate way to protect the surrounding environment from harm during proposed stormwater discharge events. A qualitative visual inspection of stormwater is not a scientific way to verify the chemistry/quality of the water, establish the concentrations of

[2] https://www.abc.net.au/news/2025-01-15/nt-beetaloo-basin-incident-experts-concerned/104816526

contaminants of potential concern or determine the water's suitability for discharge to the surrounding environment.

Based on the analysis above, it appears to be highly optimistic that the risk associated with wastewater spills, leaks and discharge to the surrounding environment is 'low' or 'very low', as put forward in the EMP.

Baseline groundwater monitoring

The effective protection of groundwater resources from contamination (or drawdown) relating to shale gas development depends on the collection of baseline groundwater data from any potentially impacted aquifers, including multi-level wells monitoring the bottom, middle and top of the aquifer – as outlined in the Preliminary Guideline: Groundwater Monitoring Bores for Exploration Petroleum Wells in the Beetaloo sub-basin (2018).

Currently, there is one active monitoring bore at the Jibera South site, screening the high-value aquifer of the region – the Gum Ridge aquifer. However, the monitoring bore screens the entire length of the formation from 144 m to 276 m below surface (i.e., a screened interval of more than 120 m). This is a very long screen interval for a monitoring bore, and data from the bore would not provide detailed depth-specific information about water quality changes occurring during hydraulic fracturing and other site activities. This monitoring well is also un-cemented, probably due to the difficulties described above with fluid loss that makes effective cementing of wells difficult. This issue not only creates a high level of risk for cross contamination of the aquifer during drilling and hydraulic fracturing (compared to non-karstic aquifers where cementing is straightforward), but also makes the task of effectively monitoring and early detection of impacts in the aquifer much more challenging, as water samples collected from the well will integrate and average the groundwater input from across the full thickness of the aquifer. Short-screened wells monitoring groundwater level and quality near the base of the formation (the highest risk zone for contaminant input) should be present to enable early detection and mitigation of contamination impacts. This does not appear to be part of the planned monitoring program in the EMP. The monitoring and data collection program in the EMP thus does not align with the following recommendation of the Pepper Inquiry (re-iterated in the Guideline):

"That prior to the grant of any further exploration approvals, in order to minimise the risk of groundwater contamination from leaky gas wells:

- Where a well is hydraulically fractured, monitoring of groundwater be undertaken around each well pad to detect any groundwater contamination using multi-level observation bores to ensure full coverage of the horizon, of any aquifer(s) containing water of sufficient quality to be of value for environmental or consumptive use;

- All existing well pads are to be equipped with multilevel observation bores;

In the monitoring plan of the EMP, it is proposed that the Control Monitoring Bore(s) for the Newcastle South well pad will be constructed less than six months prior to the drilling of gas wells on the pad – in contradiction to the Guideline and Pepper Inquiry recommendations (which cite six months as the minimum period required for baseline data). Santos argue that this is reasonable, as

monitoring bore data would still be collected at least six months before the commencement of hydraulic fracturing (as opposed to drilling). However, the risk of contamination incidents taking place may be just as high during the drilling of the gas wells - for example, via the risk pathway described above and in Figure 1, whereby hydrocarbons enter the wellbore when drilling through the Kyalla Formation and migrate into the Gum Ridge aquifer. In fact, given the highly seasonal rainfall patterns in the NT, at least one year of baseline data should be collected prior to drilling, to capture seasonal variability in groundwater conditions.

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EXPERT BRIEF

CONFIDENTIAL AND LEGALLY PRIVILEGED

Date: 12 December 2025

To: Professor Matthew Currell
Discipline Head (Civil and Environmental Engineering)
School of Engineering and Built Environment – Civil and Environmental Engineering
Griffith University

By e-mail only: m.currell@griffith.edu.au

ENVIRONMENT CENTRE NT

SANTOS – BEETALOO BASIN APPRAISAL PILOT EMP

From: Johnson Legal
Level 21, 8 Chifley Square
SYDNEY NSW 2000

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THE LAW SOCIETY OF NEW SOUTH WALES PRO BONO SCHEME SUPPORTER 2025

THE LAW SOCIETY OF NSW PROFESSIONAL STANDARDS SCHEME

Dear Prof Currell

Environment Centre NT (ECNT) – Santos QNT Pty Ltd Beetaloo Basin Appraisal Pilot Environment Management Plan (EMP)

1. We confirm that we act for ECNT in the above matter, who wish to provide submissions in relation to the EMP currently under assessment with the Northern Territory Government.

2. We wish to brief you to provide a preliminary expert report for ECNT in relation to the likely environment impacts and risks associated with the carrying out of the Project, within your scope of expertise.

The EMP

3. As part of the assessment process, the EMP was published for comment on 21 November 2025.

4. Comments on the EMP will close on **19 December 2025.**

5. The key documents subject to assessment are linked below:

    a. EMP currently open to comment and relevant appendices, including:

    - Appendix A-K - Summary of Approved Regulated Activities
    - Appendix L – Cultural Heritage Assessment
    - Appendix M - Emergency Response Plan – Mcarthur and Ameadeus Basins

The Project

6. Santos is an Interest Holder and operator of Exploration Permit (**EP**) 161 located in the Beetaloo Basin, approximately 350 kilometres south-east of Katherine in the Northern Territory.

7. Santos proposes to drill and test petroleum appraisal wells across two locations within EP 161, collectively referred to as the Beetaloo Appraisal Pilot.

8. The subject EMP covers the installation of up to twelve new petroleum appraisal wells at two separate well pads within EP 161. Some of the proposed activities include:

    a. Clearing and earthworks for 2 new well pad locations – The clearing and construction to create two new well pads and ancillary infrastructure at well pad locations referred;

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b. Drilling up to 12 appraisal wells, either vertical or horizontal well types;

c. Operating, testing, maintenance and decommissioning and hydraulic fracture stimulation of up to 12 appraisal wells;

d. Wastewater management – each well pad will include evaporation tanks, storage tanks, drilling sumps, cutting pits and any transfer infrastructure within the well pad. This also includes transportation onsite and disposal of these wastes (unless otherwise approved for reuse or burial).

9. The approval criteria are set out in reg 9 of the *Petroleum (Environment) Regulations 2016* (**the Regulations**) and include that the EMP must demonstrate that the Project will be carried out in a manner by which the environmental impacts and environmental risks will be reduced to a level that is 'as low as reasonably practicable' (ALARP) and 'acceptable'.

10. In determining whether or not to approve the EMP, the Minister must consider whether the EMP for the Project should be approved pursuant to the *Petroleum Act 1984* and the Regulations and if so, on what conditions.

Your brief

11. We request that you:

    a. Provide an expert report for ECNT by **16 December 2025** in relation to:

        i. The environmental impacts and risks (specifically, regarding wastewater spills and risks in respect of inter-aquifer connectivity) associated with the Project and the carrying out of the Project. This would include your assessment of the likelihood of any risks identified and the environmental impacts and consequences if those risks crystallise; and

        ii. Any recommended conditions or recommended amended conditions for the EMP to ameliorate the environmental impacts and risks you have identified in (i). This aspect should address the degree to which the EMP and proposed works meet the standards set by the legislation and the standards recommended by the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (Pepper Inquiry).

12. We ask that you prepare your opinion in accordance with the NT Supreme Court's Practice Direction No. 6 of 2015 – Expert Reports.

13. We note that under the Practice Direction, 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

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assist the Court impartially on matters relevant to the area of expertise of the witness.

Your fees

14. Please provide us with an estimate of your fees for carrying out this work at your earliest convenience.

Yours faithfully
Johnson Legal Pty Ltd

Matt Floro
Principal Lawyer

Encl.

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An index to the materials briefed is below. A copy of the annexures is contained at this Dropbox link.

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2	Appendix A-K	November 2025
3	Appendix L	November 2025
4	Appendix M-P	November 2025

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HYDROGEOLOGICAL ASSESSMENT OF SANTOS QNT BEETALOO BASIN APPRAISAL PILOT –

ENVIRONMENTAL MANAGEMENT PLAN.

PREPARED FOR | Environment Centre NT (ECNT)

PREPARED BY | Hydro Geo Enviro Pty Ltd

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Document Information

Prepared by: Dr Ryan Vogwill	Director & Principal Hydrogeologist	**Date:** 19/12/2025
Reviewed by:		**Date:**
Approved by:		**Date:**
Client distribution:		**Date:**

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Introduction

Santos has developed an environmental management plan (EMP) that covers the installation of up to 12 new petroleum appraisal wells (either vertical or horizontal well types) at two separate well pads within Exploration Permit (EP) 161. Santos has been undertaking seismic and drilling exploration activity within EP161 since 2012 and is now seeking approval to undertake further appraisal works to determine the size, potential production rate, and characteristics of the shale gas reservoir.

EP161 is within the Beetaloo Sub-Basin located approximately 350 kilometres south-east of Katherine in the Northern Territory. The project will rely on groundwater as the main source of water and up to 20 groundwater bores will be constructed to support petroleum operations; this includes monitoring and control bores. The target aquifer for groundwater abstraction is the Cambrian Limestone Aquifer (CLA), specifically the Gum Ridge Formation (GRF). Water Extraction Licence (WEL) GRF10280 authorises the extraction of 193.5 ML/year from the Gum Ridge Formation and was reissued to Santos on 6 December 2023 for a period of 10 years (expires 31 December 2033). Santos proposes to seek authorisation to extract up to 750 ML/year in total to support the proposed activities but hasn't yet submitted an application to increase the current licence amount (according to the EMP).

HydroGeoEnviro has been engaged by Environment Centre NT (ECNT) via Johnson Legal to provide advice regarding how the EMP addresses potential impacts and risks to water and the environment associated with Santos carrying out this program. The brief for the review is provided in Annexure A. Dr Ryan Vogwill is the primary author of the report but was assisted by Rachel Hamilton who scanned the EMP highlighting critical content for review and compiled other relevant publicly available material. The review begins with an overall summary of the concerns related to the EMP followed by an evaluation of impacts and risks. Recommendations to better ameliorate these impacts and risks are then provided, along with specific EMP comments made at the end of the document. Where considered appropriate specific page numbers within the EMP (referred to by the PDF file's page numbers) are referenced or referred to. HydroGeoEnviro has reviewed other petroleum projects in Western Australia and the Northern Territory. These notes are located at the end of this review as Appendix A to provide background context and holistically describe the potential impacts of hydraulic stimulation activities on water resources and the environment. The EMP has appendices that total over 2500 pages. Therefore, this document provides an initial review and highlights our key areas of concern regarding our expertise in hydrogeology, hydrology and environmental impacts but a detailed review of all material is warranted. We have also cross referenced the EMP against the Key Recommendations relevant to hydrogeology, hydrology and environmental impacts in the Pepper Inquiry (i.e. their Table 16.11).

This review has been prepared in accordance with the NT Supreme Court's Practice Direction No. 6 of 2015 – Expert Reports, which we agree to adhere to.

Overall Summary

A greater understanding of the connectivity and structural controls in the Beetaloo basin are required prior any petroleum development being approved past the exploratory stages, as per recommendations by The Panel in the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory – "*The conclusions from a SREBA must therefore be available and taken into account prior to the grant of any further production approvals*." (NT Government 2018). If exploration involves hydraulic fracturing, then there is a greater risk of impact than non-fracked wells (which can still leak

even if not hydraulically fracked). The ongoing Strategic Regional Baseline Assessment (SREBA) studies, particularly the work focussed on aquifer inter connectivity, sources of springs and the origins of methane, will help build these understandings. However, until high level technical studies that conclusively address basin groundwater dynamics and connections are available it is the proponents' responsibility to demonstrate lack of risk, not assume it. In our opinion, based on our experience, Santos has not adequately a demonstrated lack of risk in several areas and therefore risks have not been reduced to as low as reasonably practicable. These areas are discussed further below.

Inter-Aquifer Connectivity (deep/shallow/surface)

A lack of shallow deep connectivity potential between aquifers has been assumed and needs to be better demonstrated. The hydrogeological status of faults and fractures as flow barriers or conduits is critical to impact risk as these features could allow drawdown and contamination to impact the shallow/deep aquifers. This can occur via naturally occurring features (that could be enhanced by hydraulic stimulation) or well annuluses (that could be installed incorrectly or have their integrity compromised by hydraulic stimulation). The consequences of not identifying faults/fractures and potential migration pathways underlying the site could result in irreversible environmental damage. The geological cross-sections presented by Evans et al. (2020), *see extracted figure herein below*, shows a number of faults underlying the project area; however, it is hard to determine the exact project location on these. It is also noted a portion of the cross-sections have not been assessed and these portions align to the east of the project area. It is also likely that more faults and fractures exist than the regional scale features currently mapped hence why a detailed shallow seismic survey is recommended.

The project is in an area where deep groundwater resources are predominantly unexplored and shallow-deep aquifer connectivity exists. Nineteen springs have been identified within EP161 and the "Hot Springs Valley" (~45km north of Jibera South well pad) is associated with Beetaloo Sub-basin faults and the outcropping of Roper Group Mesoproterozoic sandstone formations e.g. Bessie Sandstone. The impermeability between the Velkerri Formation (gas target) and the underlying Bessie Creek Sandstone needs to be demonstrated not just assumed. Tickell and Zaar (2023) studied deep groundwater sources around 12 km northeast of the Beetaloo Sub-basin, in an area underlain by rocks that lie stratigraphically beneath the main gas producing zone within the Sub-basin. At one spring bubbles were rising intermittently and a gas detector indicated methane and ethane, an oily film was also present on the water and steam was rising from the water surface of the spring. The study concluded –"*the temperature of the spring waters suggests that they originate from considerable depths, of the order of 500 m for Gorge Spring and 1000m for Beauty Creek Hot Spring. In order for deep hot groundwater to reach the surface with relatively high flow rates, permeable conduits must be present to those depths. The most likely mechanism is via faults. The area is known to be within a major fault zone, the OT Downs Fault Zone."* Creating new fractures and increasing the size, extent and connectivity of the natural fractures (via hydraulic stimulation) can have significant implications for groundwater flow and conduits underground. A detailed 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. saline aquifer mixing with fresh aquifer. These shallow deep connectivity issues are essentially not explored in this EMP.

These fractures and faults could allow discharge of naturally occurring groundwater or hydraulic stimulation effluent with potential to permanently impact the upper aquifers, reducing water quality and quantity for other users and have irreversible environmental and cultural impacts. Once

hydraulically stimulated an area cannot be un hydraulically stimulated hence we would recommend the highest levels of caution prior to approval to protect the groundwater resources of the area, dependent ecosystems and related cultural values.

Essentially the vertical connectivity between deep aquifers and the surface, as well as deep shallow connectivity between aquifers needs considerably more consideration.

Pending Groundwater Licence Increase and Supporting Information

The CLA (of which the Gum Ridge Formation is the lower unit and the target aquifer for water extraction) contributes to numerous springs (e.g. Mataranka Thermal Pools and Flora River) that are located down hydraulic gradient from the Beetaloo basin region and the project area (Evans et al. 2020). The aquifer discharges into the Roper River approximately 100 kilometres north-west of the Beetaloo Basin, supporting important groundwater-dependent ecosystems (*Pg. 111 EMP*). Appendix A-K (*Pg. 2306*) states that extraction could potentially influence groundwater pressure in the Gum Ridge Formation and that this was assessed during the previous water licence (proposed extraction volume of 193.5 ML/year). This assessment has not been updated to reflect the required 750ML/yr licence proposed to support the EMP. Significant groundwater storage and regular recharge have been used to assume extraction will not impact GDEs in the current EMP. This is not precautionary, does not meet best scientific practice and not backed by data, essentially an inadequate impact assessment. Typically, water licence applications require aquifer testing and groundwater modelling. It is advised the documents that support the groundwater licence increase application (i.e. 750ML/yr to support the EMP) be assessed in conjunction with EMP approvals.

The EMP does not present critical data from previously installed groundwater monitoring bores nearby (e.g. water bores at Mount Brown (formerly Tanumbirini) and Inacumba). Santos has been active on this site since 2012, have had ample opportunity to conduct site specific groundwater investigations and collect baseline monitoring data but haven't. Aquifer testing plots, derived hydraulic parameters, bore construction logs, lithological logs and hydrographs are a suggested starting place. This is particularly important regarding the imminent groundwater licence application increase and technical assessments related to this.

The EMP considers the CLA is the only aquifer present (Anthony Lagoon and Gum Ridge formations) and states, *"No other formations in this area are classified as aquifers."* The Bukalara Sandstone aquifer is well recognised, and two studies have indicated potential for upwards groundwater flow into the CLA from this sandstone (DEPWS 2021). The Moroak Sandstone is not utilised as a groundwater resource within the Beetaloo GBA region however outside the Beetaloo GBA region (where these rocks occur near surface), the Moroak and other sandstones in the Roper Group are utilised and may also be a source aquifer for some springs (Evans et al. 2020). The degree of inter-aquifer connectivity is not well characterised (Evans et al. 2020). In some areas, the unnamed Cambrian sandstone directly underlies the CLA and may thus connect groundwater from deep Beetaloo Basin units and shallow aquifers (ELA, 2022). The disregard of several aquifers underlying the project is a broad concern regarding environmental risk impact evaluations.

Well Integrity

The integrity of the exploratory wells annular seals are of particular importance in this setting. The Cambrian Limestone 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 and the potential for rapid transport of contaminants in what is a highly porous and permeable aquifer. The cavernous and vuggy nature of the CLA

introduces 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 to the surface. CSIRO found that historically, the highest instance of well barrier integrity failure is due to insufficient or poor-quality cement coverage to seal aquifers and/or hydrocarbon-bearing formations. Therefore, the quality and extent of vertical coverage along the well during the initial cementing job, together with the maintenance of the integrity of the cement over time, are critical (NT Government 2018).

It is advised that Well Integrity Management Systems and the Well Operations Management Plan be reviewed in detail by a relevant independent drilling expert. There are multiple regulatory agencies, codes of practice and management plans for the project, this creates the potential for environmental impact mechanisms to be missed as there is no clear regulatory agency that has control over all aspect of this project's potential environmental impacts. An example of this is the information that supports the planned groundwater abstraction licence (750ML/yr) has not been included in the EMP. The new groundwater licence application would be best reviewed concurrently with the EMP.

GDEs and Cultural Value Assessments

Groundwater dependent vegetation communities have been identified within 5km of the well pads and licenced extraction bores, however no impact has been assumed as they are likely accessing a perched groundwater system. While this is likely the case, inter aquifer connectivity is not well understood and potential deeper groundwater sources (e.g. GRF) need to be better characterised in order to estimate any contribution to shallower/perched aquifers or the springs/seeps/surface. Also, the risk of surface contamination still exists to these terrestrial GDEs (see section below).

Santos has committed to collaborating with the NLC and to consider developing cultural heritage management with relevant parties in the future *(pg 17 EMP).* Traditional owners should be consulted on infrastructure locations e.g. gravel pits, well pads or camps. Consideration of aspects of cultural significance such as trees (e.g. trees with individual spiritual connections or scar trees) or springs/wetlands/soaks need to be incorporated into impact assessments better. It is important to note that the highest biodiversity values don't always line up with the highest cultural values, i.e. relatively common trees can be highly culturally significant. Traditional owners need to document (even if not released to government/licence applicants) where and what their cultural values are linked to in the environment and have an understanding of the relative cultural value of these different features or "assets." Knowledge co-production with remote land-attached Indigenous peoples can improve adaptive environmental planning and management where it fosters learning together, is grounded in the Indigenous-led institutions and addresses their priorities (Hill et. al 2022).

Surface Contamination

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. Unanticipated spills of hydraulic stimulation fluids have already occurred in this area even without widespread unconventional hydrocarbon development hence a detailed understanding of water table flow paths, travel times and receptors is required. Inflow dependant ecosystems (IDEs) and GDEs need to be considered in this context. Disposal practices (such as poorly lined pits) can release inadequately treated or untreated hydraulic fracturing wastewater to groundwater and surface water resources and subsequently the wider environment. 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 (bushfire or flooding/cyclone) occurs? Can flowlines (pipelines) be flooded safely and not exposed/compromised? Is there telemetry data to check flowlines pressure data to detect leaks while offsite. If a major leak is detected during a flood, how will this be dealt with? If flowback %'s have been underestimated, how quickly can storage tanks accommodate overflow or mitigate flowback volumes?

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? From the flood modelling presented in the EMP this does not appear to be the case; with 1 in 10, 1 in 50 and 1 in 100 flooding events presented in the flood modelling.

Environmental Impacts and Risks

The potential impact mechanisms of this project have not been adequately addressed as detailed herein in our opinion. Whether the risk is acceptable is unable to be properly evaluated due to a lack of data and assessment across several areas. These areas predominantly relate to:

1. Shallow deep connectivity potential between aquifers and GDEs, including the nearby "Hot Springs" Valley and its connections to deeper aquifers e.g. Bessie Sandstone. This includes both naturally occurring fractures/connections but also those produced or enhanced by hydraulic stimulation;
2. Further local characterisation of all types of GDEs and IDEs within and around the project area including groundwater and surface water regimes supporting them;
3. Obtaining hydrogeological parameters from aquifer testing on proposed extraction bores;
4. Groundwater model development and refinement;
5. Contamination of groundwater and surface water from petroleum operations; and
6. Expansion of groundwater monitoring sites related to cultural assets and GDEs including obtaining baseline data prior to undertaking project activities.

In our opinion, based on our experience, risks have not been reduced to as low as reasonably practicable. Carrying out the work detailed herein would reduce uncertainty allowing a realistic and site-specific contamination risk assessment, groundwater abstraction impact predictions, facilitate a comprehensive local scale GDE and IDE assessment and develop robust groundwater monitoring network including collecting of baseline data.

Recommendations

In terms of recommendations for further work which needs to be completed before water supply and hydraulic stimulation activities occur:

1. All exploration wells should be drilled to a Category 9 (or above) standard of well construction incorporating cement casing from the shale formation to the surface, as per SREBA recommendation 5.3 (NT Government 2018). Current Santos well design does not have cement to surface stipulated around the 5 ½" production casing (see pg. 65 Fig. 11 of EMP);

2. Detailed seismic survey across the area to identify the locations of minor fractures and faults that may be activated or act as existing conduits;
3. Baseline surface gas survey in all existing bores and oil gas wells, the latter of which need to be also evaluated for current well seal status;
4. Installation of groundwater monitoring network in the target aquifers, including aquifer testing, typically this occurs in the context of other development before a water licence approval and also noting the large increase currently not approved as part of the current water licence;
5. Extended constant rate aquifer tests (minimum 72hrs) should be carried out on all groundwater abstraction bores, and data should be collected from a comprehensive monitoring bore network that should be installed for all GDE types once a holistic assessment is completed. During testing discharge water should be frequently monitored (e.g. every 30 mins) for water quality parameters such as pH and salinity as this can provide important additional data. Robust estimates of hydraulic conductivity need to be available so a more defensible and preferably precautionary groundwater model can be developed/presented (see item 9 below);
6. A network of nested piezometers or a set of monitoring bores (targeting shallower aquifer units at each site ~<1km) should be established. The groundwater monitoring network should include (recommendations 7.1 and 7.3 SERBA) multilevel monitoring bores. This should include at least one site that includes all aquifers likely to be intersected (e.g. Anthony Lagoon Beds, Gum Ridge Formation, Unnamed Sandstone, Bukalara Sandstone). The deeper aquifers (e.g. Bukalara Sandstone, Moroak Sandstone and Bessie Creek Sandstone) may require a more pragmatic approach to monitoring. Deeper (than 1km) groundwater heads should be measured in all hydrostratigraphic units via techniques such as drill stem tests (DST) during hydrocarbon exploration drilling. Connections between the formations above and below the Cambrian Limestone need to be better established, including the Bessie Sandstone unit underlying the Velkerri Formation (target gas zone) prior to approval. A hydrograph of groundwater levels at each current monitoring site would be a helpful inclusion;
7. A bore census for water quality and gas at all pre-existing bores and in exploration/monitoring bores (see above) that should be installed before any approval is given to better understand the current hydrogeological conditions. This should include a methane isotopes sampling program to differentiate between biogenic and thermogenic sources of methane;
8. A detailed assessment of the distribution and groundwater dependency of GDEs is required. The first stage of the GDE toolkit (Richardson et al., 2011a) needs to be applied at all project locations at a minimum. If GDEs are detected then application of Part 2 of the GDE toolkit (Richardson et al., 2011b). This will ensure the impact assessment will include all possible drawdown receptors. To be explicit all 3 broad groups of GDEs - Aquatic (pools, springs, soaks, seeps etc), Subterranean (stygofauna and troglofauna) and Terrestrial (groundwater dependent vegetation) need to be assessed. These investigations should be completed prior to any further disturbance. Note that this should include a stygofaunal survey on all current and future groundwater monitoring bores and that linked cultural values should also be considered;
9. A groundwater model (that has undergone a sensitivity analysis, incorporating the data suggested herein) needs presenting, incorporating conceptual mechanisms (i.e. fault/fracture water and gas transport) by which any impacts may manifest. Once this is completed and a more robust impact assessment is presented, the potential impact area

may increase, in which case the receptor survey from the dot point above may need to be increased;

10. The following is a list of recommendations that should also be addressed in the context of the fault seal analysis:
    a. Gas logging during all drilling both for water bores and hydrocarbon wells;
    b. Water quality needs evaluation in deep aquifers prior to HFS, the area has unexplored water resources that could be impacted;
    c. Pressure monitoring in bores screened in the deep aquifer (i.e. the groundwater monitoring bores proposed above) with real time pressure monitoring during hydraulic stimulation should be considered. This type of monitoring is a more reliable way of assessing how the transient pressure during hydraulic fracture stimulation propagates and impacts on deep aquifers located in critical areas, particularly near faults and fractures;
    d. Monitoring of breakouts and drilling induced tensile fractures during drilling;
    e. Fracture stability assessment should be conducted as a routine. Maximum bounds for stimulation pressure require site specific thresholds based on a consideration of both the stress state and reservoir type;
    f. Fracture propagation modelling, G Function analysis and interpretation, stress barriers assessment. Stress barriers, not just geomechanical contrasts, are required for fractures to be contained within the hydraulic stimulation zone. There needs to be more detailed consideration of minimum horizontal stress in the cap rock and this needs to be completed for all areas where hydraulic stimulation is proposed.

Specific Comments

Page 15 – "A Tier 2 assessment has been undertaken (Appendix D) on these chemicals with the results showing no unacceptable risks to workers or avian species from the activity."

> Comment – Were stygofauna, troglofauna or aquatic species considered? What about contamination risks to aquifers via fractures/faults or inadequate well integrity?

Page 66 – "An intermediate casing pipe may be installed to isolate deeper aquifer systems (if present), for example the Bukalara Sandstone may be cased off to reduce the risk of impact to this layer."

> Comment – The intermediate casing should isolate any deeper aquifer systems intersected during drilling. The use of the term 'may be' makes it unclear whether deeper aquifers will be isolated by intermediate casing. Wells should be constructed to Category 9 standards as per the SERBA recommendation 5.3.

Page 66 – "After the production hole is drilled and logged, the production casing pipe is lowered to the total depth of the borehole (including horizontal laterals) and cemented in place (vertical pilot well total depth typically ten to 20 metres below the base of the lowermost hydrocarbon-bearing unit, but ideally not penetrating the underlying aquifer systems (if present)). The pilot hole will be isolated with cement. At both Jibera South and Newcastle south this is not anticipated, as the Velkerri formation (an interlaminated mudstone and siltstone) is anticipated to provide an impermeable layer between the lowest drill point and the potentially underlying Bessy Creek Sandstone partial aquifer."

> Comment – This impermeability between the Velkerri Formation and underlying Bessie Creek Sandstone needs to be demonstrated, not just anticipated. The Beetaloo Basin

Hydrogeological Assessment (Fulton & Knapton 2015 pg. 21) states that The Bessie Creek Sandstone outcrops on Tanumbirini and Carpentaria stations. The appraisal location is on Tanumbirini Station. Figure 11 in the EMP has The Bessie Creek Sandstone at 3500m below ground. The vertical separation can only be explained by faulting or major structural deformation of units. This needs to be better understood across the project, particularly to the east. Noting that the geological cross-section presented in Evans et al. (2020) do not contain information to the east of the project, see figure extracted below with approximate project area. Horizontal wells are planned to be up to 3.5km, this also needs be considered in the impact assessments.

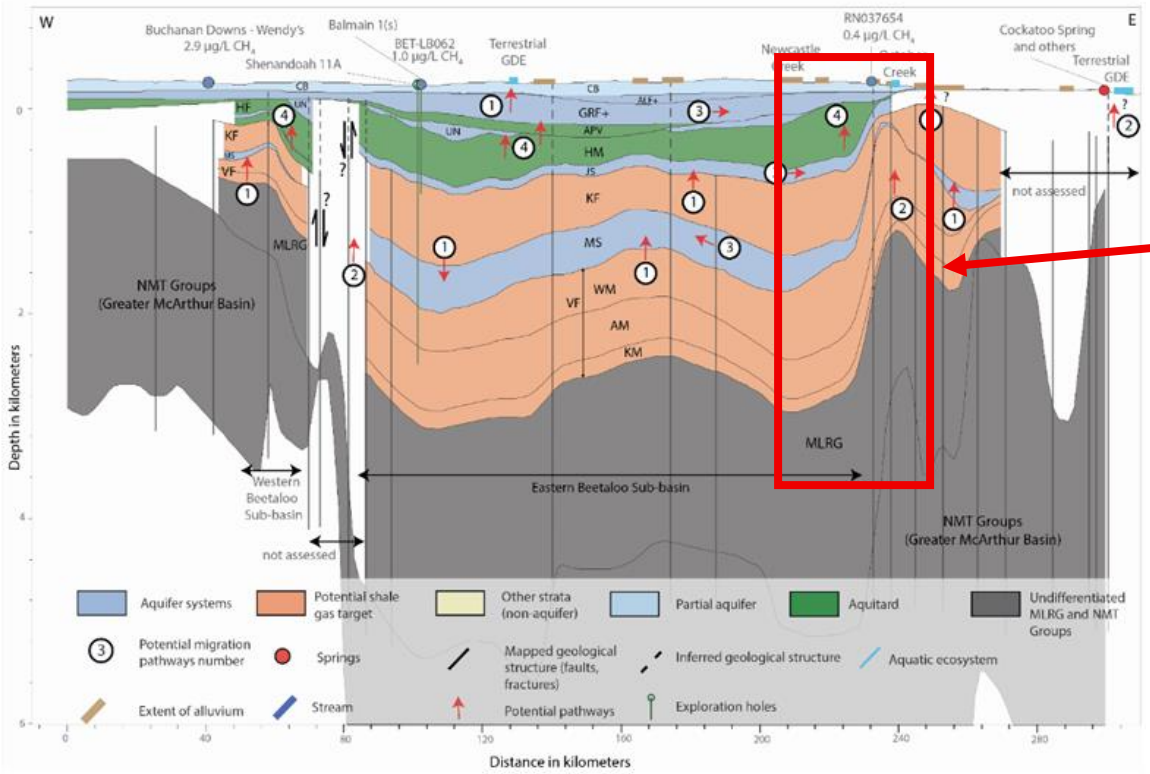

Figure 46 Cross-section B-B', with west–east orientation, across the Beetaloo GBA region, showing five potential hydrological connections for water or gas migration

The five potential hydrological connections are: 1. via direct stratigraphic contact; 2. via faults; 3. through porous/karst aquifers; 4. through partial aquifers/aquitards reaching overlying aquifers; 5. via groundwater discharge from CLA aquifer to springs.
NMT – Nathan/McArthur/Tawallah Groups; MLRG – Middle to Lower Roper Group; VF – Velkerri Formation (WM – Wyworrie Member, AM – Amungee Member; KM – Kalala Member); MS – Moroak Sandstone; KF – Kyalla Formation; JS – Jamison sandstone; HM – Hayfield mudstone; UKM – Upper Kyalla Member; UN – Undifferentiated Neoproterozoic (including Bukalara Sandstone); APV – Antrim Plateau Volcanics; GRF+ - Gum Ridge Formation and equivalents (lower CLA); ALF+ - Anthony Lagoon Formation and equivalents (upper CLA) .
Data: faults sourced from Betts et al. (2015) , unconventional gas plays footprints from Geological and Bioregional Assessment Program (2019b), springs from Department of Environment and Natural Resources (NT) (2013) and geology from Geological and Bioregional Assessment Program (2019a) and Frogtech Geoscience (2018a); methane data from Wilkes et al. (2019)
Element: GBA-BEE-2-348

Page 66 – "The production casing pipe is cemented, from bottom to inside the previous casing (and sometimes to surface), to achieve robust and effective isolation of the well from the various subsurface layers (aquifers and aquitards alike)."

> Comment – Note underline; a Category 9 standard of well construction incorporates cement casing from the shale formation to the surface. It forms part of SREBA recommendation 5.3 (NT Government 2018) "*all onshore shale gas wells (including exploration wells constructed for the purposes of production testing) be constructed to at least a Category 9 standard (unless it can be demonstrated by performance modelling/assessment that an alternative design would give at least an equivalent level of protection), with cementing extending up to at least the shallowest problematic hydrocarbon-bearing, organic carbon rich or saline aquifer zone;"* This has not been demonstrated and therefore cementing to the surface along the length of the well from the target zone upwards is required. Current Santos well design does not have cement to surface around the 5 ½" production casing (see pg. 65 EMP) and the shoe is planned to be located just above the Moroak Sandstone (a known aquifer).

Page 75 – "If the casing bond log from the primary cement job typically executed during the drilling phase identifies issues with the integrity of the cement, further evaluation is undertaken. If it is determined that the loss of integrity poses an unacceptable risk, remedial cementing works will be undertaken. This is managed by the WOMP."

> Comment - The integrity of the wells annular seals are of particular importance in this setting. The Cambrian Limestone is described as vast vuggy limestone aquifer, which can often be cavernous. Particular care needs to be taken when cementing to surface during bore construction to ensure a complete seal. The WOMP should be reviewed to assess the remedial works and whether they are sufficient.

Page 95 – "No impacts to potential Groundwater Dependent Ecosystems (GDE) are anticipated as the targeted aquifer depth for the water bore at the well site is around 120 metres below ground. Therefore, there is significant separation and geological barriers between the target zones and the shallow perched groundwater system GDEs would be sourcing from (see section 4.4.11 for further discussion on GDEs)."

1. Comment - Any shallow 'surface' aquifers in the project area have not been discussed. The identification of GDEs (*see EMP pg. 136*) 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 CLA. The Anthony Lagoon Formation and the Gum Ridge Formation of the Cambrian Limestone aquifer appear to be hydraulically connected. The major knowledge gap is the hydrogeological units that overlie the Cambrian Limestone aquifer 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 Cambrian Limestone affect water levels or quality in overlying aquifers closer to the surface which could impact on GDE's?

Page 111 – "The north-eastern portion of EP 161 is outside of the spatial extent of the CLA and is characterized by Proterozoic-aged geology."

> Comment – A structural geology map would be a useful inclusion here to show the vertical uplift/faults associated with the Proterozoic aged geology.

Page 111 – “At the location of the proposed activities, the CLA is the only aquifer present (Anthony Lagoon and Gum Ridge formations). No other formations in this area are classified as aquifers.”

> Comment – The Bessie Creek Sandstone and Bukalara Sandstone are classified as aquifers and predicted to lie beneath the site. Also, the Unnamed Sandstone and Moroak Sandstone are local aquifers.

Page 118 – “There is also a range of small wetlands associated with springs, sinkholes and minor depressions in the generally flat landscape.”

> Comment – These potential GDEs need better assessment as described herein.

Page 137 – “Given the absence of detections and the spatial separation from known occurrences, it is considered unlikely that stygofauna are present within the Project Area.”

> Comment – This is an assumption and should be demonstrated by a stygofaunal survey on all current and future groundwater monitoring bores.

Page 137 – “The closest mapped spring, Stone Spring, is located approximately 45 kilometres to the north of Jibera South well pad. Stone Spring is situated within 'Hot Springs Valley' within Tanumbirini Station. The 'Hot Spring Valley' is a series of springs likely relating to outcropping of Roper Group Mesoproterozoic formations. Lagoon Creek Spring within 'Hot Springs Valley' is interpreted to be likely sourced from the Bessie Creek Sandstone (CSIRO. 2025). The Moroak and Bessie Creek Sandstone formations within the Roper Group, believed to supply the Hot Springs Valley springs, are not considered environmentally sensitive for the Beetaloo Basin Appraisal Pilot because they occur at substantial depth beneath the proposed well pads.”

> Comment -This shows that there is connectivity in the basin between the deeper units and the surface. This needs a lot more consideration.

Appendix A-K Page 2269 – “A review of the groundwater conditions, including quantity and quality, of the lithological units intersected by the project appraisal bores indicate that the sandstone units below the CLA, due to the significant depth and poor water quality, are not classified as viable aquifers. These units are therefore not included in the project groundwater monitoring program.”

> Comment – The Bukalara Sandstone aquifer is well recognised, and two studies have indicated potential for upwards groundwater flow into the CLA from this sandstone (DEPWS 2021). The Moroak Sandstone is not utilised as a groundwater resource within the Beetaloo GBA region however outside the Beetaloo GBA region (where these rocks occur near surface), the Moroak and other sandstones in the Roper Group are utilised and may also be a source aquifer for some springs (Evans et al. 2020). Not including these aquifers in the assessment is a major oversight.

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Appendix A - 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 storage, disposal and/or Reuse - the disposal and reuse of hydraulic fracturing wastewater. Storage and 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. Hence these issues need to be assessed on case by case basis. These pathways are not only important for contamination impacts via hydraulic stimulation, they also could allow groundwater production related drawdown to propagate to the surface.

Annexure A - Expert Brief from Johnson Legal.

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EXPERT BRIEF

CONFIDENTIAL AND LEGALLY PRIVILEGED

Date: 12 December 2025

To: Dr Ryan Vogwill
Director & Principal Hydrogeologist
Hydro Geo Enviro Pty Ltd

By e-mail only: ryany@hydrogeoenviro.com.au

ENVIRONMENT CENTRE NT

SANTOS – BEETALOO BASIN APPRAISAL PILOT EMP

From: Johnson Legal
Level 21, 8 Chifley Square
SYDNEY NSW 2000

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PRO BONO SCHEME SUPPORTER 2025

PROFESSIONAL STANDARDS SCHEME

Dear Dr Vogwill

Environment Centre NT (ECNT) – Santos QNT Pty Ltd Beetaloo Basin Appraisal Pilot Environment Management Plan (EMP)

1. We confirm that we act for ECNT in the above matter, who wish to provide submissions in relation to the EMP currently under assessment with the Northern Territory Government.

2. We wish to brief you to provide a preliminary expert report for ECNT in relation to the likely impacts and risks to water and the environment associated with the carrying out of the Project, within your scope of expertise.

The EMP

3. As part of the assessment process, the EMP was published for comment on 21 November 2025.

4. Comments on the EMP will close on **19 December 2025.**

5. The key documents subject to assessment is linked below:

    a. EMP currently open to comment and relevant appendices, including:

        - Appendix A-K - Summary of Approved Regulated Activities
        - Appendix L – Cultural Heritage Assessment
        - Appendix M - Emergency Response Plan – Mcarthur and Ameadeus Basins

The Project

6. Santos is an Interest Holder and operator of Exploration Permit (**EP**) 161 located in the Beetaloo Basin, approximately 350 kilometres south-east of Katherine in the Northern Territory.

7. Santos proposes to drill and test petroleum appraisal wells across two locations within EP 161, collectively referred to as the Beetaloo Appraisal Pilot.

8. The subject EMP covers the installation of up to twelve new petroleum appraisal wells at two separate well pads within EP 161. Some of the proposed activities include:

    a. Clearing and earthworks for 2 new well pad locations – The clearing and construction to create two new well pads and ancillary infrastructure at well pad locations referred;

    b. Drilling up to 12 appraisal wells, either vertical or horizontal well types;

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c. Operating, testing, maintenance and decommissioning and hydraulic fracture stimulation of up to 12 appraisal wells;

d. Wastewater management – each well pad will include evaporation tanks, storage tanks, drilling sumps, cutting pits and any transfer infrastructure within the well pad. This also includes transportation onsite and disposal of these wastes (unless otherwise approved for reuse or burial).

9. The approval criteria are set out in reg 9 of the *Petroleum (Environment) Regulations 2016* (**the Regulations**) and include that the EMP must demonstrate that the Project will be carried out in a manner by which the environmental impacts and environmental risks will be reduced to a level that is 'as low as reasonably practicable' (ALARP) and 'acceptable'.

10. In determining whether or not to approve the EMP, the Minister must consider whether the EMP for the Project should be approved pursuant to the *Petroleum Act 1984* and the Regulations and if so, on what conditions.

Your brief

11. We request that you:

    a. Provide an expert report for ECNT by **16 December 2025** in relation to:

        i. The environmental impacts and risks (specifically, regarding wastewater spills and risks in respect of inter-aquifer connectivity) associated with the Project and the carrying out of the Project. This would include your assessment of the likelihood of any risks identified and the environmental impacts and consequences if those risks crystallise; and

        ii. Any recommended conditions or recommended amended conditions for the EMP to ameliorate the environmental impacts and risks you have identified in (i). This aspect should address the degree to which the EMP and proposed works meet the standards set by the legislation and the standards recommended by the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (Pepper Inquiry).

12. We ask that you prepare your opinion in accordance with the NT Supreme Court's Practice Direction No. 6 of 2015 – Expert Reports.

13. We note that under the Practice Direction, 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.

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Your fees

12. Please provide us with an estimate of your fees for carrying out this work at your earliest convenience.

Yours faithfully
Johnson Legal Pty Ltd

Matt Floro
Principal Lawyer

Encl.

INDEX TO BRIEF

An index to the materials briefed is below. A copy of the annexures is contained at this Dropbox link.

No.	Document	Date
1	Beetaloo Basin Appraisal Pilot Environmental Management Plan	November 2025
2	Appendix A-K	November 2025
3	Appendix L	November 2025
4	Appendix M-P	November 2025

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EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected. Please see the caveat for interpretation of information provided here.

Report created: 18-Dec-2025

Summary
Details
- Matters of NES
- Other Matters Protected by the EPBC Act
- Extra Information

Caveat
Acknowledgements

Summary

Matters of National Environment Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Importance (Ramsar	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	None
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	19
Listed Migratory Species:	15

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at https://www.dcceew.gov.au/parks-heritage/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Lands:	None
Commonwealth Heritage Places:	None
Listed Marine Species:	20
Whales and Other Cetaceans:	None
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	None
Habitat Critical to the Survival of Marine Turtles:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have

State and Territory Reserves:	1
Regional Forest Agreements:	None
Nationally Important Wetlands:	None
EPBC Act Referrals:	1
Key Ecological Features (Marine):	None
Biologically Important Areas:	None
Bioregional Assessments:	None
Geological and Bioregional Assessments:	1

Details

Matters of National Environmental Significance

Listed Threatened Species			[Resource Information]
Status of Conservation Dependent and Extinct are not MNES under the EPBC Act. Number is the current name ID.			
Scientific Name	Threatened Category	Presence Text	Buffer Status
BIRD			
Calidris acuminata Sharp-tailed Sandpiper [874]	Vulnerable	Species or species habitat may occur within area	In feature area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area	In feature area
Chloebia gouldiae listed as Erythrura gouldiae Gouldian Finch [90091]	Endangered	Species or species habitat known to occur within area	In feature area
Erythrotriorchis radiatus Red Goshawk [942]	Endangered	Species or species habitat may occur within area	In feature area
Falco hypoleucos Grey Falcon [929]	Vulnerable	Species or species habitat may occur within area	In feature area
Falcunculus frontatus whitei Crested Shrike-tit (northern), Northern Shrike-tit [26013]	Vulnerable	Species or species habitat likely to occur within area	In feature area
Grantiella picta Painted Honeyeater [470]	Vulnerable	Species or species habitat may occur within area	In buffer area only
Rostratula australis Australian Painted Snipe [77037]	Endangered	Species or species habitat may occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Tyto novaehollandiae kimberli Masked Owl (northern) [26048]	Vulnerable	Species or species habitat likely to occur within area	In feature area
MAMMAL			
Dasyurus hallucatus Northern Quoll, Digul [Gogo-Yimidir], Wijingadda [Dambimangari], Wiminji [Martu] [331]	Endangered	Species or species habitat may occur within area	In buffer area only
Macroderma gigas Ghost Bat [174]	Vulnerable	Species or species habitat may occur within area	In buffer area only
Macrotis lagotis Greater Bilby [282]	Vulnerable	Species or species habitat may occur within area	In buffer area only
Saccolaimus saccolaimus nudicluniatus Bare-rumped Sheath-tailed Bat, Bare-rumped Sheathtail Bat [66889]	Vulnerable	Species or species habitat may occur within area	In buffer area only
Trichosurus vulpecula arnhemensis Northern Brushtail Possum [83091]	Vulnerable	Species or species habitat likely to occur within area	In feature area
REPTILE			
Elseya lavarackorum Gulf Snapping Turtle [67197]	Endangered	Species or species habitat may occur within area	In feature area
Tiliqua scincoides intermedia Northern Blue-tongued Skink [89838]	Critically Endangered	Species or species habitat known to occur within area	In feature area
Varanus mertensi Mertens' Water Monitor [1568]	Endangered	Species or species habitat known to occur within area	In feature area
Varanus mitchelli Mitchell's Water Monitor [1569]	Critically Endangered	Species or species habitat may occur within area	In feature area
SHARK			

Scientific Name	Threatened Category	Presence Text	Buffer Status
Pristis pristis Largetooth Sawfish, Freshwater Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Endangered	Species or species habitat may occur within area	In feature area

Listed Migratory Species [Resource Information]

Scientific Name	Threatened Category	Presence Text	Buffer Status
Migratory Marine Birds			
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area	In feature area
Migratory Marine Species			
Crocodylus porosus Salt-water Crocodile, Estuarine Crocodile [1774]		Species or species habitat likely to occur within area	In buffer area only
Pristis pristis Largetooth Sawfish, Freshwater Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Endangered	Species or species habitat may occur within area	In feature area
Migratory Terrestrial Species			
Cecropis daurica Red-rumped Swallow [80610]		Species or species habitat may occur within area	In feature area
Cuculus optatus Oriental Cuckoo, Horsfield's Cuckoo [86651]		Species or species habitat may occur within area	In feature area
Hirundo rustica Barn Swallow [662]		Species or species habitat may occur within area	In feature area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat may occur within area	In feature area
Motacilla flava Yellow Wagtail [644]		Species or species habitat may occur within area	In feature area
Migratory Wetlands Species			
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat may occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Calidris acuminata Sharp-tailed Sandpiper [874]	Vulnerable	Species or species habitat may occur within area	In feature area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area	In feature area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area	In feature area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area	In feature area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat may occur within area	In feature area
Pandion haliaetus Osprey [952]		Species or species habitat likely to occur within area	In buffer area only

Other Matters Protected by the EPBC Act

Listed Marine Species			[Resource Information]
Scientific Name	Threatened Category	Presence Text	Buffer Status
Bird			
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat may occur within area	In feature area
Anseranas semipalmata Magpie Goose [978]		Species or species habitat may occur within area overfly marine area	In feature area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area overfly marine area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Bubulcus ibis as Ardea ibis Cattle Egret [66521]		Species or species habitat may occur within area overfly marine area	In feature area
Calidris acuminata Sharp-tailed Sandpiper [874]	Vulnerable	Species or species habitat may occur within area	In feature area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area overfly marine area	In feature area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area overfly marine area	In feature area
Cecropis daurica as Hirundo daurica Red-rumped Swallow [80610]		Species or species habitat may occur within area overfly marine area	In feature area
Chalcites osculans as Chrysococcyx osculans Black-eared Cuckoo [83425]		Species or species habitat may occur within area overfly marine area	In feature area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area overfly marine area	In feature area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat may occur within area overfly marine area	In feature area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat likely to occur within area	In feature area
Hirundo rustica Barn Swallow [662]		Species or species habitat may occur within area overfly marine area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Merops ornatus			
Rainbow Bee-eater [670]		Species or species habitat may occur within area overfly marine area	In feature area
Motacilla cinerea			
Grey Wagtail [642]		Species or species habitat may occur within area overfly marine area	In feature area
Motacilla flava			
Yellow Wagtail [644]		Species or species habitat may occur within area overfly marine area	In feature area
Pandion haliaetus			
Osprey [952]		Species or species habitat likely to occur within area	In buffer area only
Rostratula australis as Rostratula benghalensis (sensu lato)			
Australian Painted Snipe [77037]	Endangered	Species or species habitat may occur within area overfly marine area	In feature area
Reptile			
Crocodylus johnstoni			
Freshwater Crocodile, Johnston's Crocodile, Johnstone's Crocodile [1773]		Species or species habitat may occur within area	In feature area
Crocodylus porosus			
Salt-water Crocodile, Estuarine Crocodile [1774]		Species or species habitat likely to occur within area	In buffer area only

Extra Information

State and Territory Reserves [Resource Information]

Protected Area Name	Reserve Type	State	Buffer Status
Bullwaddy	Conservation Reserve	NT	In buffer area only

EPBC Act Referrals [Resource Information]

Title of referral	Reference	Referral Outcome	Assessment Status	Buffer Status
Not controlled action				
Improving rabbit biocontrol: releasing another strain of RHDV, sthrn two thirds of Australia	2015/7522	Not Controlled Action	Completed	In feature area

Geological and Bioregional Assessments			[Resource Information]
Name	State	Website	Buffer Status
Beetaloo GBA region	NT	GBA website	In feature area

Caveat

1 PURPOSE

This report is designed to assist in identifying the location of matters of national environmental significance (MNES) and other matters protected by the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act) which may be relevant in determining obligations and requirements under the EPBC Act.

The report contains the mapped locations of:

- World and National Heritage properties;
- Wetlands of International and National Importance;
- Commonwealth and State/Territory reserves;
- distribution of listed threatened, migratory and marine species;
- listed threatened ecological communities; and
- other information that may be useful as an indicator of potential habitat value.

2 DISCLAIMER

This report is not intended to be exhaustive and should only be relied upon as a general guide as mapped data is not available for all species or ecological communities listed under the EPBC Act (see below). Persons seeking to use the information contained in this report to inform the referral of a proposed action under the EPBC Act should consider the limitations noted below and whether additional information is required to determine the existence and location of MNES and other protected matters.

Where data is available to inform the mapping of protected species, the presence type (e.g. known, likely or may occur) that can be determined from the data is indicated in general terms. It is the responsibility of any person using or relying on the information in this report to ensure that it is suitable for the circumstances of any proposed use. The Commonwealth cannot accept responsibility for the consequences of any use of the report or any part thereof. To the maximum extent allowed under governing law, the Commonwealth will not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance on the contents of this report.

3 DATA SOURCES

Threatened ecological communities

For threatened ecological communities where the distribution is well known, maps are generated based on information contained in recovery plans, State vegetation maps and remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species

Threatened, migratory and marine species distributions have been discerned through a variety of methods. Where distributions are well known and if time permits, distributions are inferred from either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc.) together with point locations and described habitat; or modelled (MAXENT or BIOCLIM habitat modelling) using point locations and environmental data layers.

Where little information is available for a species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc.).

In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More detailed distribution mapping methods are used to update these distributions when time permits.

4 LIMITATIONS

The following species and ecological communities have not been mapped and do not appear in this report:

- threatened species listed as extinct or considered vagrants;
- some recently listed species and ecological communities;
- some listed migratory and listed marine species, which are not listed as threatened species; and
- migratory species that are very widespread, vagrant, or only occur in Australia in small numbers.

The following groups have been mapped, but may not cover the complete distribution of the species:

- listed migratory and/or listed marine seabirds, which are not listed as threatened, have only been mapped for recorded breeding sites; and
- seals which have only been mapped for breeding sites near the Australian continent

The breeding sites may be important for the protection of the Commonwealth Marine environment.

Refer to the metadata for the feature group (using the Resource Information link) for the currency of the information.

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact us page.

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Preliminary Expert Report Regarding the Greenhouse Gas and Climate Implications of the Santos' Beetaloo Appraisal Pilot within EP161

Dr Penny D Sackett
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ANU Institute for Climate, Energy and Disaster Solutions and ANU Fenner School for the Environment
and
Principal, Strategy Advisory Services

19 December 2025

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1 Preliminaries

1) This preliminary expert report (hereafter, **this Report**) is a response to a brief provided to me by Johnson Legal Pty Ltd (hereafter, **JL**) on 18 December 2025. Said brief (hereafter, the **JL Brief**) is annexed to this Report as Appendix A, with a list of the issues to be addressed in this Report set out in paragraph 11 of the JL Brief.

2) As detailed in the JL Brief, I understand that this Report has been requested by JL on behalf of its client, Environment Centre NT, regarding Environmental Management Plan STO 8-1 (hereafter, the **EMP**[1]) submitted by Santos QNT Pty Ltd (hereafter, the **Proponent**) to the Northern Territory (hereafter, **NT**) Government for assessment in relation to the Proponent's Beetaloo Basin Appraisal Pilot (hereafter, **the Project**) within Exploration Permit (EP) 161.

3) My independent expert advice has been sought, within my expertise, in regard to the environmental impacts and associated with the Project and the carryng out of the Project, particularly in relation to greenhouse gases (hereafter, **GHGs**) and climate change.

4) I note that `Environment' is defined in s6 of the *NT Environment Protection Act 2019* to mean "all aspects of the surroundings of humans including physical, biological, economic, cultural and social aspects." For clarity, I note that my expertise with regard to the impacts of climate change are principally centred on the physical, biological, and social cost aspects of the environment, so defined. This expertise should be assumed throughout my responses in this Report.

5) My formal training is in physics and mathematics. The first half of my research career was dedicated to astrophysics, including the study of planets. Beginning with my tenure as Australia's Chief Scientist (2008 – 2011), my work has focussed on synthesising the science and communication of anthropogenic climate change and its impacts. This work includes over 40 technical reports and other communications on climate change. I have served on the international Science Board of the Potsdam Institute for Climate Impact Research and for many years on the ACT Climate Change Council as Deputy Chair and then Chair. A

[1] Accessed at: https://haveyoursay.nt.gov.au/74566/widgets/382736/documents/319885 from https://haveyoursay.nt.gov.au/emps-under-assessment/surveys/tam1-emp1

curriculum vitae of my qualifications and experience is attached as Appendix B of this Report.

6) The issues I have been instructed to address (see JL Brief, Annexure 1) are discussed in the Sections of this Report as given below.

Issue i	Environmental Impacts, Risks and Consequences from Project GHGs and Climate Change	Section 2
Issue ii	Recommended Conditions for the EMP with regard to Standards	Section 3

7) Given the exceedingly short time I have had to prepare this Report, it should be considered preliminary. I have attempted to directly answer the issues raised in the JL Brief by highlighting main points. Considerably more analysis could be undertaken (noting difficulties posed by missing information in the EMP) should further information be required.

8) I have reviewed the NT Supreme Court Practice Direction for Expert Reports and the Expert Witness Code of Conduct[2], and agree to be bound by these directions in this Report. Specifically, I understand and agree to comply with the expectation 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.*''

9) External sources used in this Report are referenced. Unless otherwise indicated, modelling work presented in external sources is taken at face value, as verifying the results is beyond the scope of this Report. Where relevant, underlying assumptions are noted.

10) Culminating years of work, the United Nations' Intergovernmental Panel on Climate Change (**IPCC**) has recently released four assessment reports in its sixth series, one from each of its Working Groups, and an overall synthesis report. As a compendium of recent

[2] Accessed at: https://supremecourt.nt.gov.au/_resources/documents/lawyers/practice-directions/expert-reports-6-of-2015.pdf

science, these reports form an important evidentiary base and are referred to often in this Report. They are:

a) Climate Change 2021: The Physical Science Basis (hereafter, **AR6 WGI**),[3]

b) Climate Change 2022: Impacts, Adaptation and Vulnerability (hereafter, **AR6 WGII**),[4]

c) Climate Change 2022: Mitigation of Climate Change (hereafter, **AR6 WGIII**),[5] and

d) AR6 Synthesis Report, Summary for Policymakers (hereafter, **AR6 SYR SPM**).[6]

[3] IPCC (2021) Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, accessed at https://www.ipcc.ch/report/ar6/wg1/

[4] IPCC (2022) Climate Change 2022: Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, accessed at: https://www.ipcc.ch/report/ar6/wg2/

[5] IPCC (2022) Climate Change 2022: Mitigation of Climate Change, Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, accessed at: https://www.ipcc.ch/report/ar6/wg3/

[6] IPCC (2023) AR6 Synthesis Report, Climate Change 2023, Summary for Policymakers. Accessed at: https://www.ipcc.ch/report/sixth-assessment-report-cycle/

2 Greenhouse Gas and Climate Impacts and Risks from the Project

11) The JL Brief I have been provided requests that I address:

"*The environmental impacts and risks (specifically, regarding the impacts of the Project on greenhouse gas emissions and climate change, including such impacts on the locality of the Project) associated with the Project and the carrying out of the Project. This would include your assessment of the likelihood of any risks identified and the environmental impacts and consequences if those risks crystallise*."

I do so in this section of the Report.

12) In Section 2.1, I first describe the relationship between GHGs and current anthropogenic climate change.

13) The climate impacts and risks from the Project derive from (1) the GHGs directly associated with Project activities and its products, which are discussed in Section 0, and (2) GHGs from the potential activities and products that are likely to result if the premise upon which approval for the Project is sought is actually realised, which are discussed in Section 51).

14) In Section 2.4, I explain the relationship between these emissions and current, likely and potential climate change impacts, taking note of the current context of global GHG emissions, which provide the cumulative background to which Project emissions provide an additional increment.

2.1 Greenhouse Gases and their Relationship to Human-Caused Global Heating

15) Greenhouse gases (GHGs) trap energy that would otherwise escape from the Earth's upper atmosphere; they have kept the Earth's surface at temperatures suitable for modern human civilisation and agriculture for thousands of years.

16) Since industrialisation, however, and in particular over the last 70 years, **human activities have upset this long-standing balance by increasing the amount of GHGs in the atmosphere.** The additional GHGs caused by human activity create an energy imbalance. **Extra energy is returned to the Earth's surface, causing the global heating that fuels the current disruption in the global climate.**

17) An enormous amount of energy (heat) is required to raise the average surface temperature of the entire Earth by even a small amount. Consequently, **climate change impacts can be large even for rather small changes in the global surface temperature**. The large energy increase caused by human GHG emissions is 'super-charging' the Earth's physical systems that control climate.

18) The primary GHGs driving current human-caused climate change are **carbon dioxide (CO_2)**, **methane (CH_4)**, and **nitrous oxide (N_2O)**. These gases differ in their concentration in the atmosphere, residence time in the atmosphere, and potential to cause a given amount of heating per weight. Of these, **atmospheric concentration is the only property of GHGs that can be significantly influenced by humans**.

19) Excess amounts of CH_4 and N_2O persist in the atmosphere for about 12 and 109 years, respectively.[7] The life cycle of atmospheric CO_2 is more complex. **Most of the carbon dioxide that is not absorbed quickly by ocean and land 'sinks' to become part of a decades-long carbon cycle will remain in the atmosphere for thousands of years or longer.**[8] Whilst GHGs remain in the atmosphere, they continue to contribute to global heating, year after year, regardless of when they were emitted. This means that **the full effect of past GHG emissions is yet to be felt**, as the Earth continues to warm under the influence of historical emissions as well as those emitted in the current year. The long residence time of CO_2 is the primary reason why **most long-term global heating is caused by increases in the amount of CO_2 in the atmosphere**.

20) Due to differences in their atmospheric concentrations and chemical properties, at any given time different GHGs contribute differently to the Earth's energy imbalance (see **Error! Reference source not found.**), based on their radiative forcing, that is the energy flux they deliver to the Earth, generally measured in Watts per square metre.

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[7] Forster P., T. et al. (2021) The Earth's energy budget, climate feedbacks, and climate sensitivity, Chapter & of Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Table 7.15, accessed at: https://www.ipcc.ch/report/sixth-assessment-report-working-group-i/

[8] Lee, J.Y. et al. (2021) Future Global Climate: Scenario-Based Projections and Near-Term Information, Chapter 4 of Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, accessed at: https://www.ipcc.ch/report/sixth-assessment-report-working-group-i/

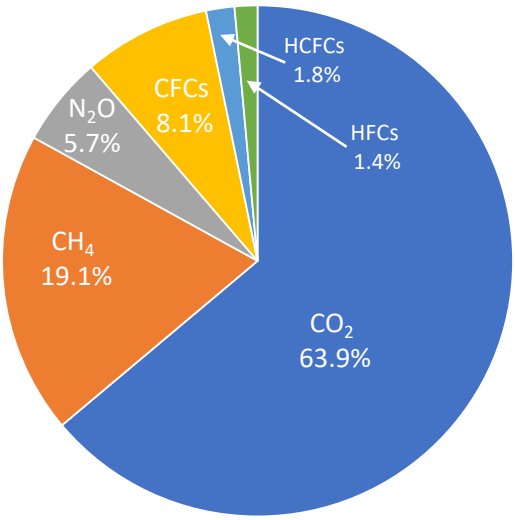

Figure 1: The relative contributions of different anthropogenic GHGs to radiative forcing in 2022. Data are taken from NOAA's Annual Greenhouse Gas Index report[9]. The chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs) are large categories of complex compounds emitted by humans; the complete list included in this chart can be found in the NOAA report.

21) However, due to their different residency times in the atmosphere, GHGs have different global warming potentials (**GWP**s) over longer timescales. That is, per kilogram they differ in the amount of radiation (heat) they trap over a given period of time after they are emitted. **Over a 20-year period, fossil methane[10] is 82.5 times more effective than CO_2 in trapping heat, and 29.8 times more effective over 100 years. Nitrous oxide has a global warming potential about 273 times that of CO_2 on timescales of 20 to 100 years.**[11]

22) **One description of the heating effect of a particular GHG compared to CO_2, its `carbon dioxide equivalent ($CO_2$-e),' can be calculated using its GWP over a particular period of time**. For example, over 100 years, 17 tonnes of fossil $CH_4$ can be accounted as 17 x 29.8 = 506.6 tonnes of $CO_2$-e. This `equivalence' only applies to the time frame of the particular GWP used.

[9] NOAA Global Monitoring Laboratory (2023) The NOAA Annual Greenhouse Gas Index. Accessed at: https://gml.noaa.gov/aggi/aggi.html on 8 November 2023.

[10] Note: Fossil methane has a higher GWP than other sources of CH_4 because it results in fossil carbon added to the atmosphere, which was not previously part of the carbon cycle of the atmosphere. The GWPs for *non-fossil* CH_4 is 80.8 and 27.2 on 20 and 100-year timescales, respectively.

[11] IPCC (2021) AR6 WGI, Chapter 7, Table 7.15

23) **Atmospheric concentrations of CO_2, CH_4 and N_2O have risen since the industrial revolution, with dramatic upward increases of each beginning 1960 – 1980 (Error! Reference source not found.).**[12]

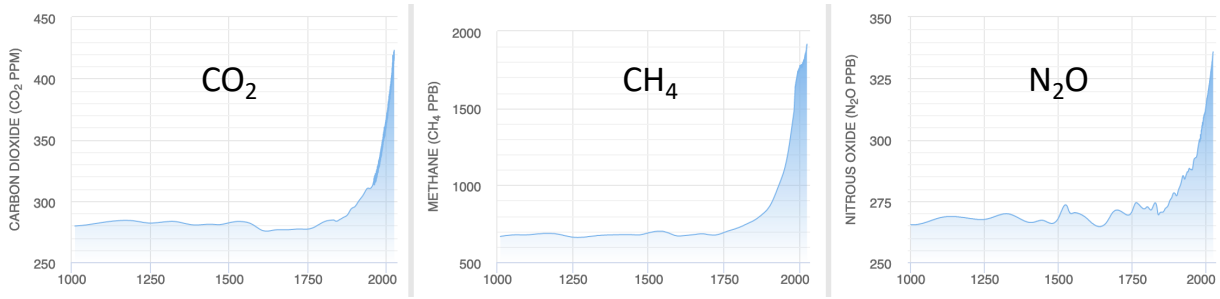

Figure 2: The rise of GHGs in the atmosphere from 1000 AD to present. Graph from the Two Degree Institute, based on ice core records (CSIRO) and in situ measurements (Scripps).

24) **Furthermore, the rate at which atmospheric concentrations of the main anthropogenic GHGs is increasing is *itself* increasing**, as illustrated in Figure 3 below.[13]

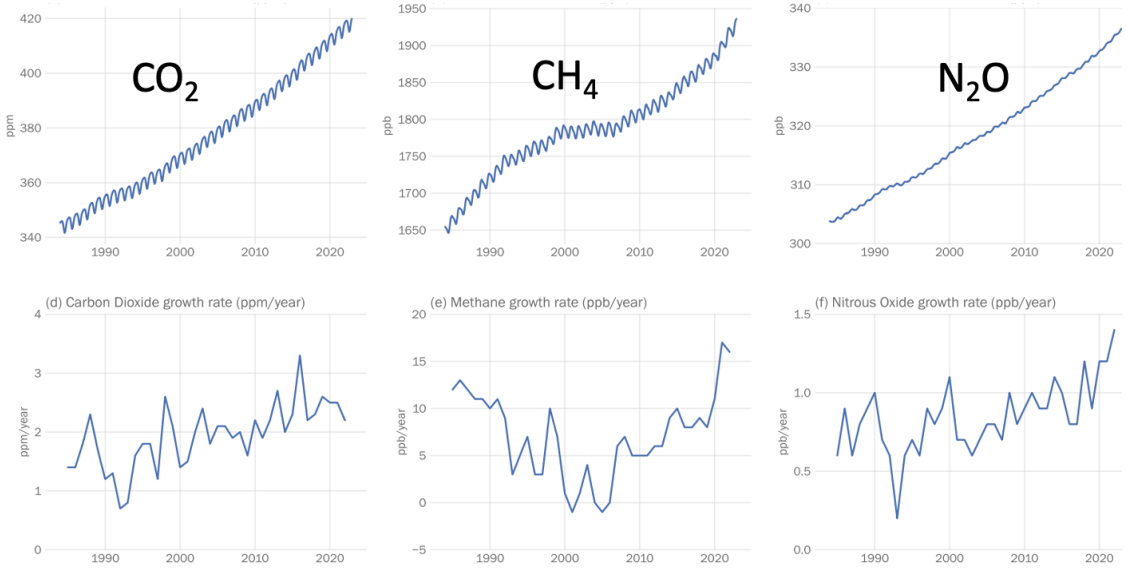

Figure 3: (Upper row) Globally averaged CO_2, CH_4 and N_2O atmospheric concentrations from 1984 to 2022. CO_2 is given in parts per million, whereas CH_4 and N_2O are given in parts per billion. (Lower row). Growth rate of these concentrations from 1984 to 2022. Observations from more than 100 stations were used for this analysis from the WMO. If the atmospheric concentrations were constant, their growth rates would be zero. Instead, the data show that each of the concentrations, although fluctuating, are growing at a faster and faster rate, particularly since about 2005. [After WMO (2023) Provisional State of the Global Climate 2023.]

[12] 2 Degrees Institute (2023) Accessed at: https://www.climatelevels.org/

[13] WMO, UNEP, GCP, UK Met Office, IPCC, UNDRR (2022) United in Science 2022. Accessed at: https://public.wmo.int/en/resources/united_in_science

25) The **current level of atmospheric CO_2 is 25% higher than any other time since the mid-Pliocene, about 2 million years ago**.[14] **Concentrations of CH_4 and N_2O are higher than at any time in at least 800,000 year**s.[15]

26) For perspective, the species modern humans (*Homo sapiens)* is thought to have arisen 300,000 to 600,000 years ago. In other words, **atmospheric levels of CO_2, CH_4 and N_2O are all higher than at any other time our species has inhabited the Earth**.

27) ***Anthropogenic* climate change is change in the Earth's climate caused by *human activities* that release additional greenhouse gases (GHGs) into the atmosphere or alter the natural land and ocean sinks for these gases**.

28) **Nearly all of the heating experienced in the past 160 years is due to human activities**, with natural forces (volcanos, changes in solar radiation, etc) playing a negligible role.[16]

29) The AR6 WGI[17] makes clear the direct relationship between humans and the global heating driving climate change (my emphasis):

   a) "It is **unequivocal that human influence has warmed the atmosphere, ocean and land**" and

   b) "**Human influence has warmed the climate at a rate that is unprecedented in at least the last 2000 years**" and

   c) "**Observed warming is driven by emissions from human activities**, with greenhouse gas warming partly masked by aerosol cooling."

30) **Reducing net anthropogenic GHG emissions to zero and maintaining them at that level is the only way that humans can stabilise the climate. The primary determinant of future climate change, beyond that which is already locked in by emissions to date, is the future trajectory of world emissions, especially the path between now and 2030**.[18] The more

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[14] Fedorov, A.V. et al (2013) Patterns and mechanisms of early Pliocene warmth, in Nature, 496, doi:10.1038/nature12003.
[15] IPCC (2021) AR6 WGI, Summary for Policymakers
[16] Gillett, N.P. et al. (2021) Constraining human contributions to observed warming since the pre-industrial period, in Nature Climate Change, https://doi.org/10.1038/s41558-020-00965-9
[17] IPCC (2021) AR6 WGI, Summary for Policymakers
[18] WMO (2019) United in Science, Report prepared for the UN Climate Action Summit 2019, https://wedocs.unep.org/bitstream/handle/20.500.11822/30023/climsci.pdf

quickly emissions are brought and held to zero, the lower the peak global heating temperature will be.

31) **At present, about 90% of the additional CO_2 emitted per year is from the production and burning of coal, gas, and oil**,[19] with most of the remainder due to land use changes (e.g., deforestation which removes a natural sink for CO_2).

32) **Human CO_2 emissions from fossil fuel use continue to rise,** although at a smaller rate than in the first decade of this century**.** Total human carbon dioxide emissions are anticipated to be 42.2 billion tonnes CO_2 (Gt CO_2) in 2025, including cement carbonation, which is a carbon sink.[20] (See Figure 4, below.)[21]

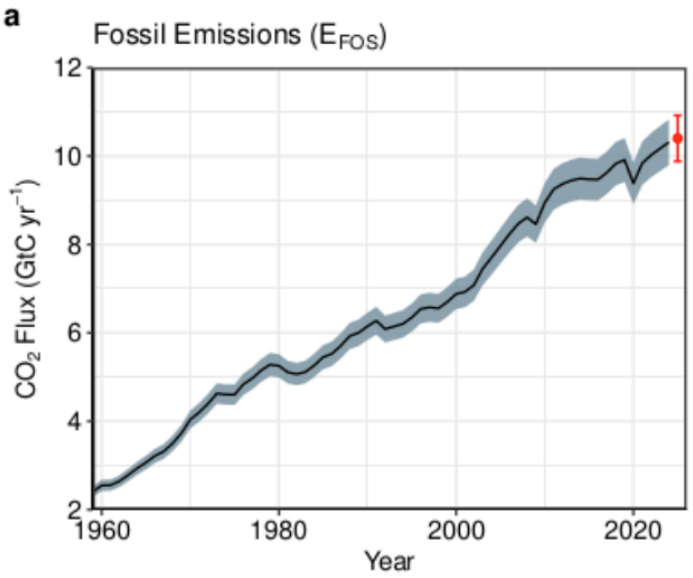

Figure 4: Global human emissions from fossil sources continue to grow, with the estimate for 2025 shown in red. Chart from Friedlingstein et al. (2025).

[19] Friedlingstein, P et al. (2025) Global Carbon Budget 2025, Earth Syst. Sci. Data. Refer to their Table 7. Accessed at https://essd.copernicus.org/preprints/essd-2025-659/

[20] Friedlingstein, P et al. (2025) Global Carbon Budget 2025, Earth Syst. Sci. Data. Accessed at: https://essd.copernicus.org/preprints/essd-2025-659/

[21] Figure from Friedlingstein, P et al. (2025) Global Carbon Budget 2025, Earth Syst. Sci. Data. Accessed at: https://essd.copernicus.org/preprints/essd-2025-659/.

33) The production, delivery and combustion of **fossil fuels is also associated with the release of CH_4.**[22] **A recent surge in atmospheric methane over the past decade** (see Figure 3) **has been attributed in equal parts to agriculture (particularly livestock) and fossil fuels**.[23]

34) However, **further research indicates that methane release from warming and flooded wetlands may play a greater role than previously thought in the accelerating increase of atmospheric methane, especially in the period 2019 – 2021**, **indicating that this climate feedback from methane may be becoming more active**. [24,25,26]

35) All extreme weather events, in fact, **all weather events are affected by climate change**, because the environment in which they occur is warmer, moister and contains more energy than used to be the case.[27] The field of **attribution science is now allowing scientists to quantify the effect of climate change on many extreme events and the consequences of anthropogenic climate change more generally**. Just a few examples are listed below.

36) Of the 131 studies investigating whether climate change is influencing extreme weather published in the Bulletin of the American Meteorological Society between 2011 and 2016, **65 percent found that the probability of the event occurring was increased due to anthropogenic climate change**. **In the case of some extreme high temperatures, the probability increased by a factor of ten or more**.[28]

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[22] WMO 2019, United in Science, Report prepared for the UN Climate Action Summit 2019, https://wedocs.unep.org/bitstream/handle/20.500.11822/30023/climsci.pdf

[23] Jackson, RB et al. (2020) Increasing anthropogenic methane emissions arise equally from agricultural and fossil fuel sources, Environ. Res. Lett., 15, 071002, https://doi.org/10.1088/1748-9326/ab9ed2

[24] Feng, L. et al. (2022) Tropical methane emissions explain large fraction of recent changes in global atmospheric methane growth rate, Nature Communications 13, 1378. https://doi.org/10.1038/s41467-022-28989-z

[25] Peng, S. et al. (2022) Wetland emission and atmospheric sink changes explain methane growth in 2020, Nature, 612, 477. https://www.nature.com/articles/s41586-022-05447-w

[26] Qu, Z. et al. (2022) Attribution of the 2020 surge in atmospheric methane by inverse analysis of GOSAT observations, *ESS Open Archive.* June 17, 2022 preprint. DOI: 10.1002/essoar.10511657.1

[27] Trenberth, K. E. (2012), Framing the way to relate climate extremes to climate change, Climate Change, 115(2), 283–290, doi:10.1007/s10584-012-0441-5

[28] WMO (2018) July sees extreme weather with high impacts. Accessed at: https://public.wmo.int/en/media/news/july-sees-extreme-weather-high-impacts

37) **The widespread coral bleaching of the Great Barrier Reef during 2016 was made 175 times more likely due to climate change**.[29]

38) A recent meta-analysis[30] of 27 studies concerning a total of 976 species found that **47% of local extinctions reported across the globe during last century could be attributed to climate change**.

39) In the period 1991–2018, **37% of warm-season, heat-related human deaths have been attributed to anthropogenic climate change**.[31]

40) **The 2019-2020 Australian bushfires were made 30 – 80% more likely due to anthropogenic climate change**.[32]

41) The **2020 Siberian heatwave would have been "almost impossible" without human-induced climate change**, as it was made at least 600 times more likely as a result of human-induced climate change.[33]

42) The current multi-year drought in East Africa, the worst in 40 years, which has resulted in an estimated 37 million people facing acute food insecurity has been made at least 100 times more likely by anthropogenic climate change.[34]

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[29] King A, Karoly D, Black M, Hoegh-Guldberg O, and Perkins-Kirkpatrick S (2016) Great Barrier Reef bleaching would be almost impossible without climate change. The Conversation, April 29, 2016.
[30] Wiens, J.J., 2016: Climate-Related Local Extinctions Are Already Widespread among Plant and Animal Species. PLOS Biology, 14(12), e2001104, doi:10.1371/journal.pbio.2001104.
[31] Vicedo-Cabrera, A.M. et al. (2021) The burden of heat-related mortality attributable to recent human-induced climate change. Nature Climate Change, 11, 492-500. Accessed at: https://www.nature.com/articles/s41558-021-01058-x
[32] Oldenborgh, G.J. et al. (2021) Attribution of the Australian bushfire risk to anthropogenic climate change, Natural Hazards and Earth System Sciences, 21, 941. Accessed at: https://doi.org/10.5194/nhess-21-941-2021
[33] Ciavarella, A. et al. (2020) Prolonged Siberian Heat of 2020. *World Weather Attribution.* https://www.worldweatherattribution.org/siberian-heatwave-of-2020-almost-impossible-without-climate-change
[34] Kimutai, J. et al. (2023) Human-induced climate change increased drought severity in Horn of Africa, Accessed at: https://spiral.imperial.ac.uk/handle/10044/1/103482

2.2 Greenhouse gases arising from the Project and its activities

43) The activities of Project EMP itself cover the installation of up to 12 new petroleum appraisal wells at two separate well pads within EP 161, with proposed activities including:

a) Clearing and earthworks for two new well pad locations;

b) Drilling up to 12 appraisal wells, either vertical or horizontal well types;

c) Operating, testing, maintenance and decommissioning and hydraulic fracture stimulation of up to 12 appraisal wells;

d) Wastewater management and associated infrastructure.

44) The Clean Energy Regulator defines three types of GHG emissions for National Greenhouse Gas Reporting, namely:

a) **Scope 1** (sometimes called direct emissions): Emissions released into the atmosphere as a direct result of the activities at a facility;

b) **Scope 2**: (a type of indirect emission): Emissions released into the atmosphere outside the facility geographical boundary to produce electricity that is used by the facility;

c) **Scope 3**: (a type of indirect emission): Upstream and downstream emissions that occur outside the facility boundary as a result of facility activities.

45) **Each `Scope' of GHG emission contributes equally to global heating and resultant climate disruption on a tonne per tonne basis for a given GHG gas.**

46) According to the EMP, **the Proponent predicts that `Scope 1' GHG emissions arising from these activities over five years spanning financial years 2025/26 through 2030/31 total 27,741 tonnes of carbon dioxide equivalent (t CO_2-e**). **Scope 3 emissions are not reported and the EMP indicates that Scope 2 emissions would be zero.**

47) **Scope 1 emissions appear to be underestimated in the EMP**; only values for vegetation clearing, fugitives, and non-routine flaring/venting are given.[35] Absent are emissions related to fuel expended by the Proponent in transporting people and materials around

[35] See Table 32 of the EMP.

the well pad sites, and fuels, such as diesel, used in drilling and other on-site activities including construction and/or installation of infrastructure. Section 3.11.9 of the EMP indicates that such supporting infrastructure would include: a designated office, workshop, and laydown areas within each well pad. Correcting these omissions would significantly increase the Scope 1 emissions of the Project above the value given in the EMP.

48) I note that a GWP of 28 tCO_2-e/tCH_4 is used in the Proponent's Scope 1 estimates. This would appear to be based on a comparison period of 100 years for the relative heating effects of CH_4 (methane) compared to CO_2 (carbon dioxide). The best *scientific* estimate for a 100-year GWP of methane is 29.8 (see paragraphs 21) and 22)), which would increase the stated CO_2-e of methane Scope 1 emissions by 6.4%.

49) This Report assumes that the direct Project activities will not involve electricity imported from outside the immediate proximity of the well pads, that is, no Scope 2 GHG emissions are associated with the Project.

50) Whereas the Proponent may not be compelled to report or estimate Scope 3 GHG emissions from the Project, those emissions would have climate impacts. Such emissions would include those associated with the production of any materials used on-site, including cement and steel used in Project infrastructure, as well as many other elements.

51) Taken together, the points above indicate that approval of the Project would result in actual GHG emissions that are substantially above those listed in the EMP. Whilst it is not possible to precisely estimate the magnitude of the under-estimation, **a similar exploration and assessment project, the Amungee NW Delineation Program operating on EP 98 in the NT, estimated a total of 522,172 tCO_2-e in Scope 1 GHG emissions from activities involving 12 new wells over four years in its Environmental Management Plan (ORI11-3), nearly 19 times the level given in the Proponent's EMP.**[36]

[36] ORI11-3 can be accessed at:
https://depws.nt.gov.au/__data/assets/pdf_file/0004/1168483/approved-emp.PDF

2.3 Greenhouse gases arising from the Realisation of the Project Premise

52) The stated premise driving the Proponent's EMP is "*With energy demand increasing, the scale of shale gas resources in the Beetaloo Sub-Basin, if appraisal confirms its potential, would be a gamechanger not only for the Territory, but also for the Australian east coast domestic gas and Asian LNG markets. Development of the Beetaloo Sub-Basin has the potential to significantly increase gas supply . . .* "[37]

53) Given the ambition expressed by the NT Government,[38] it seems reasonable to assume that the premise of paragraph 52) is shared by the NT Government so that there is a significant likelihood that gas lying beneath the surface of EP 161 will be fracked, extracted and on-sold for combustion. Were this to happen, the resultant fossil GHGs released would be enormous. According to the NT Government[39], and substantiated by the Proponent's partner Tamboran[40], EP 161 has an unrisked 2C Contingent Gas Resource of 1.617 Tera[41] cubic feet (Tcf) gas.

54) Estimating the substantial GHG emissions associated with building and operating the infrastructure to extract, process and transport such a large amount of gas as well resultant fugitive emissions are beyond the scope of this Report.

55) However, **an estimate of the GHGs released on *combustion* of the EP 161 unrisked 2C Contingent Gas Resource** can be made as follows, assuming for these purposes that the extracted gas is essentially all methane and all this is combusted:[42]

a) 1.617 Tcf of methane = 45.8 billion cubic meters of methane,

b) which has an energy content equivalent to about 1.8 billion Giga Joules (GJ)[43]

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[37] Quote from the foreword of the EMP.
[38] See, e.g., https://resourcingtheterritory.nt.gov.au/energy/oil-and-gas/onshore-exploration-highlights and https://territorygas.nt.gov.au/_resources/documents/nt-gas-plan-full-document.pdf
[39] https://resourcingtheterritory.nt.gov.au/energy/onshore-sedimentary-basin-inventories/beetaloo-sub-basin
[40] https://www.marketscreener.com/quote/stock/TAMBORAN-RESOURCES-CORPOR-124598243/news/Tamboran-Resources-Limited-Tamboran-Increases-EP161-2C-Contingent-Gas-Resource-by-164-41694188/
[41] `Tera' denotes 10^{12}, that is 1 Tcf = 1,000 billion cubic feet
[42] See https://www.dcceew.gov.au/climate-change/publications/national-greenhouse-accounts-factors-2025
[43] `Giga' denotes 10^{9}, that is 1 GJ = 1 billion Joules

c) which would result in approximately 92.7 billion kilograms of CO_2-e

d) which **is equivalent to 92.7 million tonnes (Mt) of CO_2-e**.

56) **Should the full extraction potential of EP161 crystallise, therefore, up to 92.7 Mt CO_2-e would be released into the atmosphere.** For comparison, all GHG emissions emitted within Northern Territory borders in 2023, the latest year for which data is provided in the National Greenhouse Gas Accounts, is reported as **23.58 Mt CO_2-e**. Although not all of the GHG emissions from the combustion of potential EP161 gas would occur within NT borders, on a tonne-per-tonne basis, those emissions would affect localities in the NT equally through increasingly adverse impacts of resultant climate disruption.

2.4 Climate impacts and risks arising from the Project, its Activities and Premise

2.4.1 Current and `locked-in' climate impacts in the Territory

57) **Strong climate change impacts are already being experienced across the Territory**. Although the EMP has a short section describing current temperature and rainfall averages, it is silent on the current climate *trends* experienced by localities within the Territory. According to the NT Government:[44]

a) "Over the last century, annual average temperatures across the Territory have increased by 0.5°C in the west and 2.2°C in the south-east. **There has been a significant increase in the number of extremely hot days, in both the Top End and central Australia. Climate modelling indicates that these trends will continue**."

b) "While **average rainfall** has remained fairly consistent in the southern parts of the Territory, it **has increased in the Top End**. Climate models are unclear about trends in annual rainfall, but **the intensity of heavy rainfall events is expected to increase across the Territory**. At the same time, **droughts are likely to be more severe due to increasing temperatures, and more extreme fire behaviour is expected. Tropical cyclones are expected to become less frequent but be more intense**."

c) "**Sea levels are rising, with the Territory coasts experiencing some of the highest rises in the world**. Levels are projected to rise by up to 0.17m by 2030, and by up to 0.85m by 2090, compared to levels across the 1986 – 2005 period. **Higher sea surface temperatures and ocean acidification pose significant threats to the marine environment**."

d) A 2020 report[45] prepared specifically to describe current and future climate change impacts in the NT (hereafter, the **Hub Report**), shows the clear, strong trend of increasing numbers of hot days in the Territory. Fig. 5 (below) is taken from this

[44] Northern Territory Government (2020) Northern Territory Climate Change Response: Towards 2050. Accessed at: https://climatechange.nt.gov.au/nt-climate-change-response/northern-territory-climate-change-response-towards-2050

[45] NESP Earth Systems and Climate Change Hub (2020) Climate change in the Northern Territory: state of the science and climate change impacts. Accessed at: https://denr.nt.gov.au/__data/assets/pdf_file/0011/944831/state-of-the-science-and-climate-change-impacts-final-report.pdf

report and shows that **not only have hot days above 30°C generally increased in the Territory** in the three decades between 1989 and 2018, compared to three decades prior**, but days above 38°C and 44°C in regions such as Tennant Creek and Alice Springs have risen very sharply**.

	Darwin		Tennant Creek		Alice Springs	
	Days above 30°C	Days above 35°C	Days above 38°C	Days above 44°C	Days above 38°C	Days above 44°C
1959–1988	295	7	39	0	41	4
1989–2018	327	14	48	7	49	24

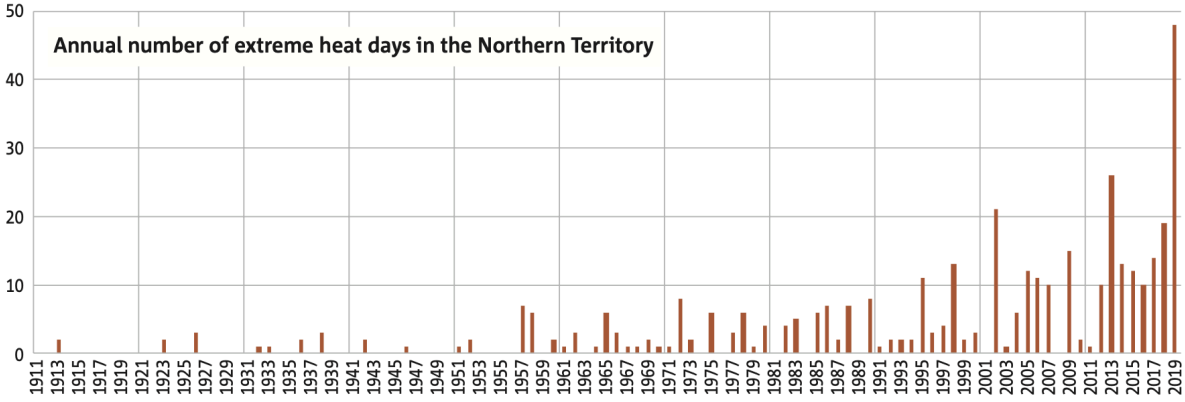

Fig. 5: Number of days each year in which the NT area-averaged daily mean temperatures were among the top 1% hottest for each month. Data from BoM.

58) **Temperatures of 38°C or more – above the internal core body temperature of humans – are particularly dangerous for human health.** NSW Health Department information on heat-related illnesses,[46] states: "When the air is hotter than around 35°C, the body can only lose heat through sweating [which] can be impaired by humidity . . ." **Heat stroke occurs when the core temperature of the human body rises, and can cause shock, arrhythmia, altered mental state, convulsions, unconsciousness, and possible death.**

59) The chart of 'heat index' (or 'apparent temperature') shown in Fig. 6 demonstrates that the heat index rises sharply as air temperature and relative humidity climb, as does the danger to human health, as indicated by the colour coding and the associated text.[47]

[46] https://www.health.nsw.gov.au/environment/beattheheat/Pages/information-for-health-professionals.aspx

[47] Figure after that published by the US National Weather Service, NOAA, What is the heat index? Accessed at: https://www.weather.gov/ama/heatindex

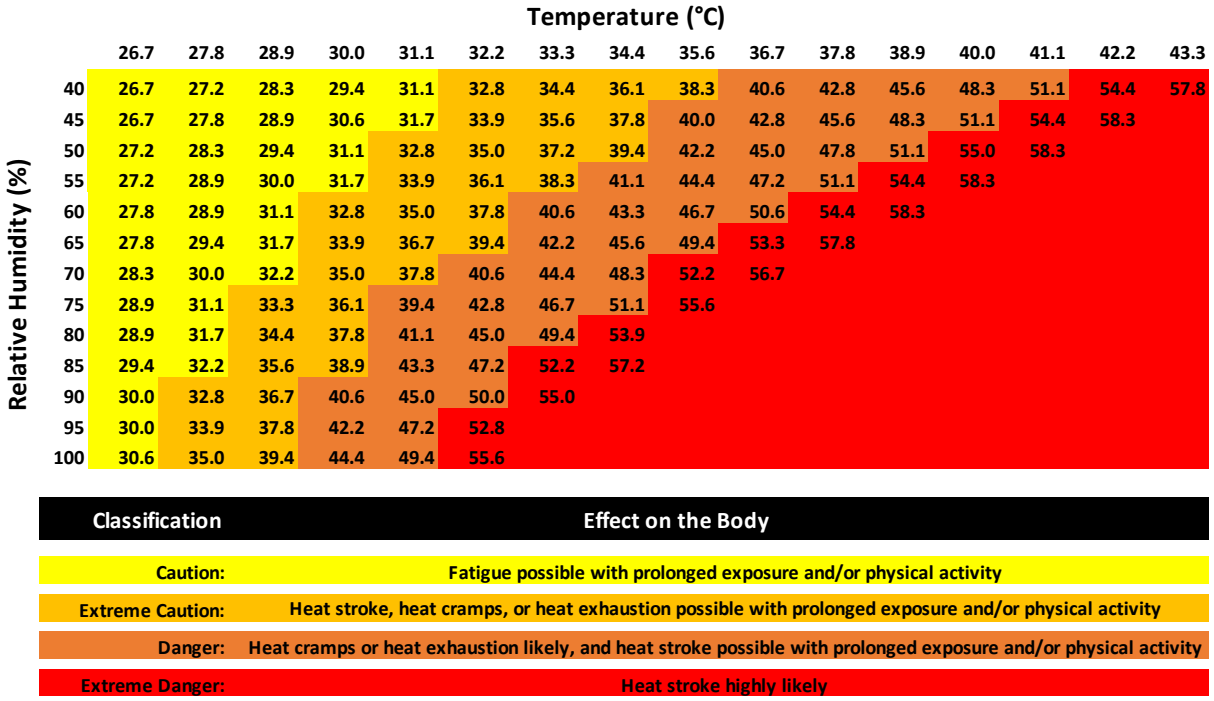

Fig. 6: Heat index for different temperatures and relative humidity. The table values are for shaded areas. ***If one is exposed to direct sunlight, the heat index value can be increased by up to 8°C.***

60) **According to data from BoM,**[48] **past *average* high temperatures** in Daly Waters (**near the Project site**) **have been 35°C or more for the months of September through February. March and September have average high temperatures of 34.9°C**. Coupled with the humidity of the region (e.g., in December 2025 Daly Waters had an average relative humidity of 69%), **very dangerous conditions exist for workers in the area**. **These conditions will worsen with increased global warming**.

61) **Sea surface temperatures bordering the Northern Territory are also rising swiftly.** Above average annual sea surface temperatures have been observed for the Australian region every year since 1995. In 2022, the anomaly was the highest on record on the Australian region overall, with the sea bordering the Northern Territory experiencing surface temperatures (see Fig. 7, below) in the top 10% ever recorded.[49] Very much above averages sea surface temperatures continued into 2024 for the Territory.[50]

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[48] http://www.bom.gov.au/jsp/ncc/cdio/weatherData/av?p_nccObsCode=122&p_display_type=dailyDataFile&p_startYear=&p_c=&p_stn_num=014626

[49] BOM (2023) Annual Climate Statement 2022, Accessed at: http://www.bom.gov.au/climate/current/annual/aus/

[50] BOM (2025) Annual Climate Statement 2024, Accessed at: https://www.bom.gov.au/climate/current/annual/aus/2024/#tabs=Maps

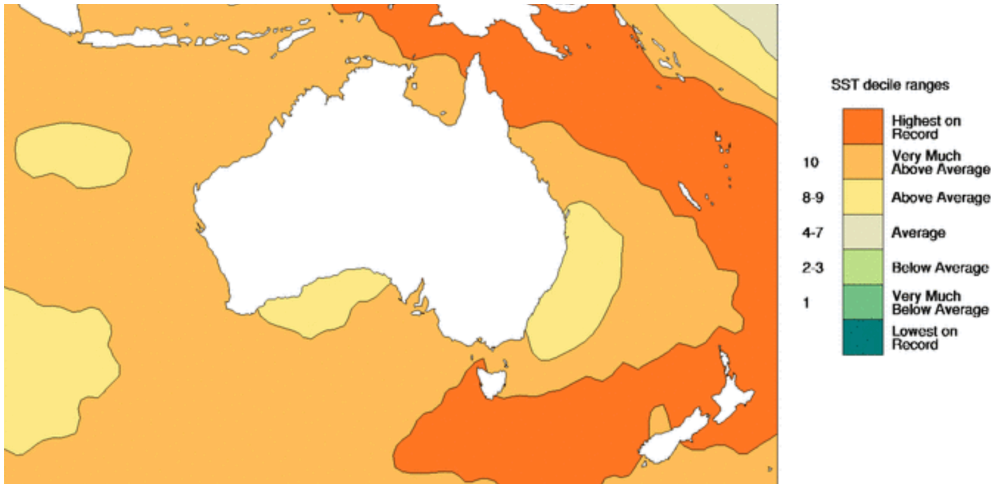

Fig. 7: Sea surface temperatures around Australia in 2022, compared to historical records. Figure from BoM Annual Climate Statement 2022.

62) The Australian Government website *Climate Change in Australia*[51] uses data, expertise and models from the CSIRO and the BOM to provide climate information and projections, using the National Resource Management (hereafter, **NRM**) subclusters to geographically index the results. The Northern Territory crosses two NRM subcluster regions, namely **Monsoonal North (West)** (incl. Darwin) and **Rangelands (North)** (incl. Alice Springs).[52] All NRM subclusters are shown in Fig. 8 (below).

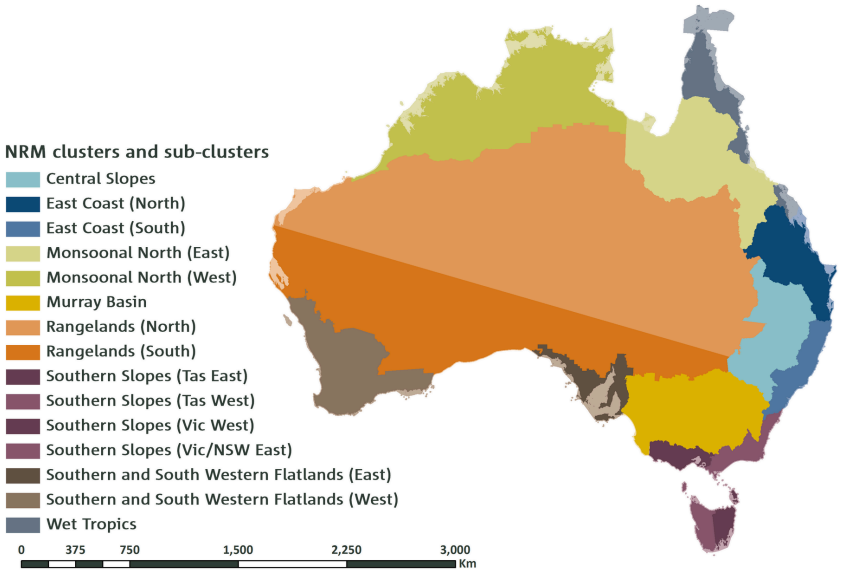

Fig. 8: The NRM subclusters of Australia.

[51] https://www.climatechangeinaustralia.gov.au/en/

[52] Climate Change in Australia: NRM Regions. Accessed at: https://www.climatechangeinaustralia.gov.au/en/overview/methodology/nrm-regions/

63) Similar NRM subclusters designations are also used by the **Actuaries Institute, the peak professional body of actuaries in Australia, to construct and maintain** (in partnership with CSIRO and BoM) **an Australian Actuaries Climate Index (AACI)**,[53] which it describes as "*an objective measure of extreme weather conditions and changes to sea levels, to help policymakers and Australia's businesses assess how the frequency of weather extremes is changing over time*." **The index is composed of sub-indices that focus on extreme events**, since these have the greatest potential impact on people and, often, the largest cost to the economy.

64) Fig. 9 (below) shows the combined AACI for all of Australia. The increase in Australian climate extremes post-2010 compared to pre-2010 is evident. This is a strong indication that **climate change impacts have accelerated over the past two decades over Australia as a whole**.

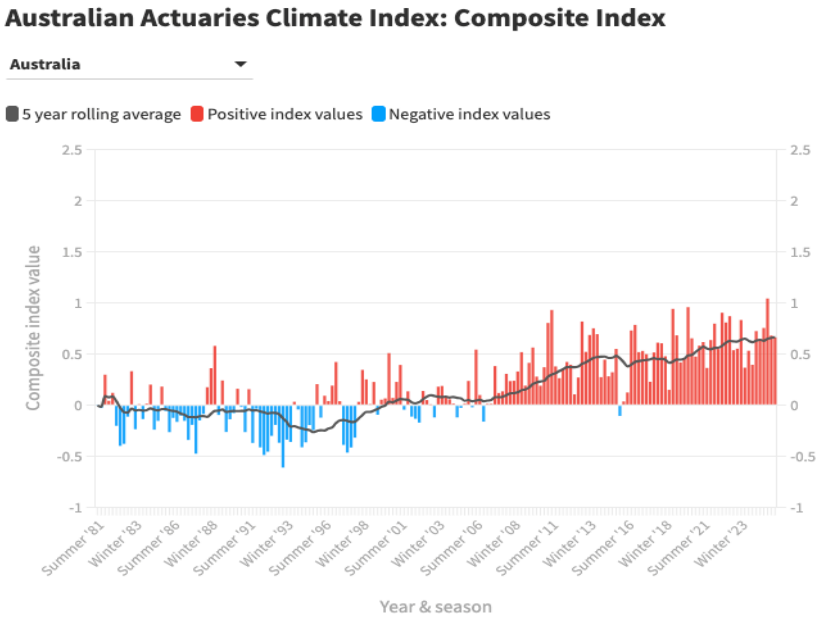

*Fig. 9 (at left): AACI trends for **Australia** over the period of summer 1981 to the date of access, 19 Dec 2025.*

Plot is from the Actuaries Institute.

65) The AACI has also been constructed for subcluster regions of Australia. The two regions relevant to the Northern Territory are shown in Fig. 10 (below) and indicate that **specifically, both regions of the NT have experienced a noticeable increase in climate**

[53] Actuaries Institute (2022) Australian Actuaries Climate Index, Accessed at: https://actuaries.asn.au/microsites/climate-index/

extremes post 2010. Furthermore, the highest value of the AACI for both regions is higher than for Australia's highest value as a whole.

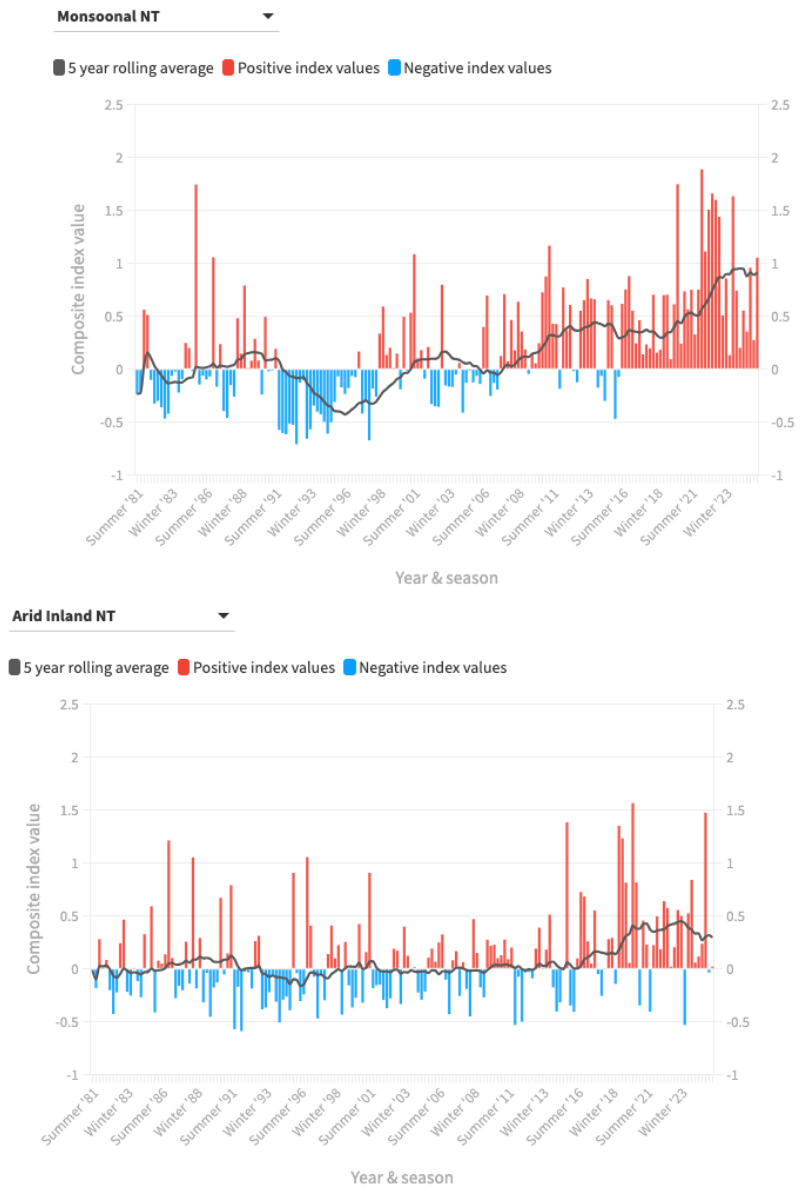

Fig. 10: AACI trends for the two NMR subregions crossed by the ***Northern Territory*** *(upper: Monsoonal NT; lower; Arid Inland NT.*

Data cover 1981 to the access date, 19 December 2025.

Both regions of the NT have experienced more periods of high climate extremes and fewer periods of low climate extremes post 2010 than in the period prior.

66) Scientists describe the amount of global heating by comparing the average global surface temperature of the Earth now to that in pre-industrial times. From all of the pathways and scenarios considered by AR6 WGIII, the **best estimate of the time that 1.5°C of global heating is reached is between 2030 and 2035.**[54] This level of heating, the highest ambition of the UN Paris Agreement, is now inevitable, and is associated with serious consequences beyond those the world is already experiencing.

[54] IPCC (2022) AR6 SYN SPM, B.1.1

67) In fact, the world surpassed this level of heating in 2024, at least as a temporary fluctuation, in 2024;[55] **the underlying level of global heating at the time of this Report is estimated, using scientifically verified methodologies, to be between 1.33°C and 1.41°C**.[5657]

68) Humanity has lost the chance to hold warming strictly below or at 1.5°C, but may still have the possibility of returning global temperatures to that value in 80 years' time. To do so requires a much faster phase out of fossil fuels, including gas, and faster action to reduce all human sources of methane.[58] Exploring and exploiting vast new areas of shale gas is not compatible in any reasonable or likely scenario with ensuring climate stability at about 1.5°C in future.

69) Regardless of whether this occurs or not, **the impacts and risks associated with 1.5°C of global heating are inevitable, and every increment of GHG emission, including that from the Project and its activities, will worsen those impacts and risks.**

[55] https://wmo.int/news/media-centre/wmo-confirms-2024-warmest-year-record-about-155degc-above-pre-industrial-level
[56] https://theconversation.com/the-climate-clock-counting-down-to-1-5-107498
[57] https://apps.climate.copernicus.eu/global-temperature-trend-monitor/
[58] Climate Analytics (2025) Rescuing 1.5°C, accessed at: https://climateanalytics.org/publications/rescuing-1-5c

2.4.2 Future likely and possible climate impacts and risks in the Territory

70) The flows of GHGs from natural sources throughout the Earth's land, ocean, cryosphere and atmosphere have been relatively constant for over 10 millennia; it is the emissions added by humans, predominantly in the last 100 years, that are responsible for current climate change. **That is why every tonne of GHGs emitted into the atmosphere from human activities worsens climate change**.

71) Furthermore, as the AR6 SYN SPM (B.1) states: "**Every increment of global warming will intensify multiple and concurrent hazards (*high confidence*).**" Consequently, there can be no doubt **that the emissions from the EMP activities will worsen future climate change and its impacts**.

72) It is **vital to stress that it is not (solely) the date that net zero is reached that will determine the degree of deterioration of the Territory's future climate, but the total amount of GHG emissions released between now and when net zero is reached**.

73) **GHG emissions from the Project should be assessed against the backdrop of cumulative emission trends, and the current and future threats posed to the Territory, its localities and peoples**. Whereas the scope of this Report does not allow a quantitative assessment of the increase in risk due to emissions from the Project and its activities, several studies have indicated the extent to which the NT will feel devastating effects if global heating surpasses the inevitable 1.5°C level.

74) **In fact, based on current actual policies and action around the world, global heating of approximately 2.6°C (and possibly as high as 3.3°C) is expected by 2100, with temperatures continuing to rise thereafter**.[59]

75) The 2025 National Climate Risk Assessment[60] produced by the Australian Government indicates that the highest risk of increased climate change will be felt by communities in the north of Australia, making the following points:

[59] Climate Action Tracker (November 2025) https://climateactiontracker.org/global/cat-thermometer/
[60] https://www.acs.gov.au/pages/ncra-climate-risks

a) "Communities in northern Australia — including the Northern Territory, Queensland north, and Western Australia north — are exposed to multiple climate hazards, including heatwaves, flooding, tropical cyclones, and bushfires. These regions also have a high proportion of their populations living in high-risk areas. Increases in extreme heat are compounding existing socioeconomic vulnerabilities, such as low income and high poverty rates. These factors particularly affect Aboriginal and Torres Strait Islander communities, as well as older populations. By 2050, the increasing frequency and intensity of many hazards, along with increasing water security challenges, are likely to further increase risks in these areas."

b) "The Northern Territory is a significant concern. At a future warming scenario of +1.5°C, almost one fifth (19.5%) of residential buildings in the region will be in high- and very high-risk areas, equating to around 52,000 buildings."

c) In the Northern Territory, 43% of commercial structures are in very high-risk areas, compared to 9% nationally.

76) Joint work[61] by the CSIRO and BoM **projects future climate conditions** by combining several global climate simulations with fine resolution "downscaled" data appropriate to local regions. **Both NRM subclusters of the NT can expect the following in future**:

a) Average temperatures will continue to increase in all seasons (*very high confidence*).

b) More hot days and warm spells are projected with *very high confidence*.

c) Increased intensity of extreme rainfall events is projected, with *high confidence*.

d) Mean sea level will continue to rise and height of extreme sea-level events will also increase (*very high confidence*).

77) In addition, for the **Monsoonal North West subcluster, in which the Project would be located, fewer but more intense tropical cyclones are projected** *with medium confidence*.

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[61] Climate Change in Australia: Regional Climate Change Explorer. https://www.climatechangeinaustralia.gov.au/en/projections-tools/regional-climate-change-explorer/sub-clusters/

78) More days of extreme high temperatures can be expected in the NT. **Darwin and Broome, for example, could experience days over 35°C on average for around a third of the year under an intermediate emission scenario by late in the century**.[62]

79) NARCLiM 1.0 studies found that under their high-emissions scenario,[63] Darwin would experience 37 heatwave days per year in the near future (2020 – 2039) and 135 heatwave days per year in the far future (2060 – 2080), compared to only 11 such days per year in the recent past (1990 – 2009). Thus, **high emission pathways would create a future for Darwin in which four months of the year exhibit heatwave conditions.**

80) The NT's strong tourism sector is driven in part by some of Australia's most iconic National Parks, including Garig Gunak Barlu (Cobourg) National Park, Litchfield National Park, Uluru-Kata Tjuta National Park and Kakadu National Park. In 2018–19 alone, tourism directly contributed $1.4 billion to the NT. However, **NT tourism will likely be adversely affected by increased climate change** for a variety of factors including: extreme weather and flooding disrupting transportation networks, late retreat of the monsoon that shortens the visitor season, and damage to key natural systems and species that are a drawcard for tourists. **Sea-level rise of 30 cm could cause the loss of 80% of Kakadu's freshwater wetlands**.[64]

81) That is part of the reason why **at 2°C and higher, the World Heritage-listed Kakadu National Park will be severely affected. Rising sea level will also continue to amplify storm impacts, damaging coastal ecosystems such as mangroves, seagrass beds, rocky intertidal zones and estuaries. Kakadu has an average elevation above sea level of only 0.5 m, placing it at extreme risk of saltwater intrusion into its unique freshwater**

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[62] Climate Change in Australia: Regional Climate Change Explorer. https://www.climatechangeinaustralia.gov.au/en/projections-tools/regional-climate-change-explorer/sub-clusters/

[63] Herold, N. (2018) Australian climate extremes in the 21st century according to a regional climate model ensemble: Implications for health and agriculture, Weather and Climate Extremes, 20, 54–68, https://doi.org/10.1016/j.wace.2018.01.001

[64] NESP Earth Systems and Climate Change Hub (2020) Climate change in the Northern Territory: state of the science and climate change impacts. Accessed at: https://denr.nt.gov.au/__data/assets/pdf_file/0011/944831/state-of-the-science-and-climate-change-impacts-final-report.pdf

ecosystems. Sea levels there have already has been rising at approximately twice the global average.[65]

82) The Hub Report[66] prepared for the NT Government spells out possible climate futures for the Territory based on projections from low (RCP2.6), medium (RCP4.5) and high (RCP8.5) emissions pathways for the near future (2030), mid-century (2050) and end of the century (2090). The RCP2.6, RCP4.5 and RCP8.5 pathways can be broadly associated with approximately at or slightly below 2°C, at or slightly above 2.5°C, and at least 4°C, respectively, by 2100.

83) The Hub Report indicates that:

a) **By the middle of the century, the number of days a year over 35°C will at least double in many places across the Territory**. Even steeper increases will occur at higher temperatures. For example, whereas Katherine has historically experienced 7 days above 40°C per year, these numbers are expected to increase to 19 days (by 2030), 28 days (by 2050), and 38 days (by 2090), under even an intermediate emissions scenario.

b) Tropical cyclones in the NT are projected to become less frequent but more intense. Coupled with higher sea levels, it is likely that flooding will increase in frequency and magnitude in the future for many coastal and estuarine regions in the NT.

c) Tides, winds and severe weather systems can cause extreme sea-level events. In the NT, tropical cyclones cause extreme storm surges. Rising sea levels will exacerbate the impacts of storm surges and other extreme sea-level events.

d) The number of marine heatwave days per year and their intensity is projected to increase throughout the century with the degree of change dependent on GHG

[65] Australian Academy of Science (2021). The risks to Australia of a 3°C warmer world (and references therein.) Accessed at: https:// www.science.org.au/warmerworld

[66] NESP Earth Systems and Climate Change Hub (2020) Climate change in the Northern Territory: state of the science and climate change impacts. Accessed at: https://denr.nt.gov.au/__data/assets/pdf_file/0011/944831/state-of-the-science-and-climate-change-impacts-final-report.pdf

emissions. **Under a high emissions pathway, the intensity of marine heatwaves could be double that of under a medium emissions pathway**.

e) The acidity of the NT's coastal waters is projected at century's end to increase by 40% in an intermediate emissions scenario, and by 100% in a high emissions scenario.

84) Specifically, in its Section 4.2.3, the Hub Report details how **increased global warming will affect the energy and minerals sector in the Territory**. These effects may include:

a) More frequent and intense natural disasters causing damage to energy infrastructure and equipment, disrupting construction and operations;

b) Disruption to production and transportation due to heavier flooding and rainfall;

c) **Disruption to supply chains** and movement of personnel and goods;

d) Increased threat to facilities from wildfire.

e) Increased threat of discharge of contaminated water into surrounding areas due to heavy rainfall.

f) **Health and safety risks** from increased natural disasters and warmer temperatures.

85) **The Cross Dependency Initiative (XDI) studied 2,639 global jurisdictions to assess their exposure to risk of physical infrastructure damage from extreme weather and climate change in 2050. The NT was ranked in the upper half (most exposed to risk) of these jurisdictions.**[67] It is important to note that the XDI metric does *not* include the social, environmental and economic effects of climate change – such as water shortages, or impacts on agricultural production, biodiversity or human wellbeing**.**[68]

86) **At 2°C global warming, the estimated change in heating and cooling demand is +61% in Darwin and +67% in Alice Springs for a 5-star energy-rated house. For 4°C of global**

[67] https://xdi.systems/gross-domestic-risk-dataset/?submissionGuid=10ade462-c25d-4cab-8eea-9fecc4e79a46, Accessed 12 May 2023.
[68] XDI, https://xdi.systems/method-background/

warming, the changes are expected to be +135% and +213%, respectively.[69] This would place increased demand on the Territory's infrastructure and monetary resources.

87) **At 2.5°C of global warming, many locations on the coast of the Northern Territory will experience what are now considered 'once-in-100-years extreme-sea-level events' *at least once a year* by 2100**.[70] **The consequences for the port of Darwin and the Territory's coastal islands would be devastating.**

88) **In additional to increasingly the likelihood and severity of all these effects on the Territory, emissions from the Project increase the likelihood of crossing tipping points in the Earth system, as explained in the following section.**

2.4.3 Earth System tipping points at risk and currently being crossed

89) **The Earth system**, which sustains life, is an interconnected complex composed of the **cryosphere** (ice systems), **biosphere** (ecosystems), **atmosphere, hydrosphere** (water systems) and the **lithosphere** (the Earth's solid surface). The **anthroposphere** (human systems) are also part of the Earth System.

90) ***Tipping points***[71,72] in the Earth System refer to thresholds that, if crossed, would lead to far-reaching, and in some cases, abrupt changes in Earth subsystems (called tipping elements). The nature of tipping points is that they are irreversible on timescales associated with natural variability in the Earth System. The most devastating risk of continued global warming is that some of Earth's subsystems will become unstable and `tip' irreversibly into new states that accelerate the effects of climate change.

91) Examples of tipping elements include permanent dieback of forests, changes in ocean circulation that would permanently alter precipitation patterns around the world, loss of ice sheets, glaciers and sea ice that would accelerate permanent sea level rise, permanent

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[69] IPCC (2022) AR6 WGII, Chapter 11

[70] Tebaldi, C. et al. (2021) Extreme sea levels at different global warming levels. In Nature Climate Change, 11, 746-751, https://doi.org/10.1038/s41558-021-01127-1 Accessed 12 May 2023

[71] Lenton, T. M., Held, H., Kriegler, E., Hall, J. W., Lucht, W., Rahmstorf, S., & Schellnhuber, H. J. (2008) Tipping elements in the Earth's climate system. Proc. Natl. Acad. Sci. (USA), 105(6), 1786–1793. https://doi.org/10.1073/pnas.0705414105

[72] Schellnhuber HJ, Rahmstorf S, Winkelmann R (2016) Why the right climate target was agreed in Paris. *Nature Climate Change*, 6:649-653

destruction of all the world's coral reefs, and uncontrolled permafrost melt that would dramatically accelerate further global warming. Some of these subsystems are already showing signs of becoming unstable, with 'tipping points' that could lie on our current trajectory of global warming above pre-industrial temperatures.[73, 74]

92) **Tipping elements have been crucial to Earth's past climate.** For example, long-term global warming 52–59 million years ago included periods of relatively rapid warming preceded by massive carbon input from an organic source into Earth's atmosphere and oceans. Detailed analysis shows that these rapid warming periods were associated with transgression of tipping points in Earth System carbon reservoirs (e.g., permafrost, submarine hydrates or peatlands).[75]

93) **Of the six tipping points listed in a report on interconnected disaster risks,[76] five are caused or exacerbated by climate change**, namely: accelerated extinctions, groundwater depletion, melting mountain glaciers, unbearable heat, and an uninsurable future.

94) **Tipping point risks are now much higher than earlier estimates suggested**. In 2019, over half the tipping elements identified in 2008[77] were recognised as 'active,' that is, moving toward irreversible change,[78] with many influencing one another.

95) A 2022 review[79] of tipping elements and observational evidence of their evolution concluded: ``*The Earth may have left a safe climate state beyond 1°C global warming. A significant likelihood of passing multiple climate tipping points exists above ~1.5°C,*

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[73] Steffen W et al. (2018) Trajectories of the Earth System in the Anthropocene. Proc. Natl. Acad. Sci. (USA) doi:10.1073/pnas.1810141115 and associated Appendix, accessed at: https://www.pnas.org/content/pnas/115/33/8252.full.pdf

[74] Lenton, T. M., Rockström, J., Gaffney, O., Rahmstorf, S., Richardson, K, Steffen, W. & Schellnhuber, H.J. (2019) Nature, vol 575, pp 592 – 595.

[75] See, e.g., Setty, S., et al. (2023) Loss of Earth system resilience during early Eocene transient global warming events, Science Advances, 9, eade5466, Accessed at: https://www.science.org/doi/10.1126/sciadv.ade5466

[76] United Nations University – Institute for Environment and Human Security (2023) Interconnected Disaster Risks: Risk Tipping Points. Eberle, Caitlyn, et al. DOI: 10.53324/WTWN2495 Accessed at: https://interconnectedrisks.org/download

[77] Lenton, T.M. et al. (2008) Tipping elements in the Earth's climate system. In PNAS, 105(6), p1786-1793. Accessed from: https://www.pnas.org/content/105/6/1786

[78] Lenton, T.M. et al. (2019) Climate tipping points — too risky to bet against. Nature, 2019; 575 (7784): 592. Accessed at: https://www.nature.com/articles/d41586-019-03595-0

[79] Armstrong McKay, D.I. et al. (2022) Exceeding 1.5°C global warming could trigger multiple climate tipping points, Science, 377, 1177. Accessed at: www.science.org/doi/10.1126/science.abn7950

particularly in major ice sheets. Tipping point likelihood increases further in the Paris range of 1.5 to <2°C warming. Current policies leading to ~2 to 3°C warming are unsafe because they would likely trigger multiple climate tipping points."

96) In late 2023, a substantial 478-page report based on the work of 200 authors from 25 institutions[80] concluded that the situation was even more urgent, stating *"Five major tipping points are already at risk of being crossed due to warming right now and three more are threatened in the 2030s as the world exceeds 1.5°C global warming."*

97) **Over 25 tipping elements have now been identified in the Earth System**.[81] **Some** of those that **had previously been identified as high-impact, but low-likelihood, events are now characterised as high-impact, high-likelihood events**, because (a) many tipping points are now thought to occur at lower global mean temperatures, and (b) anthropogenic GHG emissions continue to rise, with global current policies on track to produce about 3°C of global heating.

98) **The most recent (2025) tipping point report**, which includes increased understanding of the risks and data,[82] **concludes that some tipping elements in nature and the climate are already crossing their tipping points**, stating:

a) *"Already at 1.4°C of global warming, warm water coral reefs are crossing their thermal tipping point and experiencing unprecedented dieback, impairing the livelihoods of hundreds of millions who depend on them. Parts of the polar ice sheets may also have crossed tipping points that would eventually commit the world to several metres of irreversible sea-level rise affecting hundreds of millions. Crossing tipping points reduces Earth's ability to cope with human interference, further amplifying impacts, making it a fundamental human rights issue.*"

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[80] Lenton, T.M. et al. (2023) The Global Tipping Points Report 2023. Accessed at: https://global-tipping-points.org/

[81] Lenton, T.M. et al. (2023) The Global Tipping Points Report 2023. Accessed at: https://global-tipping-points.org/

[8282] Lenton, T.M. et al. (2025) The Global Tipping Points Report 2025. Accessed at: https://global-tipping-points.org/

b) *"Global warming is projected to overshoot 1.5°C within a few years, placing humanity at even greater risk. Climate change and deforestation together put the Amazon rainforest at risk of widespread dieback below 2°C, threatening incalculable damage to biodiversity and impacting over a hundred million who depend on the forest. The Atlantic Meridional Overturning Circulation (AMOC) is also at risk of collapse below 2°C, which would radically undermine global food and water security and plunge northwest Europe into severe winters."*

c) *"**Every fraction of a degree and every year over 1.5°C matters for preventing climate tipping points. To minimise the magnitude and duration of global temperature overshoot above 1.5°C, global anthropogenic greenhouse gas emissions need to be halved by 2030 (compared to 2010 levels), reach net zero by 2050, and then net greenhouse gas removal needs to occur. This requires unprecedented acceleration in decarbonisation, rapid mitigation of short-lived climate pollutants – especially methane emissions, and rapid scaling of sustainable and equitable carbon removal from the atmosphere."***

99) Furthermore**, continued global heating increases the risk** that crossing tipping points, which are interconnected, could cause subsystems of the Earth to rapidly collapse, one initiating another, to create **a cascade of transformations that result in what has been dubbed a 'Hothouse Earth'.**[83] Whilst not the sort of runaway heating associated with Venus, **average temperatures in a Hothouse Earth scenario would rise to match those not seen since the beginning of the Stone Age, millions of years ago, with devastating consequences**.

100) If such a cascade in a domino effect were to occur, the result would be an unrecognisable landscape for current ecosystems and human civilisation. It is **uncertain precisely where this 'Hothouse' threshold may lie, but it could be as close as a few decades away, that is, at or just beyond 2°C of warming.**[84]

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[83] Steffen W et al. (2018) Trajectories of the Earth System in the Anthropocene. Proc. Natl. Acad. Sci. (USA) doi:10.1073/pnas.1810141115 and associated Appendix. Accessed at: www.pnas.org/content/pnas/115/33/8252.full.pdf

[84] Steffen W et al. (2018) Trajectories of the Earth System in the Anthropocene. Proc. Natl. Acad. Sci. (USA) doi:10.1073/pnas.1810141115 and associated Appendix, Accessed at: https://www.pnas.org/content/pnas/115/33/8252.full.pdf

101) In scientific summary, **crossing several climatic tipping points must be considered as a possible and, in some cases, a very likely risk of any increased emissions, and are associated with dire consequences**. **The larger the increased emissions, the more tipping elements are likely to be triggered, and the higher the risk that other tipping elements will also tip, leading to a possible cascade into a world with no precedent for *Homo sapiens***.

3 Recommended Conditions for the EMP to Assist in Meeting Standards

102) The JL Brief I have been provided requests that I also address:

> *"Any recommended conditions or recommended amended conditions for the EMP to ameliorate the environmental impacts and risks you have identified in (i). This aspect should address the degree to which the EMP and proposed works meet the standards set by the legislation and the standards recommended by the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (**Pepper Inquiry**)."*

I do so in this section of the Report, but note **the recommendations offered in this Report should not be considered exhaustive**.

103) Given that fugitive emissions from fossil fuel facilities and pipelines can be measured from space as well as from the ground, and given that fugitive emissions form a large portion of Scope 1 emissions for such facilities, it would seem that **tighter restrictions could and should be placed on monitoring and repairing leaks**.

104) Table 4 of the Proponent's Methane Emissions Management Plan (Appendix H of the EMP) indicates, for example, that `minor leaks' would be fixed within 30 days of detection and `major leaks' within 72 hours of detection. However, Table 3 of Appendix H indicates that during ongoing well operation or suspension, monitoring for leaks would only be undertaken every six months. Although more frequent monitoring for and repair of leaks may come at some cost to the Proponent, doing so would seem necessary, though not sufficient, to reduce GHG emissions to `as low as reasonably practicable'. **Automatic and continual monitoring for leaked gas (with reporting of the results) would seem to be a reasonable condition, not only for the immediate area of the well pads, but also for any area above or connected to fracking zones**.

105) Indeed, **given that exploratory wells have already been placed in EP161, it would be prudent to collect and analyse a continuous stream of gas leak monitoring data, as described in paragraph 104) for those wells, both in operation and suspended, before proceeding with new exploratory wells**, particularly as there is an indication that fugitive

gas is underreported globally. **Such data would also help to establish baselines against which any further fugitive and leaked gas could be measured**.

106) The Final Report of the Scientific Inquiry into Hydraulic Fracking in the Northern Territory, (**Pepper Report**)[85] gives as its recommendation 9.8, citing principles of Economic Sustainable Development: "***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.***"

107) The Final Implementation Report of the Scientific Inquiry into Hydraulic Fracking[86] states that the NT Government continues to engage with the Australian Government and the Energy and Climate Ministerial Council (ECMC) on the implementation of Recommendation 9.8 and that the Australian Government has passed reforms to its Safeguard Mechanism, requiring new onshore petroleum entrants in the Beetaloo Sub-basin to have net zero scope 1 emissions from entry.

108) Notwithstanding the NT Government's assurance in its Implementation Report that it *has* implemented all of the Pepper Report recommendations, there is no concrete indication that this is being done as a matter of course, and certainly there is no mention of how this might be done in the EMP**. I would recommend that such a condition of net zero from inception of any activities be mandatory, as it is absolutely necessary to at least attempt to ensure that climate risks and impacts from the Project are 'as low as reasonably practicable.'**

109) Should consideration be given to meeting condition 9.8 of the Pepper Report through the use of so-called `GHG offsets,' for the Project, I make the following scientific observations:

a) **Offsets do not reduce global GHG emissions. At best, they negate emissions that have already been released. In order to do so, they must remove the same *amount*, and the same *type* of GHG at the same *time* as the original emissions**

[85] https://frackinginquiry.nt.gov.au/inquiry-reports/final-report

[86] Northern Territory Government (2023) Scientific Inquiry into Hydraulic Fracturing Final Implementation Report, Accessed at: https://hydraulicfracturing.nt.gov.au/implementation-plan/final-implementation-report

occur, and they must come from an activity that would not have occurred without the offset. These conditions are required for a true offset because different GHGs affect the climate differently and over different time periods, and because the original emission will cause some warming in the time that elapses between the emission and any later offset. Even if these conditions were met, the level of global emissions will not have been reduced, but rather maintained. Global warming will continue to rise until global emissions reach net zero.

b) **Scientifically, GHGs from fossil fuels cannot be 'offset' – in a climate sense – with biological GHG sinks.**[87] This is because the GHG emissions from fossil fuels add GHGs back into the atmosphere that have not been there for millions of years. Offsets that use biological systems (such as trees, for example) to draw down GHGs (particularly carbon dioxide) will return most of those gases to the atmosphere when they die and decompose in natural cycles of years to centuries. In addition to being temporary, biological offsets can take time to take effect and may be subject to later destruction through changed land practices or, for example, fires exacerbated by climate change itself. Fires emissions from global forests have been increasing since 2000, and are projected to become more frequent and widespread as climate change worsens. Northern Hemisphere fires alone contributed nearly 0.5 Gt of carbon (nearly 1.5 Gt CO_2) to global emissions in 2021, by far the highest fraction since 2000.[88]

c) Furthermore, it is doubtful that the biological systems will be able to `provide offsets' in the form of storage of carbon at the levels often assumed.[89,90] Furthermore, if global warming reaches a high enough level, the Earth's net

[87] Watts, K. (2015) Fossil and biological carbon: a tonne is not a tonne, Carbon Market Watch. Accessed at: https://carbonmarketwatch.org/publications/policy-brief-fossil-and-biological-carbon-a-tonne-is-not-a-tonne/

[88] Zheng, B. et al. (2023) Record-high CO2 emissions from boreal fires in 2021. Science, 379, 912-917. https://www.science.org/doi/10.1126/science.ade0805 and references therein.

[89] Green, J.K. and Keenan, T.F. (2022) The limits of forest carbon sequestration. Science, 376, 6594. https://www.science.org/doi/10.1126/science.abo6547, and references therein.

[90] Wilson, R., Hare, B. and Grant, N. (2023) Why offsets are not a viable alternative to cutting emissions. Climate Analytics. Accessed at: https://climateanalytics.org/publications/2023/why-offsets-are-not-a-viable-alternative-to-cutting-emissions/

photosynthesis may decrease, whilst transpiration will increase, even in the presence of increased atmospheric carbon dioxide.[91] **Some land `sinks' are now turning to `sources' of GHGs, including some forests in Australia**.[92]

d) It is becoming increasingly well-recognised that **many offset programs are ineffective in producing real reductions in GHGs**. A 2022 research study[93] concluded that "California's forest offsets program creates incentives to generate offset credits that do not reflect real climate benefits" and that nearly a third of the credits offered no real climate benefits. Using satellite data, it has been claimed that Indonesian credits were sold for amounts that exceeded the possible carbon sink.[94] The ineffectiveness of biological credits has been called out by insiders and previous proponents with considerable experience in such programs, both in Canada[95] and in Australia,[96,97] where **up to 80% of the carbon credits issued by Australia's Clean Energy Regulator have been claimed to be flawed in producing their intended purpose.**

110) I understand that approval criteria set out in reg 9 of the *Petroleum (Environment) Regulations 2016* include that the EMP must demonstrate that the Project will be carried out in a manner by which the environmental impacts and environmental risks will be reduced to a level that is 'as low as reasonably practicable' (ALARP) and 'acceptable.'

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[91] Duffy, K. A. et al. (2021) How close are we to the temperature tipping point of the terrestrial biosphere? Science Advances, 7, eaay1052

[92] Carle, H. et al. (2025) Aboveground biomass in Australian tropical forests now act as a carbon source. Nature, 646, 611-618. Accessed at: https://www.nature.com/articles/s41586-025-09497-8

[93] Badgley, G. et al. (2022) Systematic over-crediting in California's forest carbon offsets program, in Global Change Biology, 28: 1433-1445. Accessed at:

[94] Nikkei (2021) Indonesian carbon credit project appears to betray its purpose. Accessed at: https://asia.nikkei.com/Spotlight/Environment/Climate-Change/Indonesian-carbon-credit-project-appears-to-betray-its-purpose

[95] Bloomberg (17 March 2022) This Timber Company Sold Millions of Dollars of Useless Carbon Offsets, Accessed at: https://www.bloomberg.com/news/articles/2022-03-17/timber-ceo-wants-to-reform-flawed-carbon-offset-market

[96] Australian Financial Review (23 March 2022) Former watchdog goes public with carbon credit `fraud' claims. Accessed at: https://www.afr.com/policy/energy-and-climate/former-watchdog-goes-public-with-carbon-credit-fraud-claims-20220323-p5a77o

[97] The Guardian (23 March 2022) Australia's carbon credit scheme `largely a sham', says whistleblower who tried to rein it in. Accessed at: https://www.theguardian.com/environment/2022/mar/23/australias-carbon-credit-scheme-largely-a-sham-says-whistleblower-who-tried-to-rein-it-in

111) In respect of environmental risks and impacts caused by climate change, and given the dramatic impacts of current climate disruption, **it is reasonable to state that *current* levels of GHGs in the atmosphere are *not* `acceptable' and that increasing GHG emissions further by any amount would make those levels even more `unacceptable**.' This certainly applies in the first meaning of `acceptable,' namely to be `satisfactory,' and it could be argued perhaps also for the second meaning of `acceptable,' namely, 'able to be tolerated.' Many species and ecosystems are not tolerating current levels of global heating, nor are thousands of humans who perish each year in extreme heat and weather events caused by current levels of GHGs in the atmosphere.

Respectfully submitted on 19 December 2025,

Professor Penny D Sackett

Appendix A: Brief Provided to Author by Johnson Legal

See attached pages.

Johnson Legal
AUSTRALIAN ENVIRONMENTAL LAWYERS

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EXPERT BRIEF

CONFIDENTIAL AND LEGALLY PRIVILEGED

Date: 18 December 2025

To: Distinguished Professor Penny Sackett

By e-mail only: pd.sackett@gmail.com

ENVIRONMENT CENTRE NT

SANTOS – BEETALOO BASIN APPRAISAL PILOT EMP

From: Johnson Legal
Level 21, 8 Chifley Square
SYDNEY NSW 2000

Liability limited by a scheme approved under Professional Standards Legislation

THE LAW SOCIETY OF NEW SOUTH WALES
PRO BONO SCHEME SUPPORTER 2025
THE LAW SOCIETY OF NSW PROFESSIONAL STANDARDS SCHEME

Dear Distinguished Prof Sackett

Environment Centre NT (ECNT) – Santos QNT Pty Ltd Beetaloo Basin Appraisal Pilot Environment Management Plan (EMP)

1. We confirm that we act for ECNT in the above matter, who wish to provide submissions in relation to the EMP currently under assessment with the Northern Territory Government.

2. We wish to brief you to provide a preliminary expert report for ECNT in relation to the likely environment impacts and risks associated with the carrying out of the Project, within your scope of expertise.

The EMP

3. As part of the assessment process, the EMP was published for comment on 21 November 2025.

4. Comments on the EMP will close on **19 December 2025.**

5. The key documents subject to assessment are linked below:

    a. EMP currently open to comment and relevant appendices, including:

    - Appendix A-K - Summary of Approved Regulated Activities
    - Appendix L – Cultural Heritage Assessment
    - Appendix M - Emergency Response Plan – Mcarthur and Ameadeus Basins

The Project

6. Santos is an Interest Holder and operator of Exploration Permit (**EP**) 161 located in the Beetaloo Basin, approximately 350 kilometres south-east of Katherine in the Northern Territory.

7. Santos proposes to drill and test petroleum appraisal wells across two locations within EP 161, collectively referred to as the Beetaloo Appraisal Pilot.

8. The subject EMP covers the installation of up to twelve new petroleum appraisal wells at two separate well pads within EP 161. Some of the proposed activities include:

    a. Clearing and earthworks for 2 new well pad locations – The clearing and construction to create two new well pads and ancillary infrastructure at well pad locations referred;

    b. Drilling up to 12 appraisal wells, either vertical or horizontal well types;

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c. Operating, testing, maintenance and decommissioning and hydraulic fracture stimulation of up to 12 appraisal wells;

d. Wastewater management – each well pad will include evaporation tanks, storage tanks, drilling sumps, cutting pits and any transfer infrastructure within the well pad. This also includes transportation onsite and disposal of these wastes (unless otherwise approved for reuse or burial).

9. The approval criteria are set out in reg 9 of the *Petroleum (Environment) Regulations 2016* (**the Regulations**) and include that the EMP must demonstrate that the Project will be carried out in a manner by which the environmental impacts and environmental risks will be reduced to a level that is 'as low as reasonably practicable' (ALARP) and 'acceptable'.

10. In determining whether or not to approve the EMP, the Minister must consider whether the EMP for the Project should be approved pursuant to the *Petroleum Act 1984* and the Regulations and if so, on what conditions.

Your brief

11. We request that you:

    a. Provide an expert report for ECNT by **19 December 2025** in relation to:

        i. The environmental impacts and risks (specifically, regarding the impacts of the Project on greenhouse gas emissions and climate change, including such impacts on the locality of the Project) associated with the Project and the carrying out of the Project. This would include your assessment of the likelihood of any risks identified and the environmental impacts and consequences if those risks crystallise; and

        ii. Any recommended conditions or recommended amended conditions for the EMP to ameliorate the environmental impacts and risks you have identified in (i). This aspect should address the degree to which the EMP and proposed works meet the standards set by the legislation and the standards recommended by the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (**Pepper Inquiry**).

12. We ask that you prepare your opinion in accordance with the NT Supreme Court's Practice Direction No. 6 of 2015 – Expert Reports.

13. We note that under the Practice Direction, 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

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assist the Court impartially on matters relevant to the area of expertise of the witness.

Your fees

14. Please provide us with an estimate of your fees for carrying out this work at your earliest convenience.

Yours faithfully
Johnson Legal Pty Ltd

Matt Floro
Principal Lawyer

Encl.

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INDEX TO BRIEF

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3	Appendix L	November 2025
4	Appendix M-P	November 2025

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Appendix B: Curriculum Vitae of the Author

See attached pages.

Curriculum Vitae

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Born: 28 February 1956, Lincoln, Nebraska USA
Citizenship: U.S. and Australian
Permanent Residence: Australia
Languages: English: Mother Tongue; Dutch: Good knowledge; Spanish: Beginner's knowledge

Education:

1984 Ph.D. in Physics, University of Pittsburgh, PA, USA
Thesis Title: *Scale Parameters for Finite Temperature Actions of Lattice Gauge Theories Coupled to Fermions*
1980 M.S. in Physics, University of Pittsburgh, PA, USA
1978 B.S. in Physics, University of Nebraska-Omaha (UNO), NE, USA
1978 Teaching certification (K-12), Physics and Mathematics, UNO, USA

Distinctions and Honours:

2019 Distinguished Alumni Award, University of Pittsburgh, USA
2016 Omaha (USA) North High Magnet School "Viking of Distinction" Award
2014 UNO College of Arts and Sciences Outstanding Alumni Award
2014 Citation for Alumni Achievement: Univeristy of Nebraska-Omaha (UNO)
2011 Opening Keynote Speaker: 2011 Adelaide Festival of Ideas, SA, Australia
2005 Univ of Canberra-Australian National Univ International Women's Day Lecturer
2004 Finalist, Telstra ACT Business Women of the Year, ACT, Australia
2003 Fellow of the UK Royal Astronomical Society
Election to the Society to honour a person eminent in the field of astronomy and not normally resident in the UK for leadership, enabling activities, etc
2002 Harley Wood Lecturer, Astronomical Society of Australia
2000 Athena Lecturer, St. Andrews University, Scotland
1998 University of Groningen Teaching Award (Onderwijsprijs), The Netherlands
1992-1994 J. Seward Johnson Fellow, Institute of Advanced Study, Princeton, NJ, USA
1981-1982 O.H. Blackwood Award for Excellence in Teaching, University of Pittsburgh, PA, USA
1979-1981 Andrew Mellon Fellowship, University of Pittsburgh, PA, USA
1978 Summa Cum Laude, University of Nebraska-Omaha, NE, USA
1978 Most Outstanding Physics Student, University of Nebraska-Omaha, NE, USA
1978 Most Outstanding Mathematics Student, University of Nebraska-Omaha, NE
1974-1978 Dean's List, University of Nebraska-Omaha, NE, USA
1974-1978 Nebraska Regent's Scholarship, University of Nebraska-Omaha, NE, USA
1974-1978 National Merit Scholarship, University of Nebraska-Omaha, NE, USA

Professional Society Membership

Astronomical Society of Australia
International Astronomical Union
Royal Astronomical Society

Professional Activity and Appointments

2020-current	Distinguished Honorary Professor (E3), Institute for Climate, Energy and Disaster Solutions Australian National University, Canberra, Australia *Climate change science synthesis, analysis and communication; community engagement*
2011-current	Strategic Scientific Advisor and Principal Penny D Sackett Strategic Advisory Services *Sole trader assisting governments, communities, courts and business with matters of science, climate change, greenhouse gas assessments and sustainability*
2014-2019	Honorary Professor, Climate Change Institute, Australian National University, Canberra, Australia *Community engagement, science for policy, subnational climate change action*
2008-2014	Academic Adjunct Professor, Research School of Astronomy and Astrophysics, Australian National University, Canberra, Australia *Mentoring early career researchers*
2008-2011	Chief Scientist for Australia, DIISR, Australian Commonwealth Government, Canberra, Australia *Provision of independent, whole-of-government scientific advice, science advocacy, liaison with community, bureaucracy and state governments*
2007-2008	Professor (Level E2), Research School of Astronomy and Astrophysics, Australian National University (ANU), Canberra, Australia *Research, research training, and international research co-ordination*
2002-2007	Director, Research School of Astronomy and Astrophysics, and the Mt. Stromlo and Siding Springs Observatories, ANU, Canberra, Australia *Strategic leadership, budget, human & facility management, liaison, advocacy*
2001-2002	Chaired Professor of (Extra)Galactic Optical/Infrared Astronomy, Kapteyn Astronomical Institute, University of Groningen, The Netherlands *Research, research training, teaching, international program building*
1998-2000	Associate Professor with tenure (Universiteits Hoofd Docent), Kapteyn Astronomical Institute, University of Groningen, The Netherlands *Research, research training, teaching, international program building*
2000	Visiting Member, Institute for Advanced Study, Princeton, NJ, USA (on leave from Kapteyn Institute 1999-2000 academic year) *Research of international standing*
1999	Visiting Scientist, Anglo-Australian Observatory, Epping, Australia (on leave from Kapteyn Institute 1999-2000 academic year) *Research of international standing and international co-ordination*
1995-1997	Assistant Professor with tenure (Universiteits Docent), 75% full time Kapteyn Astronomical Institute, University of Groningen, The Netherlands *Research, research training, teaching, research program building*
1995-1997	Visiting Research Member, School of Natural of Sciences, 25% full time Institute of Advanced Study, Princeton, NJ, USA *Research of international standing*
1992-1994	Research Member & J. Seward Johnson Fellow, School of Natural of Sciences, Institute of Advanced Study, Princeton, NJ, USA *Self-directed research of international standing*

1991-1992	Program Director, Education, Human Resources and Special Programs, Div of Astronomical Sciences, National Science Foundation, Washington, DC, USA *Program management, cross-division initiatives, external liaison*
1990-1992	Research Assistant Professor, Physics and Astronomy Department, University of Pittsburgh, PA, USA *Self-directed research*
1987-1990	Adjunct Assistant Professor, Physics and Astronomy Department, University of Pittsburgh, PA, USA *Self-supported research post*
1988-1989	Visiting Scientist, Kapteyn Astronomical Institute, University of Groningen, The Netherlands *Self-directed independent research*
1987	Scientific Writing Consultant, Pittsburgh Supercomputing Center (PSC), Pittsburgh, PA, USA *Technical writing and editing*
1986-1987	Research Associate, Biological Sciences Department, University of Pittsburgh, PA, USA *Algorithm development and application to cellular activity*
1985-1986	Visiting Assistant Professor, Physics and Astronomy Department, University of Pittsburgh, PA, USA *University physics teaching*
1983-1985	Visiting Assistant Professor, Physics Department, Amherst College, MA, USA *University teaching in liberal arts setting*
Summer 1983	Science Writer Intern, *Science News* Magazine, Washington, DC, USA *Developing and writing science news stories*

Supervision of Junior Researchers

Researcher name	**Sackett Supervisory Capacity**	**Subsequent posting**
Paul Vreeswijk	1997 Honours Thesis Supervisor	Fellow, Weizmann Inst of Science, IL
Jean Philippe Beaulieu	1996-98 Postdoctoral Supervisor	Director of Research, IAP, Paris, FR
Martin Dominik	1997-99 Postdoctoral Supervisor	Reader, Univ of St Andrews, UK
Richard Naber	PhD Thesis (Co-supervisor)	Left field before completion
Scott Gaudi	2001 PhD Thesis (Co-supervisor)	Professor, Ohio State University, USA
Eduard Westra	2003 Honours Thesis Supervisor	Industrial Data Analyist, NL
Ulyana Dyudina	2004 Postdoctoral Supervisor	Assoc Scientist, Space Science Inst, USA
Jelte de Jong	2005 PhD Thesis (Co-supervisor)	Researcher, University of Groningen, NL
David Weldrake	2005 PhD Thesis Supervisor	Director, M-D Basin Authority, AU
Brandon Tingley	2006 PhD Thesis Supervisor	PostDoc, Aarhus University, DK
Christine Thurl	2007 PhD Thesis Supervisor	Industrial Physicist, DE
Thomas Evans-(Soma)	2008 Honours Supervisor	Lecturer, Univ of Newcastle, AU
Daniel Bayliss	2009 PhD Thesis Supervisor	Asst Professor, Univ of Warwick, UK
Karen Lewis	2011 PhD Thesis (Co-supervisor)	Postdoc, Earth Life Science Inst, JP

Selected Major Experiences and Accomplishments

2011-present *As Private Strategic Scientific Advisor:*

- Sole Expert Witness in BSCA vs EPA case in NSW Land and Environment Court
- Foresight analyst for 2025 Strategic Plan of BASF, world's largest chemical producer
- Scientific Assessor for Queensland $20m Smart Futures Fund
- Analyst and advisor to Australian multi-state Climate Action Roundtable

2015-2021 *As Councillor and Chair of ACT Climate Change Council:*

- Spearheaded recommendation for interim GHG emissions targets in the ACT
- With Prof. Will Steffen, introduced carbon budget approach into ACT policy-making
- Led *Canberra's Climate-Fuelled Summer of Crisis* Report

2008-2011 *As Chief Scientist for Australia:*

- Commissioned four cross-disciplinary reports for Prime Minister's Council (PMSEIC):
  Challenges at energy-water-carbon intersections
  Australia and food security in a changing world
  Transforming learning and the transmission of knowledge
  Epidemics in a changing world
- Founded Forum of Australian Chief Scientists
- Established two-way communication tools with Australian community

2002-2007 *As Director, Research School of Astronomy and Astrophysics (RSAA)*

- Managed University department and observatory staff of 100
- Responsible for annual budget of 6M AUD plus 4M AUD in 2nd & 3rd steam funds
- Oversaw rebuild of main campus of School after devastating 2003 bush fires
- Led national effort to establish next generation telescope access for Australia
- Established ANU Planetary Science Institute, joint venture with ANU Earth Sciences
- Initiated and carried out large change process at RSAA, managing
  mandated 29% increase in salary costs & 20% reduction in recurrent budget
- Spearheaded entry into two major international partnerships:
  Giant Magellan Telescope (GMT) and Murchison Wide Field Array (MWA)
- Negotiated awards of two major instrument contracts: Gemini NIFS (II) and GSAOI
- Oversaw 80% increase in research publication rate, 50% growth in PhD student body,
  and increase in student completion rate while decrease in time to submission

1989-2010 *As Scientific Researcher and Team Leader in USA, NL and Australia:*

- Streamlined massive searches for transiting planets in the Milky Way
- Founded and Principal Investigator of the international PLANET Collaboration,
  managing collaboration of 20 scientists in 7 countries using 5 telescopes to
  set first limits for Jupiter-like planets around common dwarf stars,
  determine limb-darkening of distant stars for the very first time, and
  detect first terrestrial-mass (5-Earth mass) exoplanet around a normal star
- Determined 3-D distribution of dark matter around some galaxies
- Quantified relationship between structure and dark matter in Milky Way
- Determined deep cloud structure in atmosphere of Saturn

1991-1992 *As Program Director at U.S. National Science Foundation (NSF), USA*

- Managed program of small grants to fund high-risk science
- Initiated first newsletter from NSF Astronomy division (AST) to national community
- Managed all cross-division (AST + another NSF division) awards
- Responsible for all AST projects related to education and diversity
- Initiated study into factors correlated to proposal success and failure

Local, National & International Service

2024-2025	Founding Board Member of Australian Peace and Security Forum
2015-2021	Councillor and Co-Chair/Chair, Australian Capital Territory (ACT) Climate Change Council
2017-2020	Member, Business Advisory Board, ACT Renewable Energy Innovation Fund
2017-2019	Member, Scientific Advisory Board, Potsdam Institute for Climate Impact Research
2015	Chair, Memorandum Team, Nobel Laureate Symposium: *Climate Change, Changing Cities*
2013	Invited Speaker, 2013 Geological Society of America, Denver, CO, USA Contribution: *Elemental Cycles in the Anthropocene*
2011	Drafting Team, Nobel Laureate Stockholm Memorandum on Global Sustainability
2008-2011	As Chief Scientist for Australia, Member of:

Prime Minister's Science, Engineering & Innovation Council, Executive Officer
Prime Minister's Science Prize Selection Committee
Educational Investment Fund Board
Defence Science & Technology Organisation Advisory Board
Rural Research & Development Council
Higher Education Endowment Fund Assessment Panel
Cooperative Research Centres Assessment Panel
Climate Change Science Framework Implementation Group, Chair
National Youth Science Forum, President
Forum of Australian Chief Scientists, Founder and Chair

2005-2010	Board of Directors, Association of Universities for Research in Astronomy (AURA)
2006-2008	Board of Directors, Giant Magellan Telescope (GMT) Organisation
2002-2008	ANU Member Representative to AURA
2008	Australian GMT Advisory Committee to Australia Astronomy, Ltd
2003-2007	NCA Task Force on Extremely Large Telescopes (ELT)
2002-2007	National Committee for Astronomy (NCA), Australian Academy of Science
2002-2007	Australian Gemini Telescope Steering Committee
2002-2007	Board of Management for the Australian Astronomy MNRF Award
2004-2007	Chancellor's Award Committee, Australian National University (ANU)
2004-2006	Canberra Partnership Board, ACT, AU
2003-2005	University Science, Health & Engineering Research Committee, ANU
2000-2005	European OPTICON Extremely Large Telescope (ELT) Science Working Group
2004	International review team of the South African Astro-Geoscience Facilities for the NRF
2002-2003	Academic Board, Australian National University, Canberra, AU
1995-2002	Principal Investigator, International PLANET Collaboration
2001-2002	Science Advisory Committee for the Square Kilometer Array
2001-2002	Curriculum Advisory Committee for Astronomy, Kapteyn Astronomical Institute
2000-2002	European Southern Observatory (ESO) Programmes Committee, Member-at-Large
2000-2001	Chair, Stars and Planets Panel for OPTICON ELT Working Group
1996-1998	Facilities Program Committee, Netherlands Organisation for Scientific Research

Scientific Organising and Steering Committees

2020	*Australian Climate Consensus Forum* Non-political, invitation-only brainstorming and networking of key organisations 12 March 2020, Canberra, Australia
2013-2015	*Changing Climate, Changing Cities* Nobel Laureates Symposium on Global Sustainability, Hong Kong 2015 also Chair, Symposium Memorandum Drafting Team
2008	*2008 Meeting of the Astronomical Society of Australia* Perth, Australia
2006-2007	*IAU Symposium on Exoplanets: Physics, Dynamics and Evolution* Suzhou, China
2006	*Transiting Extrasolar Planets* 25-28 September 2006, MPIA, Heidelberg, Germany
2003-2004	*Planetary Timescales: Stardust to Continents* 2003 White Conference, National Academy of Sciences, Canberra, AU
2002-2003	*Extrasolar Planets: Today and Tomorrow* 30 June - 4 July 2003, IAP, Paris, France
2001-2002	*Scientific Frontiers in Research on Extrasolar Planets* 11-14 June 2002, Washington, DC, USA
2001	*The SKA: Defining the Future* 9-12 July 2001, Berkeley, CA, USA
2000-2001	*Yale Cosmology Workshop: Shapes of Galaxies and Their Halos* 28-30 May 2001, New Haven, USA
1999-2000	*Planetary Systems in the Universe: Observation, Formation and Evolution* 7-11 August 2000, Manchester, England
1998-2000	*Microlensing 2000: A New Era for Microlensing Astrophysics* 21-25 February 2000, Capetown, South Africa Chair, Scientific Organising Committee
1997-1999	*Impact of Large-Scale Photometry on the Research of Pulsating Stars* IAU Conference, 9-13 August 1999, Budapest, Hungary
1997-1999	*VLT Opening Symposium: From Extrasolar Planets to Brown Dwarfs* 1-4 March 1999, Antofagasta, Chile
1997-1998	*4^{th} International Workshop on Microlensing Surveys* 15-17 January 1998, Paris, France
1990	*Warped Disks and Inclined Rings around Galaxies* Workshop 30 May - 1 June 1990, Pittsburgh PA Scientific and Local Organising Committee

PUBLICATIONS

Over 185 publications, 65 in refereed journals, together garnering
more than 4700 scientific citations and 1140 normalised citations
(Sackett served as PhD or postdoctoral supervisor for authors in italics)

Technical Reports, Submissions and Communications: Climate Change and Climate Policy

Expert Report: Regarding the Greenhouse Gas Implications and Climate Environmental Harm associated with Coal Mined from the West Pit of the New Acland Coal Mine
Penny D Sackett
2024, Submission to the Magistrates Court of Queensland, Case Number 00196533/23(1) [24A] in the Matter of Queensland Conservation Council v New Acland Coal

NSW Climate Change (Net Zero Future) Bill 2023
Penny D Sackett
2023, Submission to the NSW Parliament Portfolio Committee No. 7: Planning and Environment

Supplementary Expert Report: Regarding the Greenhouse Gas and Climate Implications of the Amungee NW Delineation Program (ORI11-3) Exploration Permit as submitted by Tamboran B2 Pty Ltd
Penny D Sackett
2023, Submission to the Supreme Court of the Northern Territory of Australia, Case Number No. 2023-00209-SC
in the Matter of CAFFA INC v Minister for Environment and Tamboran B2 Pty Ltd
Promised as affidavit on 5 September 2023

Export Report: Greenhouse Gas and Climate Implications of the Amungee NW Delineation Program (ORI11-3) Exploration Permit as submitted by Tamboran B2 Pty Ltd
Penny D Sackett
2023, Submission to the Supreme Court of the Northern Territory of Australia, Case Number No. 2023-00209-SC
in the Matter of CAFFA INC v Minister for Environment and Tamboran B2 Pty Ltd
Sworn as affidavit on 18 May 2023

Expert Report: Greenhouse Gas and Climate Implications of the Arrow Energy Hopeland EA Amendment for the Surat Gas Project
Penny D Sackett
2023, Report prepared responding to brief from the Environmental Defenders Office
30 March 2023

Supplementary Export Report: Matter of Bushfire Survivors for Climate Action v Narrabri Coal Operations Pty Ltd; Independent Planning Commission of NSW
Penny D Sackett
2023, Submission to the NSW Land and Environment Court, Case Number 2022/00192651
Sworn as affidavit on 30 January 2023

Expert Report: Covering Note for Submission of my Report on the Greenhouse Gas and Climate Implications of the Project as it relates to the EPBC Act and the Minister's Reconsideration of Several Coal and Gas Proposals
Penny D Sackett
2022, Covering Note, Permission for Reuse, and Scientific Update on Expert Report originally prepared for Environmental Defenders Office

Expert Report: Revised Environmental Impact Statement of the Winchester South Project as it relates to Climate Change and Greenhouse Gases
Penny D Sackett
2022, Report prepared responding to brief from the Environmental Defenders Office in relation Review by QLD Coordinator-General

Expert Report: Greenhouse Gas and Climate Implications of the Waratah Coal Pty Ltd proposal for the Galilee Power Station
Penny D Sackett
2022, Report prepared responding to brief from the Environmental Defenders Office in relation to Ministerial call-in from QLD Minister for Planning

Expert Report: Matter of Bushfire Survivors for Climate Action v Narrabri Coal Operations Pty Ltd; Independent Planning Commission of NSW
Penny D Sackett
2022, Submission to the NSW Land and Environment Court, Case Number 2022/00192651
Sworn as affidavit on 4 November 2022

Australian Carbon Credit Units
Penny D Sackett
2022, Submission to the Independent Review of Australian Carbon Credit Units

Environmental Protection and Biodiversity Conservation Amendment (Climate Trigger) Bill 2022
Penny D Sackett
2022, Submission to Senate Environment and Communications Legislation Committee

Inquiry into Climate Change Bill 2022 and Climate Change (Consequential Amendments) Bill 2022
Penny D Sackett
2022, Supplementary submission to Senate Environment and Communications Legislation Committee

Climate Change Bill 2022 and Climate Change (Consequential Amendments) Bill 2022
Penny D Sackett
2022, Submission to Senate Environment and Communications Legislation Committee

Expert Report: Greenhouse Gas and Climate Implications of the proposed Origin Beetaloo Sub-Basin Exploration Project (ORI11-1)
Penny D Sackett
2022, Report prepared responding to brief from the Environmental Defenders Office

Expert Report: Greenhouse Gas and Climate Implications of the proposed Mt Pleasant Optimisation Project (SSD - 10418)
Penny D Sackett
2022, Submission to the NSW Independent Planning Commission

Expert Report: Greenhouse Gas and Climate Implications of the proposed Dendrobium Mine Extension (SSI - 33143123)
Penny D Sackett
2022, Submission to the NSW Independent Planning Commission

Expert Report: Greenhouse Gas and Climate Matters Related to the Judicial Review of Woodside's Pluto Train 2 Works Approval
Affirmed as Affidavit on 9 May 2022
Penny D Sackett
2022, In Support of Applicant's Application for Leave to Adduce Expert Evidence in Case before the Supreme Court of Western Australia (CIV 2273 of 2021)

Expert Report: Greenhouse Gas and Climate Implications of the Glencore Glendell Continued Operations Coal Project (SSD 9349 and SSD 5840 Mod 4): Response to Additional Material
Penny D Sackett
2022, Submission to the NSW Independent Planning Commission

Expert Report: Greenhouse Gas and Climate Implications of the Glencore Glendell Continued Operations Coal Project (SSD 9349 and SSD 5840 Mod 4)
Penny D Sackett
2022, Submission to the NSW Independent Planning Commission

Expert Report: Greenhouse Gas and Climate Implications of Waratah Coal Pty Ltd proposal for Galilee Power Station (EPBC Referral 2021/9108)
Penny D Sackett
2022, Part of a submission to the Commonwealth Minister for the Environment

Expert Report: Greenhouse Gas and Climate Implications of the Narrabri Underground Mine Stage 3 (SSD 10269), Response to Additional Material
Penny D Sackett
2022, Submission to the NSW Independent Planning Commission

Expert Report: Greenhouse Gas and Climate Implications of the Narrabri Underground Mine Stage 3 (SSD 10269)
Penny D Sackett
2022, Submission to the NSW Independent Planning Commission

Expert Report: On the Environmental Impact Statement of the Winchester South Project as it relates to Climate Change
Penny D Sackett
2021, Part of a submission to the Queensland Coordinator-General

Expert Report: Matter of Bushfire Survivors for Climate Action Inc v Environment Protection Authority Affirmed as Affidavit D on 10 August 2021
Penny D Sackett
2021, Submission to the NSW Land and Environment Court, Case No. 20/106678

Expert Report: Matter of Bushfire Survivors for Climate Action Inc v Environment Protection Authority Affirmed as Affidavit C on 5 August 2021
Penny D Sackett
2021, Submission to the NSW Land and Environment Court, Case No. 20/106678

Expert Report: Matter of Bushfire Survivors for Climate Action Inc v Environment Protection Authority Affirmed as Affidavit B on 4 June 2021
Penny D Sackett
2021, Submission to the NSW Land and Environment Court, Case No. 20/106678

Expert Report: Matter of Bushfire Survivors for Climate Action Inc v Environment Protection Authority Affirmed as Affidavit A on 5 March 2021
Penny D Sackett
2021, Submission to the NSW Land and Environment Court, Case No. 20/106678

The Social Cost of Carbon and Implications for the ACT
Paul Bannister, Cristopher Brack, Mark Howden, Karen Jesson, Ben Ponton, Penny D Sackett (Chair), Sophia Hamblin Wang
2021, ACT Climate Change Council, Canberra

Expert Submission: Tahmoor South Coal Extension Project (SSD 17-8845)
Objecting: On the basis of greenhouse gas implications
Addendum in Response to Additional Material
Penny D Sackett
2021, Submission to the NSW Independent Planning Commission

Expert Report: Matter of Mullaley Gas & Pipeline Accord Inc v Santos NSW Pty Ltd; Independent Planning Commission of NSW
Affirmed as Affidavit C on 5 August 2021
Penny D Sackett
2021, Submission to the NSW Land and Environment Court, Case No. 20/363113

Expert Report: Greenhouse Gas and Climate Implications of the Narrabri Gas Project (SSD 6456) Response to Additional Material
Penny D Sackett
2020, Submission to the NSW Independent Planning Commission

Expert Report: Greenhouse Gas and Climate Implications of the Narrabri Gas Project (SSD 6456)
Penny D Sackett
2020, Submission to the NSW Independent Planning Commission

Learning from Canberra's Climate-Fuelled Summer of Crisis
Paul Bannister, Cristopher Brack, Mark Howden, Karen Jesson, Ben Ponton, Penny D Sackett (Chair), Sophia Hamblin Wang
2020, ACT Climate Change Council, Canberra

Community Listening Report on Adaptation to Climate Crises: The Extreme Summer of 2019/20
Penny Sackett, Will Steffen and Karen Jessen
2020, ACT Climate Change Council, Canberra

Expert Submission: Tahmoor South Coal Extension Project (SSD 17-8845)
Objecting: On the basis of greenhouse gas implications
Addendum: In Response to the Greenhouse Gas Assessment of the Amended Project
Penny D Sackett
2020, Submission to the NSW Independent Planning Commission

Climate of fear: summit aims to create action consensus
S. Robson and P. Sackett
2020, in 'Insight' of the Medical Journal of Australia, 2 March 2020

Expert Submission: Tahmoor South Coal Extension Project (SSD 17-8845)
Objecting: On the basis of greenhouse gas implications
Penny D Sackett
2019, Submission to the NSW Independent Planning Commission

Independent Assessment: Rix's Creek South Continuation of Mining Project (SSD 6300)
Objecting: On the basis of greenhouse gas implications
Penny D Sackett
2019, Submission to the NSW Independent Planning Commission

Who is Counting our Carbon Budget?
P.D. Sackett and W. Steffen
2019, in 'Policy Forum' of the Asia and The Pacific Policy Society, 7 May 2019

What is a Carbon Budget?
Penny Sackett, Will Steffen and Karen Jessen
2018, ACT Climate Change Council, Canberra

Sub-National Climate Policies: How does the ACT compare? Part I: Report
Luke Kemp, Penny Sackett, and Frank Jotzo
2015, ACT Climate Change Council, Canberra

Sub-National Climate Policies: How does the ACT compare? Part II: Data Tables
Luke Kemp, Penny Sackett, and Frank Jotzo
2015, ACT Climate Change Council, Canberra

Refereed Scientific Publications

Gas is not a transition fuel to a safe climate. That ship has sailed.
Penny D. Sackett
2020, Journal and Proceedings of the Royal Society of New South Wales, 153, 2

Elemental cycles in the Anthropocene: Mining AboveGround
Penny D. Sackett
2016, in Geoscience for the Public Good and Global Development: Toward a Sustainable Future, eds. G.R. Wessel and J.K. Greenberg, J.K., Geological Society of America Special Papers 520, p. SPE520-11, doi:10.1130/2016.2520(11)

HATS-3b: An Inflated Hot Jupiter Transiting an F-type Star
Daniel D. R. Bayliss et al (29 authors, including Penny D Sackett)
2013, AJ, 146, 113, arXiv:1306.0624

Endangered Elements: Conserving the Building Blocks of Life
(Invited Review) Penny Sackett
2012, Solutions, Volume 3, Issue 3

HATSouth: a global network of fully automated identical wide-field telescopes
G. Á. Bakos et al (24 authors, including *Daniel D. R. Bayliss* and Penny D. Sackett
2013, PASP, 125, 154, arXiv:1206.1391

The Frequency of Hot Jupiters in the Galaxy: Results from the SuperLupus Survey
Daniel D. R. Bayliss and Penny D. Sackett
2011, ApJ, 743, 103, arXiv:1112.0359

Confirmation of a Retrograde Orbit for Exoplanet WASP-17b
Daniel D. R. Bayliss, Joshua N. Winn, Rosemary A. Mardling & Penny D. Sackett
2010, ApJ Letters, 722, L224-L227, arXiv:1009.5061

An *a priori* Investigation of Astrophysical False Positives in Ground-Based Transiting Planet Surveys
Tom M. Evans & Penny D Sackett
2010, ApJ, 712, 38, arXiv:1002.0886

Microlensing exoplanets
Penny D Sackett
2010, Scholarpedia, 5(1):3991

The Lupus Transit Survey for Hot Jupiters: Results and Lessons
Daniel D. R. Bayliss, *David T. F. Weldrake*, Penny D. Sackett, *Brandon W. Tingley* & *Karen M. Lewis*
2009, AJ, 137, 4368, astro-ph/0903.5121

Possibility of Detecting Pulsar Moons through Time-of-Arrival Analysis
Karen M. Lewis, Penny D. Sackett & Rosemary A. Mardling
2008, ApJL, 685, L153, astro-ph/0805.4263

Lupus-TR-3b: A Low-Mass Transiting Hot Jupiter in the Galactic Plane?
David T. F. Weldrake, *Daniel D. R. Bayliss*, Penny D. Sackett, *Brandon W. Tingley*, Michaël Gillon & Johny Setiawan
2008, ApJL, 675, L37, astro-ph/0711.1746

The Frequency of Large Radius Hot and Very Hot Jupiters in ω Centauri
David T. F. Weldrake, Penny D. Sackett & Terry J. Bridges
2008, ApJ, 674, 1117, astro-ph/0710.3461

A Deep Wide-Field Variable Star Catalog of ω Centauri
David T. F. Weldrake, Penny D. Sackett & Terry J. Bridges
2007, AJ, 133, 1447, astro-ph/0610704

Resolving Stellar Atmospheres I: The Hα line and comparisons to microlensing observations
Christine Thurl, Penny D. Sackett & Peter H. Hauschildt
2006, A & A, 455, 315, astro-ph/0604088

MACHOs in M31? Absence of evidence but not evidence of absence
Jelte T.A. de Jong, Lawrence M. Widrow, Patrick Cseresnjes, Konrad Kuijken, Arlin P.S. Crotts, Alexander Bergier, Edward A. Baltz, Geza Gyuk, Penny D. Sackett, Robert R. Uglesich & Will J. Sutherland
2006, A & A, 446, 855, astro-ph/0507286

Discovery of a cool planet of 5.5 Earth masses through gravitational microlensing
J.-P. Beaulieu, et al (PLANET, OGLE and MOA, 73 authors, includ. Penny D. Sackett)
2006, Nature, 439, 437, astro-ph/0601563

The color signature of the transit of HD 209458 and discrepancies between stellar atmospheric models and observations
B. Tingley, *C. Thurl* & P. Sackett
2006, A & A, 445, L27, astro-ph/0510633

A Photometric Diagnostic to Aid in the Identification of Transiting Extra-solar Planets
Brandon Tingley & Penny D. Sackett
2005, ApJ, 627, 1011, astro-ph/0503575

An Absence of Hot Jupiter Planets in 47 Tucanae: Results of a Wide-Field Transit Search
David T.F. Weldrake, Penny D. Sackett, Terry J. Bridges, & Kenneth C. Freeman
2005, ApJ, 620, 1043, astro-ph/0411233

A Method for the Detection of Planetary Transits in Large Time-Series Datasets
David T.F. Weldrake & Penny D. Sackett
2005, ApJ, 620, 1033, astro-ph/0411234

Phase light curves for extrasolar Jupiters and Saturns
Ulyana A. Dyudina, Penny D. Sackett, *Daniel D.R. Bayliss*, Sara Seager, Carolyn C. Porco, Henry B. Throop & Luke Dones
2005, ApJ, 618, 973-986, astro-ph/0406390

A Comprehensive Catalogue of Variable Stars in the field of 47 Tucanae
David T.F. Weldrake, Penny D. Sackett, Terry J. Bridges, & Kenneth C. Freeman
2004, AJ, 128, 736, astro-ph/0405133

First Microlensing Results for the MEGA Survey of M31
Jelte T.A. de Jong, Konrad H. Kuijken, Arlin P.S. Crotts, Penny D. Sackett, Will J. Sutherland, Robert R. Uglesich, Edward A. Baltz, Patrick Cseresnjes, Geza Guyk, Lawrence M. Widrow (MEGA Collaboration)
2004, A & A, 417, 461-477, astro-ph/0307072

PLANET II: A Microlensing and Transit Search for Extrasolar Planets
Penny D. Sackett, M.D. Albrow, *J.-P. Beaulieu*, J.A.R. Caldwell, C. Coutures, *M. Dominik*, J. Greenhill, K. Hill, K. Horne, U.-G. Jorgensen, S. Kane, D. Kubas, R. Martin, J. Menzies, K.R. Pollard, K.C. Sahu, J. Wambsganss, R. Watson, A. Williams (PLANET),
in Bioastronomy 2002: Life Among the Stars, eds. R. Norris, C. Oliver & F. Stootman
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Penny D. Sackett
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Respondent No: 5
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Responded At: Dec 16, 2025 10:37:34 am
Last Seen: Dec 16, 2025 00:50:10 am
IP Address: 167.103.102.84

Q1.	**Given name**	Eric
Q2.	**Family Name**	Smith
Q3.	**Location**	MOIL, NT
Q4.	**Stakeholder type**	Community member
Q5.	**Email address**	bigekka@hotmail.com
Q6.	**Interest area**	Social and cultural Flora and fauna Water Waste management Climate change Human health Chemicals Regulation and compliance Well integrity

Q7. **Please provide your comments**

Submission: STO8-1 – EP161 Beetaloo Basin Appraisal Pilot Environment Management Plan Eric Smith bigekka@hotmail.com 13/12/2025 I am a long term Northern Territory resident living in Darwin and I am making this submission to object to Santos' proposed EP161 Beetaloo Basin Appraisal Pilot Environment Management Plan. I am deeply concerned that this EMP does not adequately address the risks posed to groundwater, surface water, springs, biodiversity, and climate, and that it relies on incomplete baseline data and optimistic assumptions rather than precaution. In my view, this project should not proceed under an EMP alone and requires a full Environmental Impact Statement (EIS) and referral under the EPBC Act. Water and aquifer risks The most serious issue with this proposal is water. The project involves drilling and hydraulic fracture stimulation in an area connected to major groundwater systems, including the Cambrian Limestone Aquifer. This aquifer feeds ecologically and culturally important springs and waterways across the NT, including systems connected to the Roper and Daly catchments. The EMP does not convincingly rule out hydraulic connectivity between deep shale formations and overlying aquifers or springs. Faults, fractures, well integrity failure and long-term degradation of cement and casing are all known risks in shale gas development, particularly over timeframes far longer than the appraisal phase. Of particular concern is Hot Springs Valley on Tanumbirini Station and nearby spring systems. These springs are fed by deep groundwater and are increasingly recognised as environmentally significant. They appear to be poorly understood, and their discovery and study are relatively recent. The EMP does not demonstrate that these systems are protected from potential impacts of drilling, fracking, pressure changes or contamination pathways. Given the permanence of groundwater damage, this lack of certainty is unacceptable. The EMP also acknowledges groundwater dependent ecosystems within 5 km of the project area, yet relies on assumptions rather than detailed, site-specific studies of how these systems function and how vulnerable they are. Baseline monitoring must come before approval, not after disturbance has occurred. Surface water risks are also underplayed. Runoff from the project area drains into the Limmen River catchment, with Limmen National Park and downstream coastal systems potentially affected. Any failure of wastewater storage, particularly during extreme rainfall or cyclonic events (which are normal in this region), could transport contaminants such as salts, heavy metals and naturally occurring radioactive material far beyond the site boundary. Once groundwater or connected surface waters are contaminated, remediation is complex, expensive and often incomplete. The EMP does not demonstrate that these risks have been reduced to an acceptable level. Wastewater, spills and extreme

weather The proposal relies on evaporation ponds, tanks, drilling sumps and waste pits to manage large volumes of contaminated wastewater. These systems are inherently vulnerable to liner failure, overtopping, flooding and human error. The EMP does not adequately demonstrate that these facilities can withstand extreme rainfall events or cyclones, nor does it provide realistic worst-case spill modelling or long-term liability arrangements. Recent incidents in the Beetaloo region show that spills do occur. This EMP does not inspire confidence that similar incidents would not impact connected waterways and ecosystems. Stygofauna and subterranean ecosystems The EMP states that stygofauna are unlikely to be present, yet no targeted stygofauna surveys were undertaken at bores near the project area. Instead, the assessment relies on historical surveys conducted many kilometres away, some of which actually recorded stygofauna presence. Stygofauna are highly sensitive to changes in water chemistry and pressure and are often endemic to specific aquifer systems. Without targeted local surveys, claims about their absence are not credible. This is a clear gap in the environmental assessment. Threatened fauna and inadequate surveys The EMP acknowledges the potential presence of threatened species, including the northern blue-tongue skink, which is listed as critically endangered. Despite this, the survey methodology relied mainly on active searches and did not include complementary methods such as pitfall traps, funnel traps or drift fences, which are standard practice for detecting cryptic reptiles. Declaring impacts “unlikely” without using appropriate survey methods is not a sound basis for approval. This is especially concerning given the scale of clearing proposed (over 87 hectares) in relatively intact savanna and floodplain habitat. The NT has some of the last remaining large areas of intact tropical savanna in the world. Clearing this habitat for short-term appraisal activities, without robust baseline data and avoidance measures, is not justified. Climate impacts This project cannot be viewed in isolation. The purpose of the appraisal phase is to enable large-scale gas development. Independent estimates indicate that full development of the Beetaloo could result in approximately 1.1–1.2 billion tonnes of CO_2-equivalent emissions over its lifetime, increasing Australia’s emissions by roughly 20%. The EMP’s greenhouse gas figures for this pilot phase appear unrealistically low compared to similar projects with fewer wells. There is no meaningful assessment of cumulative or downstream emissions, nor of how approving this project aligns with Australia’s net zero commitments or the recommendations of the Pepper Inquiry. Approving appraisal projects without considering the emissions they enable is effectively approving the larger development by stealth. Failure to consider connected systems A recurring problem throughout the EMP is its narrow site-based focus. Water does not respect lease boundaries. Aquifers, springs, rivers, floodplains and coastal systems are connected. Impacts may occur far from the well pads and long after the appraisal phase ends. The EMP does not adequately consider these broader, connected systems or the cumulative impacts of multiple projects across the Beetaloo Basin. What should happen Given the scale of uncertainty and the potential for irreversible harm, I believe this EMP should not be approved in its current form. At a minimum, I ask that: * The EMP be rejected unless comprehensive, independent baseline studies are completed for groundwater, springs (including Hot Springs Valley), surface water, stygofauna and threatened fauna. * A full Environmental Impact Statement be required under the Environment Protection Act 2019 (NT). * The project be referred to the Federal Environment Minister under the EPBC Act due to likely significant impacts on water resources and matters of national environmental significance, including threatened species. * The precautionary principle be applied, recognising that uncertainty about serious environmental harm is a reason to delay approval, not proceed. This project presents risks that are not temporary, not localised, and not easily reversible. Once groundwater is damaged or species are lost, those impacts cannot be undone. The current EMP does not meet the standard required to protect the Northern Territory’s water, environment or climate future. Thank you for considering my submission. Eric Smith

Q8. **Add an attachment - Max file size: 5MB**	https://s3-ap-southeast-2.amazonaws.com/ehq-production-australia/cf970d80e79df38a0494452a9e8487733f31238c/original/1765847190/96000a32e6205561dd82df023a983de2_Submission%20STO81%20EP161.docx?1765847190
Q9. **Tick this box if you wish for your name and contact details to be confidential**	not answered

Submission: STO8-1 – EP161 Beetaloo Basin Appraisal Pilot Environment Management Plan

Eric Smith

bigekka@hotmail.com

13/12/2025

I am a long term Northern Territory resident living in Darwin and I am making this submission to object to Santos' proposed EP161 Beetaloo Basin Appraisal Pilot Environment Management Plan.

I am deeply concerned that this EMP does not adequately address the risks posed to groundwater, surface water, springs, biodiversity, and climate, and that it relies on incomplete baseline data and optimistic assumptions rather than precaution. In my view, this project should not proceed under an EMP alone and requires a full Environmental Impact Statement (EIS) and referral under the EPBC Act.

Water and aquifer risks

The most serious issue with this proposal is water. The project involves drilling and hydraulic fracture stimulation in an area connected to major groundwater systems, including the Cambrian Limestone Aquifer. This aquifer feeds ecologically and culturally important springs and waterways across the NT, including systems connected to the Roper and Daly catchments.

The EMP does not convincingly rule out hydraulic connectivity between deep shale formations and overlying aquifers or springs. Faults, fractures, well integrity failure and long-term degradation of cement and casing are all known risks in shale gas development, particularly over timeframes far longer than the appraisal phase.

Of particular concern is Hot Springs Valley on Tanumbirini Station and nearby spring systems. These springs are fed by deep groundwater and are increasingly recognised as environmentally significant. They appear to be poorly understood, and their discovery and study are relatively recent. The EMP does not demonstrate that these systems are protected from potential impacts of drilling, fracking, pressure changes or contamination pathways. Given the permanence of groundwater damage, this lack of certainty is unacceptable.

The EMP also acknowledges groundwater dependent ecosystems within 5 km of the project area, yet relies on assumptions rather than detailed, site-specific studies of how these systems function and how vulnerable they are. Baseline monitoring must come before approval, not after disturbance has occurred.

Surface water risks are also underplayed. Runoff from the project area drains into the Limmen River catchment, with Limmen National Park and downstream coastal systems potentially affected. Any failure of wastewater storage, particularly during extreme rainfall or cyclonic events (which are normal in this region), could transport contaminants such as salts, heavy metals and naturally occurring radioactive material far beyond the site boundary.

Once groundwater or connected surface waters are contaminated, remediation is complex, expensive and often incomplete. The EMP does not demonstrate that these risks have been reduced to an acceptable level.

Wastewater, spills and extreme weather

The proposal relies on evaporation ponds, tanks, drilling sumps and waste pits to manage large volumes of contaminated wastewater. These systems are inherently vulnerable to liner failure, overtopping, flooding and human error. The EMP does not adequately demonstrate that these facilities can withstand extreme rainfall events or cyclones, nor does it provide realistic worst-case spill modelling or long-term liability arrangements.

Recent incidents in the Beetaloo region show that spills do occur. This EMP does not inspire confidence that similar incidents would not impact connected waterways and ecosystems.

Stygofauna and subterranean ecosystems

The EMP states that stygofauna are unlikely to be present, yet no targeted stygofauna surveys were undertaken at bores near the project area. Instead, the assessment relies on historical surveys conducted many kilometres away, some of which actually recorded stygofauna presence.

Stygofauna are highly sensitive to changes in water chemistry and pressure and are often endemic to specific aquifer systems. Without targeted local surveys, claims about their absence are not credible. This is a clear gap in the environmental assessment.

Threatened fauna and inadequate surveys

The EMP acknowledges the potential presence of threatened species, including the northern blue-tongue skink, which is listed as critically endangered. Despite this, the survey methodology relied mainly on active searches and did not include complementary methods such as pitfall traps, funnel traps or drift fences, which are standard practice for detecting cryptic reptiles.

Declaring impacts "unlikely" without using appropriate survey methods is not a sound basis for approval. This is especially concerning given the scale of clearing proposed (over 87 hectares) in relatively intact savanna and floodplain habitat.

The NT has some of the last remaining large areas of intact tropical savanna in the world. Clearing this habitat for short-term appraisal activities, without robust baseline data and avoidance measures, is not justified.

Climate impacts

This project cannot be viewed in isolation. The purpose of the appraisal phase is to enable large-scale gas development. Independent estimates indicate that full development of the Beetaloo could result in approximately 1.1–1.2 billion tonnes of CO_2-equivalent emissions over its lifetime, increasing Australia's emissions by roughly 20%.

The EMP's greenhouse gas figures for this pilot phase appear unrealistically low compared to similar projects with fewer wells. There is no meaningful assessment of cumulative or downstream emissions, nor of how approving this project aligns with Australia's net zero commitments or the recommendations of the Pepper Inquiry.

Approving appraisal projects without considering the emissions they enable is effectively approving the larger development by stealth.

Failure to consider connected systems

A recurring problem throughout the EMP is its narrow site-based focus. Water does not respect lease boundaries. Aquifers, springs, rivers, floodplains and coastal systems are connected. Impacts may occur far from the well pads and long after the appraisal phase ends.

The EMP does not adequately consider these broader, connected systems or the cumulative impacts of multiple projects across the Beetaloo Basin.

What should happen

Given the scale of uncertainty and the potential for irreversible harm, I believe this EMP should not be approved in its current form.

At a minimum, I ask that:

* The EMP be rejected unless comprehensive, independent baseline studies are completed for groundwater, springs (including Hot Springs Valley), surface water, stygofauna and threatened fauna.

* A full Environmental Impact Statement be required under the Environment Protection Act 2019 (NT).

* The project be referred to the Federal Environment Minister under the EPBC Act due to likely significant impacts on water resources and matters of national environmental significance, including threatened species.

* The precautionary principle be applied, recognising that uncertainty about serious environmental harm is a reason to delay approval, not proceed.

This project presents risks that are not temporary, not localised, and not easily reversible. Once groundwater is damaged or species are lost, those impacts cannot be undone. The current EMP does not meet the standard required to protect the Northern Territory's water, environment or climate future.

Thank you for considering my submission.

Eric Smith

From: Gill Abraham
To: SantosPetroleum DLPE
Cc: Joshua Burgoyne; Justine Davis; Senator.McCarthy@aph.gov.au; senator.watt@aph.gov.au; Luke.Gosling.MP@aph.gov.au; Marion.Scrymgour.MP@aph.gov.au
Subject: SANTOS EP 161 Submission -
Date: Monday, 15 December 2025 10:17:20 PM
Attachments: Submission ST08-1 EP161 Beetaloo Basin Appraisal Piloy EMP.docx

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 a submission for The Beetaloo Basin Appraisal Pilot EMP
Regards
Gillian Abraham

Gillian Abraham

gillabraham@netspace.net.au

15 Dec 2025

Submission: STO8-1: EP161 Beetaloo Basin Appraisal Pilot EMP

Thank you for the opportunity to make a submission on this referral.

My name is Gillian Abraham and I live in Millner, NT. I am writing to you to share my strong belief that this project should be assessed more thoroughly before gaining any approval to proceed.

I am a long term Territory resident, and I am worried about the large scale development of fracking in the Territory and particularly the current Santos EMP which is without comprehensive surveys and assessments of the impact to water systems and the consequent impact downstream, and the impact of activities to air quality, threatened species and impacts on climate.

The Beetaloo Basin, and Tanumbirini Station are a part of the Northern Territory landscape that includes rolling hills, pristine creeks, large floodplains and rivers that flow into Limmen Bight Marine Park. Limmen Marine Park contains the sea grass fields of the Gulf of Carpentaria. It is important that the cumulative impact of the expansion of the industry on the waterways, run off, surface water contamination, and flow into the Gulf is thoroughly examined before further fracking is undertaken.

Newly discovered Hot Springs from a deep aquifer in the Cox River area have not been mentioned by Santos in their submission. Concern about cross contamination of aquifers must be examined, along with surface water contamination in floodways. Research to fully assess these remarkable springs before Santos starts in the area must be completed.

The current owners of Tanumbirini Station have strong concerns about this EMP including air quality. The well is to be located 3 kilometres from the station and this is considered dangerously close for human health. Their broader concerns are mirrored by the Traditional Owners in the region and they have fought alongside the Traditional Owners to resist fracking activity on their station.

I am worried about the reliance on the 2024 survey of 18 sites which consisted of broad brush strokes and inadequate details of the impact on the environment. It is an environment that must be protected and preserved, and this cannot be guaranteed

with Santos, who has a history of leaving degraded sites after production, including wastewater pits and subsequent uncontrolled run off into surrounding creeks. Further Details of the Tier 1 and 2 chemicals have been found to be untrue. This is evidence of Santos's disregard of risk governance and risk assessment.

The NT has some of the last remaining large swathes of undisturbed savanna anywhere in the world and we cannot afford to clear more for short-sighted ventures. The EMP plans to clear 87 hectares of savanna woodland and floodplain, in an area where there are a diverse array of relatively undisturbed habitat and few weeds.

My key concerns regarding this EMP are that Santos has not thoroughly investigated issues of water, endangered species, climate, and the environment pertaining to the proposed activity, and is thus putting the future safety of Territorians, and nature at irreparable risk.

I recommend that The Minister reject this version of the proposed EMP, requests inclusion of reports and actions to ensure all aspects of water quality, endangered species protection, environment protection, air quality and climate are investigated and included. I also request that the minister refer this project for assessment under the Environment Protection Act.

Yours sincerely,

Gillian Abraham

From:	George Woods
To:	SantosPetroleum DLPE
Cc:	louis@lockthegate.org.au
Subject:	Submission: EP161 STO8-1 Beetaloo Basin Appraisal Pilot EMP
Date:	Thursday, 18 December 2025 12:31:14 PM
Attachments:	STO8-1 Beetaloo Basin Appraisal Pilot _LTGsubmission.pdf

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Department of Lands, Planning and Environment

To the Petroleum Regulations Unit

Please find attached a submission on the draft STO8-1 Beetaloo Basin Appraisal Pilot EMP from Lock the Gate Alliance. I am submitting on behalf of Louis Boyle-Bryant who is copied on this email.

Please confirm receipt of this submission.

Thank you

Georgina Woods
Head of Research and Investigations
Lock the Gate Alliance

LOCK THE GATE ALLIANCE
AUSTRALIANS WORKING TOGETHER TO PROTECT OUR LAND, WATER, AND FUTURE

Reply to: Louis Boyle-Bryant
Top End Regional Campaigner
louis@lockthegate.org.au

18 December 2025

Department of Lands, Planning and Environment
Via email: Santos.ep161@nt.gov.au

Submission: EP161 STO8-1 Beetaloo Basin Appraisal Pilot EMP

Thank you for the opportunity to make a submission on this referral.

Lock the Gate Alliance is a national network of grassroots organisations made up of over 120,000 supporters and over 100 local groups concerned about the risks of coal mining, coal seam gas extraction and hydraulic fracturing. Several of these groups are located in the Northern Territory, including Darwin, Katherine and Alice Springs, as well as other rural and remote areas around the NT. Our members include pastoralists, traditional custodians, conservationists and suburban families. Together we share a vision of healthy, empowered communities that have access to fair and democratic processes to care for land and water.

This project could have a significant impact on the environment if it were allowed to proceed and should be referred to the EPA for a full Environmental Impact Statement (EIS). The environmental risks from this project, particularly with regards to threatened species, climate and water, could be profound, and the EPA must ensure that it undergoes the most comprehensive assessment possible. It is our view that the risks posed by this project should ultimately prevent it from proceeding.
It also needs to be referred to the Commonwealth as a controlled action under the EPBC Act, as it is likely to have a significant impact on threatened species, including the Carpentarian grasswren, and water resources.

Lock the Gate objects to this EMP on the grounds that it will significantly affect water resources and the landscape, and will contribute greenhouse gas emissions that will worsen climate change and harm every Territorian.

In any case, this EMP fails to adequately capture the scale and nature of impacts from this project and the Department must not grant approval to this project in that circumstance. Some of the material provided by the proponent is incomplete and/or inaccurate. It downplays the impacts of the project by omitting important information and failing to capture and describe in greater detail some of its major environmental impacts.

Beyond the known risks to the environment associated with hydraulic fracturing, we are particularly concerned about the following matters raised by this EMP:

1. The section of the EMP dealing with the principles of ecologically sustainable development doesn't actually address those principles. Given the inter-generational consequences of groundwater removal and greenhouse gas emissions, proper consideration of these statutory matters is required.
2. We are concerned about the adequacy of the assessment and the risk management arrangements for the proposed onsite burial of fracking waste in burial pits, which is similarly an inter-generational issue. Proper assessment via an EIS should explore the contamination risks of this proposal and efficacy of proposed containment measures.
3. The project is likely to have a serious impact on water resources, which is largely understated in the EMP. In terms of surface water, the project is largely located on a floodplain, and the consequences of that on highly significant downstream areas have not been properly considered. In addition, the project is in close proximity to springs in the Hot Springs Valley and too little is known about the source aquifers for the springs to assume this project will not affect them.
4. The EMP asserts that it is unlikely that stygofauna occur in the project area, but provides no evidence to support this claim, despite records from previous surveys occurring within 17km of the disturbance area. Dedicated stygofauna surveys must be conducted in the locality.
5. The EMP fails to assess the impact of the project on the Carpentarian grasswren (*Amytornis dorotheae*), a federally listed endangered species with very few recent records in the NT which it appears has been recorded as present. Targeted surveys for the Carpentarian grasswren must take place before any works proceed, including a full assessment of the likely impacts on any grasswren populations present in the area.
6. The EMP acknowledges the possible presence of the federally listed crested shrike-tit [northern] (*Falcunculus frontatus whitei*), but did not employ a best-practice methodology to ascertain the presence or absence of the species. More scientifically robust surveys for the crested shrike-tit (northern) must be conducted at the project site before any works take place and a full impact assessment conducted, owing to the small home range of the species and its vulnerability to disturbance.
7. The EMP acknowledges the presence of Groundwater Dependent Ecosystems (GDEs) within 5km of the project area, but fails to adequately assess potential impacts on these GDEs.
8. The EMP acknowledges the possible presence of the federally-listed northern blue-tongue skink (*Tiliqua scincoides intermedia*), but did not employ best-practice methodology to ascertain the presence or absence of the species.
9. The EMP acknowledges the likely presence of the federally-listed Gouldian finch (*Erythrura gouldiae*), but did not employ best-practice methodology to ascertain the presence or absence of the species.
10. The Weed Management Plan submitted as part of this EMP will be insufficient to prevent the introduction of new weed species to the project area.
11. Estimates for total greenhouse gas emissions across the life of the project are exceptionally low for a project of this size. The methodology used to calculate these emissions should be independently reviewed and a new assessment conducted that evaluates the likely emissions if a beneficial use of gas agreement is made, and if it isn't.
12. The EMP omits greenhouse gas emissions from flaring or venting and does not describe how gas flow can be appraised without undertaking these activities, unless the gas is captured, processed and transported for sale which would come with its own environmental

consequences. A decision cannot be made on this EMP without exploration of the environmental consequences, particularly the greenhouse gas emissions, of each of these scenarios.

Further information on some of these matters is provided below.

Greenhouse gas emissions and climate change

This project is incompatible with Australia's commitment preventing dangerous levels of global warming by reducing emissions to net zero by 2050 and with Recommendation 9.8 from the Pepper Inquiry which states:

"*the NT and Australian governments [should] 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*."

This project is designed to appraise the commercial viability of onshore gas reserves in the NT, and its success could form part of a network of hundreds or even thousands of wells, with associated greenhouse gas emissions that will drive global warming above the temperature goals of the Paris climate agreement and bring risk and harm to Territorians. Some of the risks accruing to the people of the NT now and in the next two decades as a result of global warming were laid out in the recent National Climate Risk Assessment and include:

- In the Northern Territory, 43% of commercial structures are located in very high-risk areas for sea level rise[1];
- Already 19% of households in the Territory have difficulty affording insurance[2];
- Modelled total annual economic cost of cyclones in the NT in 2050 of $2.1 billion[3];
- Increase in the number of heatwave days experienced each year and the peak temperatures of heatwaves[4];
- Regional aquifers that are sensitive to seasonal rainfall, such as the Katherine-Tindall aquifer, were identified as posing an extreme risk of ecosystems being detrimentally impacted by changed water availability with decreased reliability in wet season rainfall.[5]

WIth regards to this EMP specifically, Santos estimates that its project will only generate 27,741 tonnes $CO_{2\text{-}e}$ of scope 1 greenhouse gas emissions over the next five years as part of this project. The EMP is not sufficiently transparent in its calculation of this assumptions used to reach this estimate as other regional projects of a comparable size (e.g. Beetaloo Energy Australia's Carpentaria Project) estimate they will generate 180,000 tonnes $CO_{2\text{-}e}$ of scope 1 greenhouse gas emissions with only nine wells over the same five-year period.

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[1] Australian Climate Service, September 2025. *National Climate Risk Assessment: Communities Technical Report*. p27.
[2] Australian Climate Service, September 2025. *National Climate Risk Assessment.* p108.
[3] Australian Climate Service, September 2025. *National Climate Risk Assessment*. p110.
[4] Australian Climate Service, September 2025. National Climate Risk Assessment: Health and Wellbeing Technical Report pp42-44.
[5] Australian Climate Service, September 2025. *National Climate Risk Assessment: Water Security Technical Report* pp72-75.

According to the schedule laid out in the EMP, the company is proposing a full year of testing of the 2-3 wells expected to be drilled and fracked in 2026, but does not appear that any estimate has been made of the greenhouse emissions that would arise from these testing activities. One item in the greenhouse inventory is "non-routine venting and flaring," which is noted to be "distinct from extended production testing" but there is no corresponding estimate of emissions from scheduled flaring or venting during testing. The EMP indicates that in Q1 2027 there will be "Production testing in line with beneficial use arrangements" but provides no assessment of emissions with and without such arrangements being settled. Beneficial use of appraisal gas will require gas compression and transmission, both of which come with environmental effects, and in the event that an agreement is not reached, appraisal testing cannot occur without venting or flaring. For this reason, a decision cannot be made on this EMP without exploration of the environmental consequences, particularly the greenhouse gas emissions, of each of these scenarios.

The greenhouse gas assessment for this project needs independent review and verification if the government and the public are to have confidence in it.

Impacts on water resources

The project is likely to have a serious impact on water resources, which is largely understated in the EMP. In terms of surface water, the project is largely located on a floodplain, and the consequences of that have not been properly considered. Any spills from these wells are likely to flow into Tanumbirini Creek and then into the Cox/Limmen River, which is recognized as having high cultural and ecological significance. In addition, the project is in close proximity to springs in the Hot Springs Valley.

CSIRO has described the area as having significant environmental values, stating that:

> *The Hot Springs Valley is a relatively understudied area that holds significant environmental and cultural value. The valley is located to the northeast of the Beetaloo Sub-basin, within the headwaters of the Cox River catchment. In addition to discharging hot water, the springs also feature bubbling natural sources of methane and ethane.*[6]

CSIRO has indicated that there is limited data in the area:

> *Past studies have included:*
> - *limited baseline hydrochemistry sample collection*
> - *greenhouse gas surveys around the springs*
> - *aquatic ecology surveys.*

[6] CSIRO, March 2024. (Gas Industry Social and Environmental Research Alliance). Fact Sheet: Establishing an environmental baseline characterisation of the springs in Hot Springs Valley, Northern Territory." Available: https://gisera.csiro.au/research/surface-and-groundwater/environmental-baseline-characterisation-of-the-springs-in-hot-springs-valley-nt/

> *However, significant gaps in baseline data remain. There is limited documented information about the perspectives of Indigenous communities in the area, and the source of groundwater and gas discharging from springs remains poorly understood.*
>
> *And previous research has not included data on atmospheric gas measurements, quantification of emission rates from the gas seepages, water chemistry, geochemistry or geological mapping.*[7]

CSIRO is currently conducting "a field campaign to collect detailed data on the geology, hydrogeology and ecology of the Hot Springs Valley." This will extend on the data collected in previous surveys of the area. Baseline environmental data on the Hot Springs Valley springs "will provide an important benchmark and evidence base for the protection and management of this environmentally and culturally significant area."

The progress report for the CSIRO project highlights the limited current understanding and the risk of connectivity between gas reservoirs and the springs.

> *… only a limited understanding of the source aquifer of geothermal springs in the Hot Spring Valley and their connections to, or isolation from, gas reservoirs exist at present (e.g., ELA, 2022; Frery et al., 2022). The groundwater sampling in this project focusses on closing these important knowledge gaps through the collection and analysis of spring samples for a wide range of hydrochemical, gaseous and isotopic parameters from Hot Springs valley. This will provide an important baseline data set to benchmark the present state to help track any changes should they occur. This will also help to better understand the origin of gas and hydrogeological connectivity pathways.*

It is clear that this EMP should not be approved and proposed fracking should not proceed unless or until the baseline data being collected by CSIRO is complete, and in particular, that likely risks of connectivity between deeper shale aquifers and the springs are far better understood.

Stygofauna

The environmental assessment conducted for this EMP asserts that it is "unlikely" that stygofauna are present in the project area, despite no targeted stygofauna surveys having been conducted. Instead, AECOM have relied on 4 historical surveys conducted within a 50 km radius of the project area, 2 of which recorded stygofauna, including one monitoring bore only 17 km from the project site. The EMP notes that, "stygofauna are typically associated with specific aquifer conditions, such as stable water chemistry, low disturbance, and suitable pore spaces" and implies that the project site might lack these characteristics, without providing any evidence to support this inference.

The use of historical survey data from less than 4 wells in a 50km radius to support a claim that there are no stygofauna present at the project site, when in fact stygofauna were found at two of those sites, is woefully inadequate and entirely inappropriate. Lock the Gate submits that targeted,

[7] ibid

scientifically robust stygofauna surveys must be conducted at local water monitoring bores to ascertain the presence or absence of any local stygofauna, alongside a full impact assessment report if any stygofauna are found to be present.

Nationally-threatened species

It does not appear that survey methods for nationally-listed species, including the Northern blue-tongue lizard adhere to best-practice guidelines. For the Gouldian finch, for example, the *Survey guidelines for Australia's threatened birds* specifies "Targeted searches and watches at waterholes late in the dry season" for Gouldian finches and effort of 12 hours over four days.[8]

Carpentarian grasswren

The desktop survey conducted to assess the environmental impact of this project failed to capture the likely presence of the Carpentarian grasswren (*Amytornis dorotheae*), a federally-listed Endangered species under the EPBC Act. While the project area was not identified as likely habitat under the PMST search tool used in AECOM's desktop surveys, there is a nearby record of the species from 1999. Additionally, the 10-15 incidental fauna surveys conducted for this EMP record the presence of a bird from the *Amytornis* genus. Given there are no other *Amytornis* records from any other species in the genus within at least 150 km of the site, it could reasonably be inferred that this incidental observation was a Carpentarian grasswren. Given the small home range of this species, its vulnerability to disturbance and its listing as an Endangered species under the *EPBC Act*, targeted surveys for the Carpentarian grasswren must take place before any works proceed, including a full assessment of the likely impacts on any grasswren populations present in the area.

Crested shrike-tit (northern)

The EMP notes that a 10-15 minute survey was conducted at each survey site, with at least some of this survey designated as call playback for the crested shrike-tit (northern). While it is commendable that surveyors sought to specifically detect the presence of the shrike-tit, more robust methodology, such as that adopted for the *Regional Report: SREBA for the Beetaloo Sub-basin* (2022), require returning to sites morning and evening across at least two days. Single site visits conducted as part of this EMP are insufficient for establishing the presence of the species, particularly given the report's acknowledgement that there is suitable breeding and foraging habitat for the species present on the project site. More scientifically robust surveys for the crested shrike-tit (northern) must be conducted at the project site before any works take place and a full impact assessment conducted, owing to the small home range of the species and its vulnerability to disturbance.

Terrestrial GDEs

Santos acknowledges the presence of three GDEs within a 5 kilometre radius of the project site, including melaleuca forests and riparian woodland, stating that it is likely that these GDEs rely on a shallow perched groundwater system rather than the CLA. However, the proximity of these sites to the project area, coupled with several contemporary examples of wastewater from hydraulic fracturing projects in the Beetaloo sub-basin escaping from ponds and contaminating the

[8] DCCEEW (2010) Survey guidelines for Australia's threatened birds. https://www.dcceew.gov.au/sites/default/files/documents/survey-guidelines-birds-april-2017.pdf

surrounding landscape requires that a full risk assessment be undertaken of the threat to these GDEs from surface water or shallow ground water contamination as a result of fracking operations.

Weeds

This EMP proposes the clearing of approximately 87 hectares of relatively undisturbed tropical savanna in moderate to good condition, with only one species of weed - Hyptis (*Mesosphaerum suaveolens*) - noted as present in the project area. This level of land clearing merits referral to the EPA for proper assessment.

Additionally, Lock the Gate submits that the Weed Management Plan included as part of this EMP is insufficient at meeting the stated goal of "no introduction of new species of weeds or plant pathogens, or increase in abundance of existing weed species, as a result of project activities." The WMP only includes one annual weed survey: many declared and priority weed species in the Northern Territory are annual weeds and could prospectively establish themselves and set seed in the intervening time period between weed surveys. Any weed survey(s) seeking to prevent the introduction of new weed species must take place **at least** twice per year to capture any newly introduced weeds or weeds that were at an unidentifiable growth stage at the time of the first survey.

This EMP does not meet the criteria for approval under NT regulations. The impacts of unconventional shale gas exploration and its associated infrastructure at EP 161 on threatened species, climate and groundwater should be subject to thorough assessment by the NT EPA prior to the approval of any further activities.

Thank you for your consideration.

Yours sincerely,

Louis Boyle-Bryant
Lock the Gate Alliance

Respondent No: 12
Login: Anonymous
Email: n/a

Responded At: Dec 19, 2025 16:14:30 pm
Last Seen: Dec 19, 2025 16:14:30 pm
IP Address: n/a

Q1.	**Given name**	[redacted]
Q2.	**Family Name**	[redacted]
Q3.	**Location**	DARWIN, NT
Q4.	**Stakeholder type**	Community member
Q5.	**Email address**	[redacted]
Q6.	**Interest area**	Flora and fauna Water Waste management Climate change Human health Chemicals Regulation and compliance Well integrity

Q7. **Please provide your comments**

I would like to see this proposal rejected outright due to the real risks to the environment and human health. At the very least it must be referred to the Federal review process.

Q8.	**Add an attachment - Max file size: 5MB**	https://s3-ap-southeast-2.amazonaws.com/ehq-production-australia/dd1e2ba8914e00721ae0291833b5e292fac6fb1d/original/1766126661/709942c61d6968128148332ec5c7b313_2025%2012%2019%20Submission%20to%20Betaloo%20EMP%20.docx?1766126661
Q9.	**Tick this box if you wish for your name and contact details to be confidential**	Make my name and contact details private

STO8-1: EP 161 - Betaloo Basin Appraisal Pilot Environmental Management Plan

Thank you for the opportunity to make a submission on this referral.

This Environmental Management Plan should be rejected because of its unacceptable risks and impact on our environment. The Northern Territory has arguably the weakest environmental regulation of any Australian state or territory. Due to the potential for environmental risk to water, land and endangered species, and due to the scale of the future development planned if proceeded, this proposal must be referred to the Federal Environment Minister for detailed assessment. At the very least it must be assessed in conjunction with all other applications for hydraulic fracturing across the NT to obtain a comprehensive picture of impact.

I have loved living in Darwin for the past 13 years and have developed a passionate interest in protecting the fragile environment that we live in. Accordingly, I am studying environmental science and know the environmental disturbance that will be created by this proposal. My early background in health provides me with understanding of the documented public health risks of fracking (Haswell & Bethmont, 2016).

Along with many in the NT and national community, I understand that the risk-benefit analysis for fracking does not stack up. The risks of fracking and development of an industry with an estimated 1200 gas wells, will fundamentally change the landscape of the NT . It risks our water, our vegetation and our wildlife and ultimately the liveability of the NT. As government debt has burgeoned, the promoted economic benefits of this type of development for the NT have not been realised by previous projects (e.g. INPEX) despite massive injection of taxpayer funds and government support.

The resulting downstream development planned for Darwin Harbour risks public health on a large scale due to proximity of industrial processing and gas infrastructure to the population centres of Darwin and Palmerston. Highly credible scientific evaluation shows increased health risks such as increased severity of child asthma, increased death rates from cardiovascular and respiratory diseases and some cancers, and severe birth defects (Haswell et al., 2023).

The NT community does not support fracking. The Summary Report of the Pepper Inquiry used superlative language to indicate the level of antipathy around hydraulic fracturing that has not reduced in the years since . The view of the »significant.majority‹ of those engaged in the community consultations and the »overwhelming.consensus.was.that.hydraulic.fracturing.for.onshore.shale.gas.in.the.NT.is.not.safe?is.not.trusted.and.is.not.wanted.(Pepper.et.al¡?867❹)¡

Sadly, the community has discovered that gas companies have sprayed toxic fracking wastewater onto land surrounding wells, used bolt cutters to access land where owners were totally opposed to their access, covered up major methane leaks for years and spilled toxic oils into our harbour. All this without appropriate fines or requirement for reparation by our regulators. It would be a major stretch for the community to trust that fracking can be carried out safely in the NT »adequately.safeguarded.by.a.sufficiently.robust.and.rigorously.enforced.improved.regulatory.regime‹ (Pepper et al., 2018).

In addition, there is concern whether fracking is even needed. This fracking proposal indicates that gas is critical for energy security however, there is already an abundance of gas extracted in

Australia. The energy security problem appears to be related to policy and pricing failures and export of the majority of gas with minimal taxation or royalties (Campbell & Ogge, 2025).

Environmental risks posed by this proposal include:

- Water quality and quantity including groundwater and river catchments
- Land clearing, road infrastructure, weed invasion
- Impact on all species but specifically endangered species
- Destruction of ecological and nature significant landscape
- Contribution to massive greenhouse gas emissions throughout the gas lifecycle
- Public health consequences
- Uncertainty of economic benefit
- Continued lack of social license for this venture

Excessive water extraction is a major concern. There remains significant opposition to the water allocation plans approved by the NT Government due to the massive increases in extraction allowed. Concerns have been raised repeatedly concerning the lack of robust science to support the decisions being made and the uncertainty for the future of iconic waterways. Local Indigenous elders have seen the reduction of flows along the Roper River, for example. Nationally, water science experts have questioned the sustainability of massive extraction approved. Robust, independent scientific data must be used to provide community confidence in the levels of water use that is sustainable.

The Pepper Inquiry recommendations specifically included the need for ALL wastewater to be kept in covered tanks, Recommendation 7.12 (Pepper et al., 2018).

The proposal indicates (p 63) that flowback water will be kept in enclosed tanks except for:

- If it is being treated for re-use
- It is being evaporated to manage volumes
- Except during heavy rainfall
- It is being used for dust suppression

It seems that these exceptions could be most of the time. In addition, wet season mitigation is planned accounting for a one in 1000-year flood. This consideration is largely superseded by recent climate change impacts as we now experience flooding events more frequently.

Aquifers as the “lungs for life”, have enabled survival in the dry outback NT providing sinks, springs and hidden water sources for Aboriginal communities, wildlife and vegetation for millennia. These very slow recharging aquifers are not ours to exploit but to protect. The risk of leakage of toxic chemicals is real, or if just one fracking well results in contamination or destruction of the aquifer, the result will be widespread, devastating and irreversible. This risk is too large and has contributed to the banning of fracking in other states.

The footprint of each well includes depths of around 4 kilometres, which I do not consider “relatively small”. With over 300 toxic chemicals and the real risk of flooding and spillage of toxic wastewater, the surrounding waterways and catchments must also be considered and scientifically assessed. Flood waters in the project area flow into the Limmen River and Limmen National Park and ultimately into the gulf. Contamination from one flood event would have devastating consequences for this entire river system. Not only is the area ecologically and culturally significant, but it is also an area of spectacular natural beauty. The “Hot Springs”

are an area of ecological research interest which could be considered national park status and must be considered in the decisions for this proposal.

The referral states a list of environmental outcomes. Outcomes are specific and measurable such as how much by when. The following statements are not outcomes being subjective, unmeasurable and unenforceable. They provide no level of certainty as to what would be achieved by each of them. This undermines the integrity of the statements and hence the referral plan to be virtually meaningless.

e.g. “Maintain air quality by minimising emissions and dust generation from exploration and appraisal activities to ensure that environmental values are protected.”

- Minimising emissions to what level over what timeframe, protection of which environmental values and to what level?

e.g. “Maintain greenhouse gas emissions below acceptable levels.”

- Acceptable to who or what standard?

e.g. “Minimise soil disturbance and erosion during site preparation, drilling, and rehabilitation to preserve land capability and support natural land functions.”

- How much soil disturbance is acceptable, what standard is this measured against?

e.g. “Maintain the stability and integrity of distinctive physical landforms, avoiding unnecessary modification or degradation.”

- By what standard or measure is a modification or degradation considered unnecessary? This appears to be a matter of opinion. Rio Tinto seemed to consider the destruction of Juukan Gorge as “necessary”.

e.g. “Protect the quality and integrity of surface water and groundwater by preventing contamination and maintaining natural flow regimes where practicable.”

- This statement is patently unenforceable. “Where practicable” is the description used for Santos to avoid mitigation of the major methane leak on Darwin Harbour and appears to mean “too expensive.”

e.g. “Manage wastes and hazardous chemicals and dangerous goods responsibly to prevent environmental harm and support efficient resource use.”

- How much harm to what specific situations will be considered responsible? Will this simply defer to reduce cost to support efficient resource use?

e.g. “Protect the health, safety, and wellbeing of NT communities by preventing exposure to pollutants, contaminants, bush fires or other environmental hazards.”

- This statement appears to be impossible to achieve. Can Santos guarantee that there will not be a bushfire in this area, and that they will protect communities if there is? How? Will they have a fire and emergency team on standby to relocate people/ fight fires in communities?

In summary, I believe that this proposal should be rejected due to the devastating environmental and health risks it poses, the strong community opposition and the uncertainty regarding financial benefit for Territorians.

REFERENCES

Campbell, M., & Ogge, M. (2025). Understanding the December 2025 gas policy scramble. https://australiainstitute.org.au/report/understanding-the-december-2025-gas-policy-scramble

Haswell, H., & Bethmont, A. (2016). Health concerns associated with unconventional gas mining in rural Australia. Rural.and.Remote.Health?7❷9❹8❶. https://www.rrh.org.au/journal/article/3825/

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Pepper, R., Hart, B., Jones, D., Smith, R., Priestly, B., Anderson, A., Beck, V., Ashworth, P., & Ritchie, D. (2018). Scientific.inquiry.into.hydraulic.fracturing.in.the.Northern.Territory._ summary.of.the.final.report. www.frackinginquiry.nt.gov.au

Respondent No: 8
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Responded At: Dec 18, 2025 15:42:59 pm
Last Seen: Dec 18, 2025 15:42:59 pm
IP Address: n/a

Q1.	**Given name**	Jenny
Q2.	**Family Name**	Davis
Q3.	**Location**	LARRAKEYAH, NT
Q4.	**Stakeholder type**	Community member
Q5.	**Email address**	Jenny.Davis@cdu.edu.au
Q6.	**Interest area**	Water

Q7. **Please provide your comments**

My main concerns relate to potential impacts of the proposed development on water, particularly groundwater. Given the importance of the groundwater resources in this region for the environment, for Indigenous culture and livelihoods, for water supply for towns and communities, and for pre-existing industries such as pastoral enterprises, the EMP provides little detailed information on local groundwater resources, nor how they will be protected. The recent IESC advice on unconventional gas exploration and appraisal activities in the Beetaloo Basin advice (IESC, 2024) emphasised the importance of collecting adequate pre-development groundwater and surface water quality data, and the need for local scale investigations of the connectivity from the surface to the underlying aquifers (see the attached advice). Very little local-scale information is provided in the Santos EMP. This is a knowledge gap that must be addressed. Detailed local-scale environmental studies are needed to ensure adequate understanding and protection of the groundwater water resources in the areas where Santos's unconventional gas development is planned. The recent GISERA projects that have been initiated to provide an 'Environmental baseline characterisation of the springs in Hot Springs Valley, NT' and to characterise 'Groundwater connectivity between the CLA and the surface in the Eastern Beetaloo Sub-basin extension (see https://gisera.csiro.au) indicate that there are still substantial knowledge gaps in the region very close to that covered by the EMP. This recent information suggests that risks to groundwater resources in the local region could be much higher than the Santos EMP has currently recognised. The groundwater monitoring program described in Appendix I of the EMP is unlikely to provide any real ability to respond in a timely way to contamination events or unacceptable drawdowns. The ability to have in situ continual groundwater data logging, as described in Section 5.8 (see insert below) should treated as a major priority, not something that might be implemented 'where possible'. Similarly, the groundwater monitoring triggers described in Section 6 -Table 5 do not provide confidence that real time responses will be achieved. (Insert from Appendix I 5.8. In situ continual groundwater data logging Due to the remote nature of the site and the associated limitations with access and oversight of monitoring wells, in situ continual data logging may be implemented where possible. Once monitoring wells are established and the monitoring program commenced, loggers will be deployed to measure and record groundwater pressure, temperature and EC at no longer than 12 hour timestep intervals. A barometric logger will be installed at a nearbylocation and used to correct data for barometric pressure changes. The Preliminary Groundwater Guideline states that EC should be measured in real-time as an indicator providing'early warning' of contamination, with the results telemetered for Santos' oversight and to be the provided regulator. It is recognised by the DLPE that this may be difficult to implement in the first stages of exploration, but proponents should provide a plan and timetable to meet this requirement, preferably before HFS occurs.) It is also now feasible to use eDNA to characterise microbial assemblages and stygofauna presence as part of the establishment of a groundwater baseline for the local region associated with the well fields. Given the potential impacts of the Beetaloo gas industry on water resources, it is unacceptable to proceed without freshwater baselines being developed with best possible methodologies, and this includes the use of eDNA datasets. It is disappointing that so much of the terrestrial and surface water environmental information provided in the EMP is sourced from desk top studies. The regional GBA and SREBA reports are helpful, but there is much that remains known about the biota and the ecosystem processes that support local and regional biodiversity in this remote region of the NT. These knowledge gaps need to be addressed before the Santos development can be considered to be anything other than a high risk activity environmentally.

Q8. **Add an attachment - Max file size: 5MB**	https://s3-ap-southeast-2.amazonaws.com/ehq-production-australia/43de7073e483877527195e44851505fed3c313cb/original/1766038120/787250c324ec2401e134675023ddabf7_iesc-advice-beetaloo-basin-2024-150.pdf?1766038120
Q9. **Tick this box if you wish for your name and contact details to be confidential**	not answered

Advice on unconventional gas

IESC 2024-150: Beetaloo Basin – Unconventional gas exploration and appraisal

Requesting agency	The Australian Government Minister for the Environment and Water
Date of request	5 July 2024
Date request accepted	5 August 2024
Advice stage	Advice request

The Independent Expert Scientific Committee on Unconventional Gas Development and Large Coal Mining Development (the IESC) provides independent, expert, scientific advice to the Australian and state government regulators on the potential impacts of unconventional gas and large coal mining proposals on water resources. The advice is designed to ensure that decisions by regulators on unconventional gas or large coal mining developments are informed by the best available science.

The IESC was requested by the Australian Government Minister for the Environment and Water to provide advice on the potential impacts and/or risks to water resources and water-dependent matters of national environmental significance arising from potential unconventional gas exploration and appraisal activities in the Beetaloo Basin, Northern Territory. This advice draws upon available documentation, data and methodologies, together with the expert deliberations of the IESC.

Plain English summary

Exploration and appraisal activities for unconventional gas may expand in the Beetaloo Basin, Northern Territory, likely leading to production. There is concern about the implications of these activities for surface waters, groundwaters and water-dependent plants and animals, some of which are Matters of National Environmental Significance.

Much of the Basin is semi-arid and lacks permanent surface water. However, important groundwater-dependent ecosystems occur in the region, such as the Roper River, Mataranka Springs and numerous springs and perched aquifers.

In July 2024, the Minister for the Environment and Water requested scientific advice from the Independent Expert Scientific Committee on Unconventional Gas Development and Large Coal Mining Development (the IESC) about the potential nature, extent and cumulative impacts of exploration and appraisal activities for unconventional gas on the Basin's water resources.

The IESC considers that the key potential impacts from these activities are loss and fragmentation of native vegetation and altered surface runoff (mainly from constructing access roads to well pads), and groundwater drawdown caused by wells supplying groundwater for use in hydraulic fracturing. Impacts may also arise from accidental spills of chemicals or flowback wastewaters, failure of well integrity and the spread of invasive species. Hydraulic fracturing of the deep shales for exploration and appraisal is not considered to be a major risk to the Basin's groundwaters if conducted according to industry best practice.

Providing mitigation strategies are adopted and correctly implemented, the IESC considers that the potential impacts on the Basin's water resources from initial exploration and appraisal activities for unconventional gas are minor. However, these activities will likely lead to further production, exploration and appraisal which will inevitably intensify impacts, along with those from current and proposed land-uses such as irrigated agriculture (e.g. cotton, mangoes) and from climate change.

Preliminary regional surveys have been undertaken of the Basin's water resources and its native plants and animals but substantial gaps still exist in our knowledge about how these may respond to impacts from unconventional gas development. Detailed local-scale environmental studies are needed to ensure adequate understanding and protection of the Basin's surface and groundwater water resources in areas where unconventional gas development is planned.

Summary

On 5 July 2024, the Minister for the Environment and Water requested scientific advice from the Independent Expert Scientific Committee on Unconventional Gas Development and Large Coal Mining Development (the IESC) on potential impacts and/or risks to water resources and water-dependent Matters of National Environmental Significance (MNES) arising from unconventional gas exploration and appraisal activities in the Beetaloo Basin, Northern Territory. The Minister also requested advice on potential cumulative impacts of these activities and what material gaps exist in current scientific understanding of the Basin that affected the IESC's ability to provide advice.

The IESC notes that the scope of this request is solely on 'exploration and appraisal activities' but considers that subsequent activities associated with production (if approved) would lead to additional impacts not considered here. As in all advice previously provided by the IESC, the term "water resources" is defined as per the *Water Act 2007* (Commonwealth of Australia 2007) and is used here to include all groundwaters and surface waters (permanent and ephemeral), including their organisms, water quality and associated water-dependent ecosystems.

In the context of this advice, the Beetaloo Basin refers to the 86,400-km^2 Beetaloo Biophysical Study Area (BBSA) used for the Strategic Regional Environmental and Baseline Assessment (SREBA) (DEPWS 2022). This area encompasses known reserves of unconventional gas (the 28,000-km^2 Beetaloo Sub-basin and 'eastern depocentre'), several catchments (e.g. Lake Woods, southern catchment of the Roper River) and various groundwater-dependent ecosystems (GDEs).

The BBSA is centred around Daly Waters, some 600 km south-east of Darwin (Figure 1). Mean annual rainfall declines from approximately 1,200 mm in the tropical north to approximately 500 mm in the semi-arid south (DEPWS 2022, pp. 11-12) which creates a north-south gradient of decreasing permanence of surface waters and rain-fed groundwater recharge. Regional groundwater occurs within the Cambrian Limestone Aquifer (CLA) (classified as karst in the north) which flows from the southern BBSA north-west to discharge into rivers to the north (e.g. the Roper and Flora rivers, DEPWS 2022, p. 66). Other aquifers occur in strata above and below the CLA, either as localised perched aquifers near the ground surface or as fractured rock (e.g. Antrim Plateau Volcanics) or sandstone (e.g. Bukulara Sandstone) aquifers below the CLA (DEPWS 2022, p. 42). The Mesoproterozoic shales targeted by unconventional gas exploration

are deeper (> 2000 m); in most areas, they are separated from the CLA by one or more aquitards, but there are locations where there is evidence of connection (DEPWS 2022, pp. 63-65).

The surface waters of the BBSA can be broadly divided into (i) largely ephemeral systems in the southern region that drain into Newcastle Creek and ultimately into Lake Woods and (ii) waterways in the north with ephemeral upper reaches but groundwater-fed perennial lower reaches and springs that typically provide diverse aquatic and riparian ecosystems that support MNES species such as Gulf Snapping Turtle (*Elseya lavarackorum*), Largetooth Sawfish (*Pristis pristis*) (DEPWS 2022, p. 272) and Speartooth Shark (*Glyphis glyphis*) (Constance et al. 2024).

To address the Minister's questions, the IESC developed indicative Impact Pathway Diagrams (IPDs) (Commonwealth of Australia 2024) that illustrate how activities associated with exploration and appraisal may impact key water resources. Separate IPDs were derived for sites in the southern and northern parts of the Basin to capture the latitudinal differences in ecohydrology described above. Estimates of the likelihood and consequence of each pathway, the two broad components of risk, are also portrayed on the IPDs.

The IESC has carefully considered the risks to water resources in the Beetaloo Basin from hydraulic fracturing of deep shales during exploration and appraisal, and concludes that infrastructure, transport and surface operations represent greater risks.

Key potential impacts from exploration and appraisal activities in the **southern region** include:

- vegetation removal for new infrastructure (e.g. roads, well pads, temporary accommodation) which may (i) directly impact water-dependent vegetation, (ii) alter catchment drainage and surface runoff patterns, impacting the water regime, water quality and biota of ephemeral reaches of Newcastle Creek and other waterways, including permanent and semi-permanent refugial waters (e.g. Longreach Waterhole) and (iii) promote habitat fragmentation and loss that may reduce the condition and/or persistence of populations of dependent wildlife, impact surface runoff and water quality, alter erosion rates and fire regimes and promote the spread of invasive species;

- alteration of surface water runoff and drainage patterns by roads and seismic lines which may impact the water regime, water quality and biota of ephemeral reaches of Newcastle Creek and other waterways, including permanent and semi-permanent refugial waters (e.g. Longreach Waterhole); and

- in the event of a hazardous chemical or flowback wastewater spill near a waterway or refugial waterhole, impacts on water quality and aquatic and riparian biota.

Key potential impacts from exploration and appraisal activities in the **northern region** include:

- vegetation removal for infrastructure which may (i) directly impact terrestrial GDEs (e.g. *Melaleuca* forests) and other water-dependent vegetation, (ii) alter the water regime, water quality and biota of ephemeral waterways (e.g. Birdum and Western creeks), refugial waters (e.g. permanent waterholes in Western Creek) and aquatic GDEs (e.g. groundwater-fed reaches of the Roper River) and (iii) promote habitat fragmentation and loss that may impact the condition and/or persistence of populations of dependent wildlife, alter fire regimes and promote the spread of invasive species;

- alteration of surface water runoff and drainage patterns by roads and seismic lines which may affect the water regime, water quality and biota of ephemeral waterways and refugial waters;

- extraction of groundwater for water supply from the CLA for hydraulic fracturing and general usage that will cause groundwater drawdown and changes in groundwater flow rates, potentially impacting the lower reaches of the Roper River and other GDEs; and

- in the event of a hazardous chemical or flowback wastewater spill near a waterway, refugial water or sinkhole connected to the CLA, impacts on water quality, aquatic and riparian biota and/or stygofauna.

Overall, the spatial scales of these different impacts vary from local (< 1 km^2) for most activities at a single site (e.g. clearing of vegetation for a single well pad or gravel pit) to broad-scale (> 100 km^2) impacts from activities such as construction of extensive roads and multiple well pads, groundwater drawdown (assuming that water for multiple hydraulic fracturing operations is sourced from dedicated water bores), and the collective effects of multiple other activities. Impacts from a large spill of chemicals, waste or flowback wastewater near a flowing river or a sinkhole connected to karst systems may also extend over a large area, depending on the volume of the spill and the extent of impact attenuation with distance from the spill site.

The temporal scales of these different potential impacts vary from short (< 1-5 years) for transient activities such as vegetation clearing for well pads and accommodation to longer term (>100 years) for broad-scale activities, legacy effects of roads that continue to be used, or impacts from spills where the contaminants are particularly persistent and cannot be readily cleaned up.

Collective impacts of exploration and appraisal activities on water resources in the Beetaloo Basin could include altered flow regimes, impaired surface water quality and reduced biodiversity and densities of water-dependent biota in ephemeral waterways; increased risks of reduced groundwater availability and water quality leading to loss of groundwater biota; removal or fragmentation of water-dependent vegetation; and changes to hydrological regimes and water quality of perennial waters and aquatic refuges that affect their physicochemistry, biota and ecological processes. These impacts will interact with other processes such as introduction of invasive species and altered fire regimes.

These collective impacts will add to the cumulative impacts of changes in amounts, seasonality and intensity of rainfall and evaporation arising from climate change, and to the changes associated with existing activities such as pastoral uses, irrigated agriculture and urbanisation, and possible future activities such as solar farms.

Material gaps remain in the current scientific understanding of the hydrology, hydrogeology and other aspects of the Beetaloo Basin that affected the IESC's ability to provide advice on potential impacts, impact pathways and risks associated with exploration and appraisal activities. These include:

- geological and hydrogeological characterisation of the aquitards and aquifers, including their inter-connectivity;

- spatial and temporal dynamics of runoff, surface water flows, groundwater recharge and surface water-groundwater connections and how these affect water resources;

- adequate baseline groundwater and surface water quality data; and

- species composition, distribution, groundwater-dependence and condition of subterranean, aquatic and terrestrial GDEs.

Information is needed on where, how much and when exploration and appraisal activities are likely to occur, and their proximity to surface and subterranean water resources in the Basin. Detailed information is also needed on treatment, transport and disposal of flowback wastewaters.

This advice focuses solely on potential impacts to water resources from exploration and appraisal activities associated with unconventional gas development. It does not extend to other activities (e.g. production, decommissioning) or land-uses, other ecosystems not directly associated with water resources, or other impact pathways such as noise, light or greenhouse gas emissions.

Context

Scope of advice and the IESC's remit

On 5 July 2024, the Minister for the Environment and Water wrote to the Chair of the Independent Expert Scientific Committee on Unconventional Gas Development and Large Coal Mining Development (the IESC) requesting scientific advice from the Committee on the likely nature and scale of potential impacts and/or risks to water resources and water-dependent Matters of National Environmental Significance (MNES) resulting from a program of unconventional gas exploration and appraisal activities in the Beetaloo Basin, Northern Territory. The Minister also requested advice on potential cumulative impacts of these activities and what material gaps existed in the current scientific understanding of the hydrology and hydrogeology of the Beetaloo Basin that affected the IESC's ability to provide advice. Recommendations were sought on the research needed to address these gaps at basin and "site" (local) scales.

It is important to note that this request specifies only the activities undertaken during exploration and appraisal. Exploration is defined as locating producible quantities of gas and characterising the gas reservoir. Appraisal is defined as proving and assessing commercially productive gas reserves and their spatial distribution and composition. The IESC acknowledges that these two activities are likely to lead to production (currently out of scope) if prospectivity is confirmed. Production would intensify many of the potential impacts and risks arising from, for example, groundwater drawdown and transport of chemicals and wastes, and would likely be accompanied over decades by ongoing exploration and appraisal.

Consistent with the IESC's remit (https://www.iesc.gov.au/), the request relates to advice on 'water resources', which includes all groundwaters and surface waters (permanent and ephemeral), their organisms, water quality and associated water-dependent ecosystems (*Water Act 2007*). The IESC is not a regulatory body and does not decide which projects should proceed or how they should be regulated.

The following advice is a high-level, independent, scientific assessment of the risks of potential impacts on the Basin's water resources from activities associated with exploration and appraisal for unconventional gas and does not address any specific current or proposed projects. Material gaps in the information needed to fully assess these risks (see response to Question 3 below) hamper Basin-scale assessments of these potential impacts and so the IESC has used Impact Pathway Diagrams (described below) to infer and illustrate likely pathways and the nature of their impacts. Although this approach is a useful initial step, the IESC acknowledges that the predictions drawn from these diagrams will not apply to all locations across the Basin and that the likelihood and consequences of particular pathways will vary in space and time. These caveats are discussed in more detail below.

Ecohydrological context

For this advice, the spatial extent of the Beetaloo Basin is considered to comprise the 86,400-km^2 Beetaloo Biophysical Study Area (BBSA, Figure 1) used for the Strategic Regional Environmental and Baseline Assessment (SREBA, DEPWS 2022). This area encompasses the known reserves of unconventional gas (the 28,000-km^2 Beetaloo Sub-basin and 'eastern depocentre'), several surface-water catchments (e.g. Lake Woods, southern catchment of the Roper River) and various groundwater-dependent ecosystems (GDEs). The GDEs include springs and perennial river reaches which are likely to be surface expressions of aquifers overlying the prospective gas basins (DEPWS 2022, p. 38).

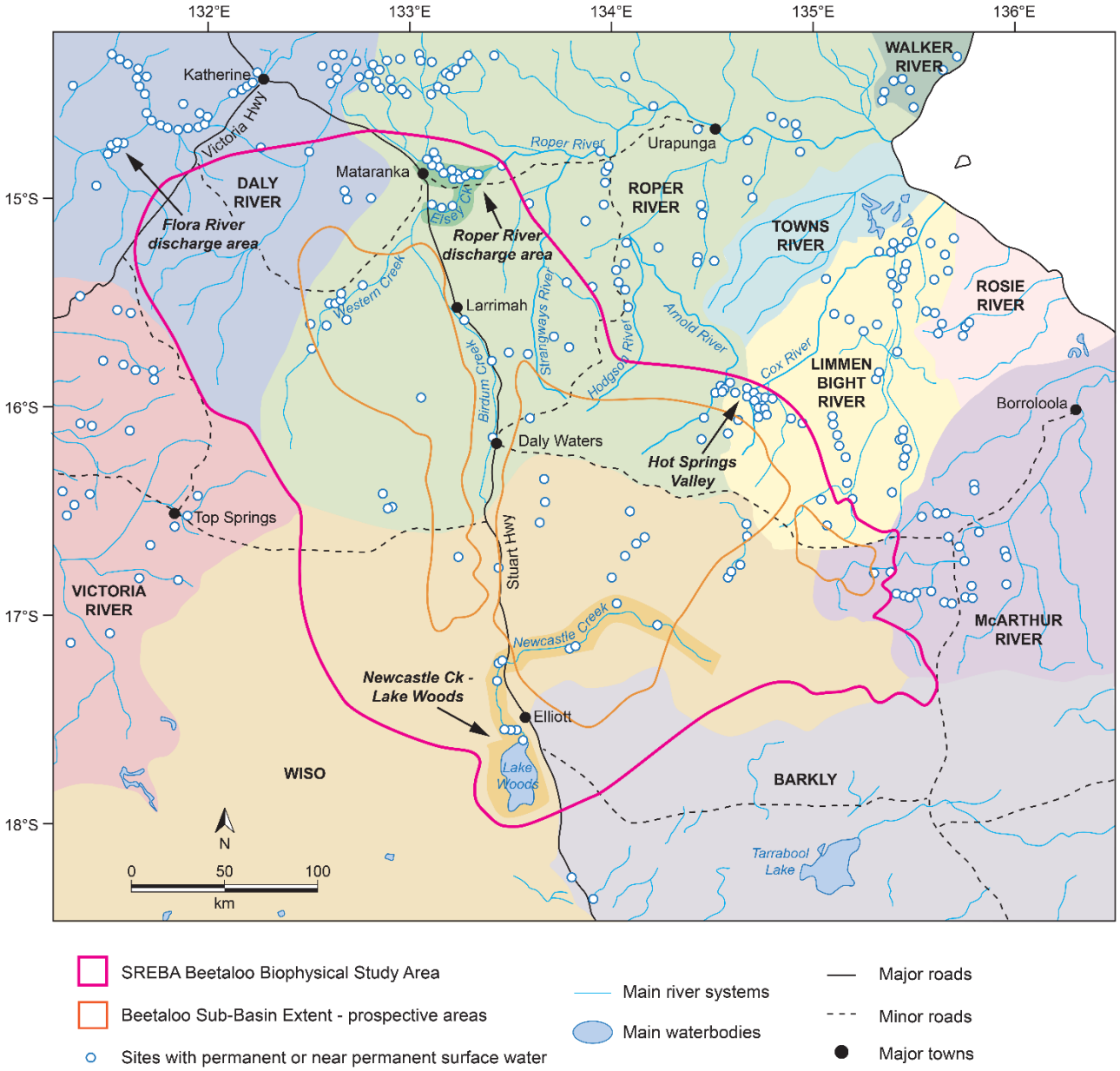

Figure 1. The Beetaloo Basin (represented by the SREBA's Beetaloo Biophysical Study Area (BBSA) in this advice). Different colours depict the surface water catchments labelled in upper case (e.g. BARKLY). Figure adapted from Figure 3-1, Figure 4-21, Figure 5-3 and Figure 10-3 in DEPWS (2022).

The BBSA is centred around Daly Waters, some 600 km south-east of Darwin (Figure 1). Mean annual rainfall declines from approximately 1,200 mm in the Wet-Dry tropical north to approximately 500 mm in the semi-arid south (DEPWS 2022, pp. 11-12), resulting in more permanent surface waters and higher rain-fed groundwater recharge in the north than the south.

Vegetation composition varies across the BBSA following the north-south rainfall gradient, with additional influences from soil type, grazing and fire regime (Young et al. 2022, p. 5). Five broad vegetation groups in the BBSA have high ecological value: three in the north, which are also groundwater-dependent (*Monsoon forest and thicket (riparian rainforest)*, *Melaleuca forests* and *Riparian woodland)*, and two more widely distributed ones (*Ephemeral wetland* and *Lignum shrubland*) (Young et al. 2022, p. 6).

Pastoralism, the main industry to date, has not required large-scale clearing of savanna woodland across this region.

Most surface water drainages in the BBSA are ephemeral, particularly to the south and within the Beetaloo Sub-basin. Several of these ephemeral waterways have semi-permanent or permanent pools (e.g. Longreach Waterhole in Newcastle Creek), which provide vital refuges for aquatic biota and key water sources for nearby water-dependent plants and animals. 'Run-on' areas adjacent to ephemeral waterways are flooded after heavy rain and often support distinct vegetation and biodiversity values (DEPWS 2022, p. 162). This area is characterised by a 'boom-and-bust' ecology (Kingsford et al. 1999, Sheldon et al. 2010).

In the northern BBSA, groundwater from aquifers overlying the prospective gas basins provides perennial flows in the lower reaches of the Roper and Flora rivers (DEPWS 2022, p. 12), while their upper reaches are ephemeral. Groundwater-fed springs also occur in the western, northern and eastern margins of the BBSA (Figure 1), many supporting species-rich aquatic ecosystems and fringing vegetation.

The most important groundwater system in the study area is the Cambrian Limestone Aquifer (CLA). This vast, multilayered system includes the Daly, Wiso and Georgina geological basins. In the north, the CLA hosts a highly connected karst system (Tindall Limestone Aquifer). It is the main source of groundwater for extractive use in the region (DEPWS 2022, p. 42). Groundwater in the CLA flows north-west from the southern Beetaloo Basin to discharge into the Flora, Daly and Roper rivers where the Lower CLA outcrops at or near the surface. Groundwater discharge occurs diffusely along riverbeds (e.g. Elsey Creek, the Roper River), from springs (e.g. Bitter Springs, Rainbow Spring) and as evapotranspiration, including through groundwater-dependent vegetation (DEPWS 2022, p. 14). Other aquifers occur in strata above and below the CLA. Localised perched aquifers near the ground surface potentially support groundwater-dependent vegetation (Young et al. 2022, p. 6). Below the CLA, there are also fractured rock aquifers (e.g. Antrim Plateau Volcanics) and sandstone aquifers (e.g. Bukulara Sandstone) (DEPWS 2022, p. 42).

The Mesoproterozoic strata targeted by unconventional gas exploration are deeper (> 2000 m). In areas where data are available, they are generally hydraulically disconnected from the CLA by one or more aquitards (low-permeability layers), but there are locations where there is evidence of connection (DEPWS 2022, pp. 63-65). Inter-aquifer connectivity mostly depends on the distribution of sinkholes, aquitards and geological fault zones.

Water-dependent MNES in the region include two Sites of Conservation Significance:

i. Mataranka Thermal Pools. These lie in the Roper Discharge Zone where groundwater in the Roper flow path discharges to the surface near Mataranka and are considered of 'outstanding value' (DEPWS 2022, p. 272). SREBA surveys (DEPWS 2022) indicate that, compared to other sections of the BBSA, this area has the highest aquatic biodiversity value, the highest number of unique aquatic species and the greatest presence of threatened species, including a significant population of the Gulf Snapping Turtle (*Elseya lavarackorum*). It also supports most of the terrestrial GDEs in the BBSA and is a breeding locality for the threatened Red Goshawk (*Erythrotriorchis radiatus*).

ii. Lake Woods and Longreach Waterhole. Lake Woods, when full, is one of the largest temporary freshwater lakes in northern Australia. Compared to other waters of the BBSA, it typically harbours the most waterbirds, and has the highest concentration of migratory shorebird records, including the only record of the Critically Endangered Curlew Sandpiper (*Calidris ferruginea*), and a record of the Endangered Australian Painted Snipe (*Rostratula australis*). Together with Longreach and South Newcastle Waterholes, Lake Woods is listed as a 'Key Biodiversity Area', an 'Important Bird Area' and a 'NT Site of

Conservation Significance' (DEPWS 2022, p. 199) and is also listed on the Directory of Important Wetlands in Australia.

Five aquatic fauna species listed under the *Environment Protection and Biodiversity Conservation Act 1999* occur in the BBSA: Gulf Snapping Turtle (*Elseya lavarackorum*, Endangered), Largetooth Sawfish (*Pristis pristis*, Vulnerable), Mitchell's Water Monitor (*Varanus mitchelli*, Critically Endangered), Mertens' Water Monitor (*Varanus mertensi*, Endangered) (DEPWS 2022, p. 263) and Speartooth Shark (*Glyphis glyphis*, Critically Endangered) (Constance et al. 2024). Other listed MNES fauna in the BBSA (e.g. see Table 6-4, DEPWS 2022, p. 179) are not aquatic but many, such as the Gouldian Finch (*Chloebia gouldiae*, Endangered), require regular access to water and are considered water-dependent.

Systematic surveys by the SREBA at 44 sites across the BBSA identified 291 species of aquatic fauna, including 36 fish species and 11 aquatic and semi-aquatic reptile species (including 7 turtle species) (DEPWS 2022 p. 15). Species richness was greatest along the northern margin of the study area, especially in the perennial reaches of the upper Roper River. At least 28 species of stygofauna (groundwater invertebrates) were recorded, with one or more species collected in 23 of the 66 groundwater bores sampled by the SREBA (DEPWS 2022, p. 264).

Approach to this advice using Impact Pathway Diagrams (IPDs)

Typically, the IESC provides independent scientific advice in response to specific questions from regulators about Environmental Impact Statements for proposed developments (examples in https://www.iesc.gov.au/advice/scientific-advice). The current request is very different because the Committee has not been provided with project-specific Environmental Impact Statements to assess and the regional spatial scale substantially exceeds that of any previous request to the Committee. Therefore, the IESC adopted a different approach to this advice, necessitating some explanation.

An extensive literature describes results from regional surveys and high-level risk assessments in the area (e.g. SREBA (DEPWS 2022) and the Geological and Bioregional Assessment (Huddlestone-Holmes et al. 2020, 2021)). Rather than reiterate this literature in this advice, the IESC has drawn on relevant material to derive Impact Pathway Diagrams (IPDs, described in Commonwealth of Australia 2024) that portray potential impact pathways from activities associated with exploration and appraisal in the Beetaloo Basin. On an IPD, impact pathways are shown as consecutive links (arrows) between activities to endpoints via one or more components (boxes) that represent various stressors and processes (Commonwealth of Australia 2024). In this advice, the endpoints of each impact pathway have been set as habitats (e.g. ephemeral stream reaches, terrestrial GDEs) rather than, for example, individual species (cf. the causal networks used by the GBA, e.g. Huddlestone-Holmes et al. 2021, Figure 6). This simplifies the IPDs but assumes that the main potential impacts on water-dependent MNES species would be those affecting their habitats.

The north-south gradient in hydrogeology and hydrology across the BBSA must be considered in regional assessments of the potential impacts of unconventional gas exploration and appraisal activities on water resources. Consequently, this advice discusses two sets of potential impact pathways – one for the southern BBSA where surface waters are ephemeral and groundwater is deep below the surface, and one for the northern BBSA where groundwater in the CLA is closer to the surface and supports multiple GDEs. The IESC derived two indicative IPDs based on information from two localities in the BBSA: Newcastle Creek and Lake Woods in the south and the Roper Discharge Zone in the north. The IPDs are intended to illustrate the impact pathways from exploration and appraisal activities in the prospective areas (Figure 1) that may affect water resources in the broader catchments of Lake Woods and the Roper River, respectively.

Each IPD is accompanied by a narrative that explains the nature and scale of key pathways and qualitatively assesses two components of risk: likelihood and consequence. Potential likelihood for a given link (i.e. an arrow) between components was assessed as 'low' if it was considered unlikely to occur

across most of the broader catchment during initial exploration and appraisal activities. However, where a link was inevitable or likely to occur, the likelihood was assessed as 'high'. This high-level qualitative rating attempts to 'average out' the relative likelihood of a given link across the catchment represented by the IPD but will not represent all locations within the catchment. When considering cumulative impacts, the IESC assumed that the likelihood of many pathways and their links would likely increase, especially in locations where intensive activities occur near potential receiving waters.

The potential consequences of a given link between components were assessed as 'low' if, on average across the catchment, there would not be a material and/or lasting change in the receiving component (box) that could be reasonably predicted to arise from that link alone. Conversely, if a link could reasonably be expected to propagate impacts causing a material and/or lasting change in the receiving component, it was rated 'high'. Again, these predicted ratings of consequence are high-level, qualitative and spatially variable. When making these assessments for both IPDs, the IESC was constrained by material information gaps (see response to Question 3). Therefore, the predicted likelihoods and consequences of the impact pathways and their constituent links should be considered as indicative and in need of testing and validation with site- or project-specific monitoring data and modelling.

It is important to reiterate that both of the IPDs and their narratives presented below are simply examples of inferred impact pathways for contrasting localities in the BBSA. Other pathways (and risks) may exist in other parts of the Basin. For example, gas leakage into aquifers from loss of well integrity may pose potential impacts to surface-expression GDEs such as springs in the Hot Springs Valley, north-east of the Beetaloo Sub-basin.

The IPDs assume that the impact pathways portrayed reflect 'best available practice' in the mitigation, monitoring and management of potential impacts, but the IESC acknowledges that sometimes these may fail such as during extreme weather events or as a result of human error. This means that for many links, the qualitative assessments of likelihood and/or consequences are lower than if no mitigation options were applied. However, some links may be almost impossible to mitigate or manage such as contamination of springs due to groundwater transporting contaminants through the karstic CLA aquifer, and the IESC considered this when assessing relative consequences.

Response to questions

The IESC's advice in response to the Minister's specific questions is provided below.

Question 1: What would be the likely nature and scale of potential impacts and/or risks to water resources and water-dependent MNES from the range of activities conducted during an unconventional gas exploration and appraisal program in the Beetaloo Basin?

1. An exploration and appraisal program for unconventional gas in the Beetaloo Basin would be expected to involve most or all of the following activities:

    - construction of surface infrastructure including roads, temporary accommodation, gravel pits, temporary water pipelines and well pads,
    - acquisition of geophysical and seismic data,
    - drilling of exploration and appraisal gas wells,
    - drilling of groundwater supply bores and construction of temporary water storages,
    - hydraulic fracturing,
    - transport of personnel, equipment and materials (including wastewater, drilling waste and chemicals) by road and potentially pipelines,

- storage of flowback wastewater, solid waste and chemicals, and
- decommissioning and restoration.

2. Each of these activities potentially poses risks of impacts to water resources and water-dependent MNES in the Beetaloo Basin. The nature of these impacts largely depends on the:

   a. likelihood of the impact pathways between these activities and the endpoints (in this advice, water resources represented by aquatic habitats, including their water quality and biota) and,

   b. vulnerability of each endpoint to individual and collective impacts. Vulnerability is a complex characteristic of each endpoint and is influenced by the endpoint's proximity to the source of the impact(s) and inherent features of the endpoint (e.g. resilience to disturbance, sensitivity to specific impact(s), condition/integrity).

   Both these parameters will vary spatially and temporally across the BBSA which makes it difficult to specify the precise scales of potential impacts at a site, or their cumulative impacts (see response to Question 2).

3. In the following paragraphs, we use IPDs (Commonwealth of Australia 2024) and brief supporting narratives to describe the likely nature of impacts and their pathways between the activities listed in Paragraph 1 and aquatic habitats in two contrasting localities in the BBSA. The narrative for each IPD concludes with a high-level description of the likely spatial and temporal scales of the potential impacts in each locality, reiterating the caveat that these scales will vary spatially and temporally across the Basin for each endpoint. Although other impact pathways (and risks) to water resources may exist in other parts of the Basin, the IESC considers that the extent and scale of impacts arising from exploration and appraisal activities for unconventional gas are largely captured in the following two examples.

Likely nature and scales of potential impacts in the Newcastle Creek-Lake Woods catchment (southern region)

4. Impacts that arise from vegetation removal for construction of infrastructure and possibly seismic lines may include (Figure 2):

   a. direct impacts on water-dependent vegetation (e.g. riparian vegetation where stream crossings are built),

   b. alterations of catchment drainage patterns and surface runoff that impact the water regime, water quality and biota of Newcastle Creek and other waterways, including permanent and semi-permanent refugial waters (e.g. Longreach Waterhole), and

   c. fragmentation and loss of vegetated habitats, including groundwater-dependent vegetation, that may reduce the condition and/or persistence of populations of dependent wildlife, and possibly impact surface runoff patterns and water quality, alter erosion and sedimentation rates and promote the spread of invasive species, some of which (e.g. Gamba Grass *Andropogon gayanus*) may also change fire regimes.

5. Roads and, if constructed, seismic lines and/or pipelines, are likely to permanently alter catchment drainage patterns and surface runoff, causing on-going impacts to water regimes, water quality and biota of receiving surface waters. Most of these waters are ephemeral creeks whose flow regimes are strongly influenced by catchment runoff. Changes to ecologically relevant components (e.g. frequency and durations of low- and zero-flow periods, flow pulses and overbank inundation) of these flow regimes are likely to have impacts on the species composition and persistence of aquatic and riparian biota of these creeks as well as some aspects of their

water quality (e.g. dissolved oxygen) and ecological processes (see chapters in Datry et al. 2017).

6. Waste includes drilling muds and flowback wastewater which contains hydraulic fracturing chemicals and natural compounds from the shale rock (geogenics), including naturally occurring radioactive materials (NORM). Where wastewater, drilling muds and chemicals are transported or stored, there is a risk of spillage which, if it occurs near a creek line or refugial waterhole, may impact water quality and aquatic and riparian biota (Figure 2). For this advice, the IESC assumed that wastewater will not be discharged into local waterways or stored in open ponds but will be transported off site by road.

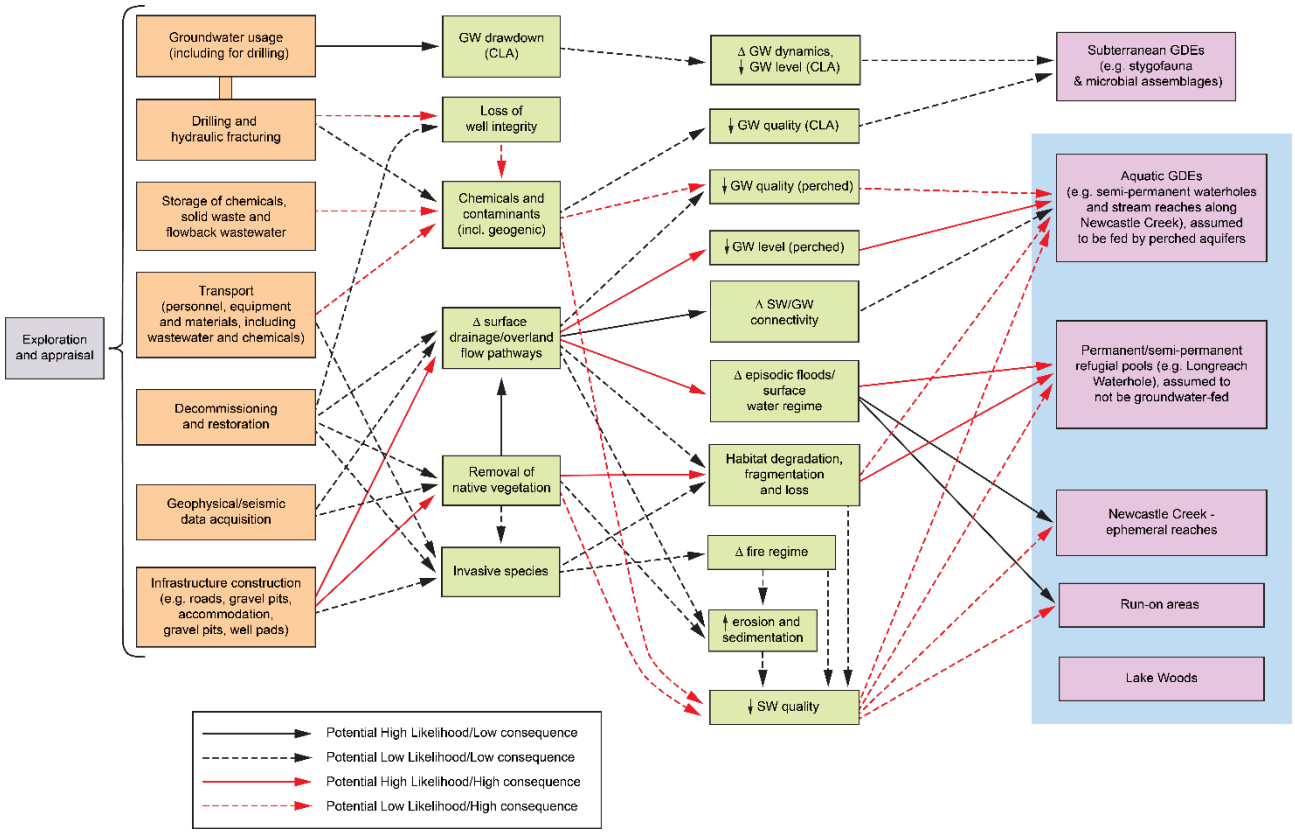

Figure 2. IPD of the potential impacts of exploration and appraisal activities on water resources in the Newcastle Creek-Lake Woods catchment. Activities are shaded in apricot, intermediate components (stressors and processes) in green, and endpoints in pink. The endpoints are grouped in a blue box to indicate that they are hydrologically connected. Potential likelihood and potential consequence (risk) are indicated by lines of different colour and style (see legend). Within the green boxes, Δ represents 'change in'; ↑ represents 'increase' and ↓ represents 'decrease'. SW and GW refer to surface water and groundwater respectively.

7. Groundwater is typically at least 20 m below the surface and there is no evidence for springs or other surface-expression GDEs in this locality (DEPWS 2022, Figure 5.9, p. 44). Consequently, activities involving groundwater usage from the CLA (e.g. water supply for hydraulic fracturing, drilling of exploratory bores through the CLA to deeper strata) may cause localised drawdown (Figure 2) but not affect surface-expression GDEs, and would be unlikely to pose material risks to subterranean GDEs (e.g. stygofauna) in this locality. When inundated, Newcastle Creek and its terminus, Lake Woods, both potentially recharge the CLA (ELA 2022, Figure 37, p. 81).

Therefore, reductions or alterations of inundation patterns of these surface waters may have a minor impact on groundwater levels in the CLA.

8. Perched aquifers support permanent and semi-permanent refugial waters (e.g. Newcastle Waters) along Newcastle Creek (DEWPS 2022, p. 100). If terrestrial GDEs occur in the area, they are likely to also rely on perched aquifers. Recharge of these perched aquifers may be impacted by altered surface water/groundwater connectivity (Figure 2) and their water quality could be affected by a spill of flowback wastewater or chemicals in their recharge area (Figure 2).

9. Many of the links in Figure 2 were predicted to have 'low' likelihoods and consequences (black dashed lines). These include all the links from activities associated with acquiring seismic data and with decommissioning and restoration, all the links associated with groundwater levels and quality in the CLA, invasive species, fire regime and erosion and sedimentation, and all the links to the subterranean GDE endpoint (Figure 2). This implies that many of the activities associated with exploration and appraisal are less likely to result in impacts on the endpoints, although this may change under a maximum development scenario (see response to Question 2). Some of the links, such as between invasive species and fire regime, were rated as 'low' likelihood and consequence because they may already occur, have occurred or would be difficult to attribute purely to exploration and appraisal activities. Only one full impact pathway (chemicals and contaminants from hydraulic fracturing altering groundwater quality in the CLA and affecting subterranean GDEs) has low-likelihood links throughout (Figure 2).

10. It is important not to dismiss the links qualitatively predicted to have a low likelihood or consequence because there may be specific locations and/or times during the exploration and appraisal activities in the Lake Woods catchment when these links are more likely and/or consequential than shown on the IPD. Nonetheless, the IESC considers that the impacts propagated along impact pathways with one or more black dashed links are, on average, less material than, for example, impact pathways where likelihood and/or consequence are high (e.g. removal of native vegetation during construction of infrastructure that could degrade, fragment or remove vegetation fringing refugial pools along Newcastle Creek) (Figure 2).

11. The spatial and temporal scales of these impacts (Paragraphs 4 to 10) in this southern locality are likely to be dictated by the extent and duration of the exploration and appraisal activities and their cumulative impacts (including production, other land-uses and consequences of predicted climate change, see response to Question 2). Spatially, collective impacts resulting from clearing native vegetation, constructing roads and altering surface runoff and drainage patterns may be substantial (>100 km^2). This is because in addition to localised impacts of direct clearing for infrastructure construction, there may be large areas affected by roads that fragment vegetation (including 'edge effects' that may extend hundreds of metres from the road, e.g. Pocock and Lawrence 2005) and alter natural dynamics of runoff and sediment, especially when roads traverse floodplains and run-on areas. These impacts may also be long-lasting (decades), especially if the infrastructure is not decommissioned after exploration and appraisal. Impacts arising from the spillage of flowback wastewater or hazardous chemicals may persist for decades if large volumes are involved and if the contaminants are particularly toxic, persistent and cannot be readily cleaned up.

<u>Likely nature and scale of potential impacts in the Roper River catchment (northern region)</u>

12. In contrast to the previous example, GDEs are more prevalent, diverse and ecologically important in the northern region which means that the likely nature and scale of some of the potential impacts of exploration and appraisal will be different. In addition, exploration and appraisal activities are unlikely to occur across much of the north-eastern Roper River catchment because of its limited overlap with the areas of prospectivity (Figure 1). Nonetheless, surface and subsurface flow paths provide potential routes for propagation of impacts and some GDEs

outside the prospective areas may be vulnerable to altered groundwater volumes and water quality arising from exploration and appraisal.

13. Where the Roper River catchment overlaps the prospective area (Figure 1), impacts arising from removal of vegetation for construction of infrastructure and possibly seismic lines may include (Figure 3):

    a. direct impacts on terrestrial GDEs (e.g. *Melaleuca forests*) and other water-dependent vegetation (e.g. riparian vegetation where stream crossings are built),

    b. changes to the water regime and water quality that have impacts on the aquatic and riparian biota of ephemeral waterways (e.g. Birdum and Western creeks), refugial waters (e.g. permanent waterholes in Western Creek) and aquatic GDEs (e.g. groundwater-fed reaches of the Roper River), and

    c. fragmentation and loss of vegetated habitat that may impact the condition and/or persistence of populations of dependent wildlife, alter fire regimes and promote the spread of invasive species. Altered fire regimes and habitat fragmentation are likely to impact on terrestrial GDEs and, potentially, fringing vegetation around refugial waters in the ephemeral upper reaches of the Roper River.

    As seen for the previous example, roads and any seismic lines or pipelines are likely to permanently alter catchment drainage patterns and surface runoff (especially if gas production commences), causing on-going impacts to water regimes, water quality and biota of receiving surface waters.

14. Where flowback wastewater, solid waste and chemicals are transported or stored, there is a risk of spillage which, if it occurs near a creek line, refugial waterhole or groundwater recharge area, may impact on surface and/or groundwater water quality and biota (Figure 3).

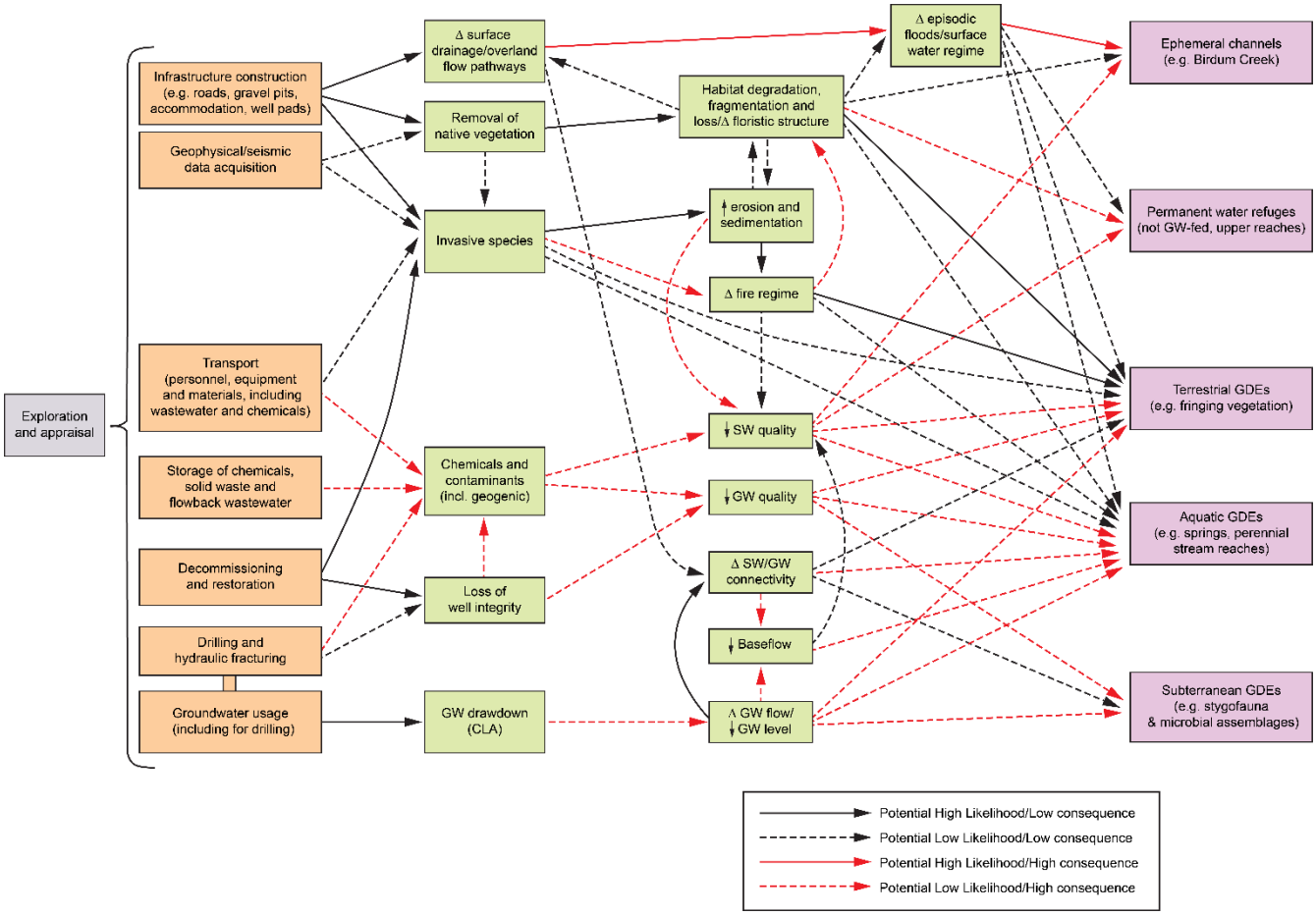

Figure 3. IPD of the potential impacts of exploration and appraisal activities on water resources in the Roper River catchment. Activities are shaded in apricot, intermediate components (stressors and processes) in green, and endpoints in pink. Potential likelihood and consequence (risk) are indicated by lines of different colour and style (see legend). Within the green boxes, Δ represents 'change in'; ↑ represents 'increase' and ↓ represents 'decrease'. SW and GW refer to surface water and groundwater respectively.

15. Usage of groundwater from the CLA, including for drilling exploratory wells and for hydraulic fracturing, may cause drawdown leading to reductions in baseflow and changes to surface water/groundwater connectivity that impact subterranean, aquatic and terrestrial GDEs (Figure 3). These GDEs are also potentially vulnerable to impacts arising from reduced water quality caused by spills (Paragraph 14) and unsuccessful well decommissioning (Figure 3). Much of the groundwater discharging into the upper Roper River and the springs in Elsey National Park and Elsey Creek appears to come from a recharge area between Mataranka and Larrimah which is largely replenished each wet season (Pepper et al. 2018, p. 126). This groundwater moves more rapidly through the system than groundwater from further south (Pepper et al. 2018, p. 127). This recharge zone in the northern CLA with its fast-moving groundwater may be especially vulnerable to accidental spills of flowback wastewater or hazardous chemicals that could affect GDEs downstream in the Roper and Daly rivers.

16. Almost half of the links in Figure 3 were predicted to have 'low' likelihoods and consequences (black dashed lines), including all the links from activities associated with acquiring seismic data. However, unlike the previous IPD for the Lake Woods catchment, there are no components or endpoints of this IPD that are solely linked by low-likelihood arrows. Several complete impact pathways (e.g. from transport and geophysical/seismic data acquisition via invasive species to

terrestrial and aquatic GDEs) are qualitatively rated as low likelihood (Figure 3). As discussed earlier, links qualitatively predicted to have a low likelihood or consequence should not be dismissed because there may be specific locations and/or times during the exploration and appraisal activities in the Roper catchment when these links are more likely and/or consequential than shown on the IPD.

17. As in the example from the southern region, the spatial and temporal scales of the impacts of exploration and appraisal in this northern locality are likely to be dictated by the extent and duration of the activities and their cumulative impacts (including production, other land-uses and consequences of predicted climate change, see response to Question 2). However, in contrast to the previous example, high-value GDEs are more prevalent.

18. Spatially, collective impacts resulting from clearing native vegetation, constructing roads and altering surface runoff and drainage patterns, and alterations of groundwater dynamics (e.g. drawdown, water quality) may be substantial (>100 km^2) but largely occurring outside the Roper catchment. Nonetheless, because of the direction of groundwater flow paths, and high rates and volumes of groundwater movement (Paragraph 15), there may be multiple impacts on high-value GDEs in the Roper River and these impacts may occur over large areas and for decades. In particular, spillage of wastewater or hazardous chemicals near groundwater recharge zones may persist for decades if large amounts are involved and if the contaminants are particularly toxic, persistent and cannot be readily cleaned up. Material gaps still exist in our understanding of the likely spatial and temporal scales of most of the impacts and impact pathways shown in Figures 3, the response thresholds of different water resources (e.g. aquatic habitats and their biota) to predicted impacts on water regimes and water quality, and even the species composition and structure of most of the aquatic, riparian and groundwater assemblages of this locality and the wider BBSA (see response to Question 3).

Question 2: What are the potential cumulative impacts that may occur as a result of this range of exploration and appraisal activities, including an increase in scale and frequency of activities or multiple exploration and appraisal programs?

19. To infer potential cumulative impacts on the Basin's water resources, the IESC assumed a 'maximum development scenario' (MDS) and that in addition to successful exploration and appraisal, production would occur. This MDS is based on the 'GALE scenario' used by Pepper et al. (2018) and was also used in the Stage 3 impact assessment by the Geological and Bioregional Assessment Program (https://www.bioregionalassessments.gov.au/34-resource-development-scenario). It assumes a peak production rate of 365 petajoules per year (or 1,000 terajoules per day), a project life of 25 years (including five years of exploration and appraisal activities) and the drilling of a maximum of 1,150 wells with 4 to 10 wells per pad. The Geological and Bioregional Assessment Program inferred that this scenario would directly disturb 8-35 km^2 for infrastructure such as access roads and well pads, and require a total of up to 46 gigalitres of water over the 25-year development period (assuming 40 megalitres for drilling and hydraulic fracturing per well).

20. As in the response to Question 1, it was also assumed that exploration and appraisal activities would only take place in the Beetaloo Sub-basin and eastern depocentre considered prospective for unconventional gas. Therefore, when using IPDs to infer potential collective impacts from exploration and appraisal activities alone, it was assumed that many of the 'low likelihood' links in Figures 2 and 3 would now become more likely under an MDS. IPDs can only show collective rather than cumulative impacts because some combinations of impact pathways are not simply additive but may be synergistic or antagonistic (Commonwealth of Australia 2024). Material gaps in current understanding of these synergistic and antagonistic processes (see response to Question 3) constrains the IESC's predictions of likely cumulative impacts in this advice.

21. Although Question 2 only specifies exploration and appraisal activities, it is important to acknowledge that other land-uses exist in the area or are planned. These include irrigated agriculture (e.g. cotton, mangoes, melons), pastoral activities (e.g. cattle), domestic use (e.g. stations, communities), solar farms and wind farms (Northern Territory Government 2024). The two land-uses considered most likely to have potential cumulative impacts on water resources in addition to exploration and appraisal activities are irrigated agriculture and pastoral developments.

22. Finally, the cumulative impacts of all these activities and land-uses on water resources in the Beetaloo Basin will be in addition to, and modified by, the current and predicted changes in climate. Heavy rainfalls are projected to increase by 8%-15% per degree of global warming (Wasko et al. 2024), and while the frequency of cyclones is likely to decrease, their intensity will increase (Walsh et al. 2016). There will be considerably more days above 40°C, and evapotranspiration will potentially increase (NESP 2020). Projected change in average annual rainfall is unclear, where both wetter and drier futures are plausible depending on the degree of global warming.

Potential cumulative impacts that may occur as a result of exploration and appraisal activities under maximum development

23. Under an MDS, all of the predicted impacts described in the response to Question 1 could reasonably be expected to occur. However, many of the links and impact pathways shown in Figures 2 and 3 are now more likely and their collective impacts may extend further and persist for longer. For example, in the Lake Woods-Newcastle Waters catchment (Figure 2), exploration and appraisal activities under an MDS would likely increase the risk of introducing invasive species that could directly impact surface waters (e.g. trampling and rooting by feral pigs), increase fire frequency and intensity via increased spread of flammable weeds such as Gamba Grass and Buffel Grass (*Cenchrus ciliaris*) and exacerbate rates of erosion and sedimentation. These may all combine with existing and potentially greater alterations in surface runoff patterns and native vegetation removal (Figure 2) to have collective and possibly cumulative impacts on the water quality, biota and ecological processes of the connected surface waters of Newcastle Creek and Lake Woods (blue box in Figure 2). However, it is unlikely that increased exploration and appraisal activities will materially impact subsurface GDEs in the CLA.

24. In the Roper River catchment (Figure 3), increased exploration and appraisal activities under an MDS are likely to increase the potential collective impacts on GDEs via impact pathways that affect either groundwater quality, groundwater dynamics or both. For example, greater numbers of exploratory wells increase the likelihood of drawdown and failed well integrity that, in combination with increased risks of chemical or flowback wastewater spills, may have cumulative impacts on GDEs through reduced groundwater quality, volumes or both. Increased exploration and appraisal activities also enhance the likelihood of introducing or spreading invasive species that may directly impact surface water resources and/or alter fire regimes and erosion/sedimentation dynamics that will, in turn, potentially have cumulative impacts on the water quality, biota and ecological processes in surface-expression aquatic and terrestrial GDEs.

Potential cumulative impacts that may occur as a result of exploration, appraisal and production activities, additional land-use activities and predicted climate change

25. It is highly likely that exploration and appraisal activities will continue after production commences as operators seek to locate and prove further gas reserves. As an example, Figure 4 shows how drilling of exploration and appraisal wells has continued for coal seam gas (CSG) projects in Queensland concurrently with production from 2000 to 2024.

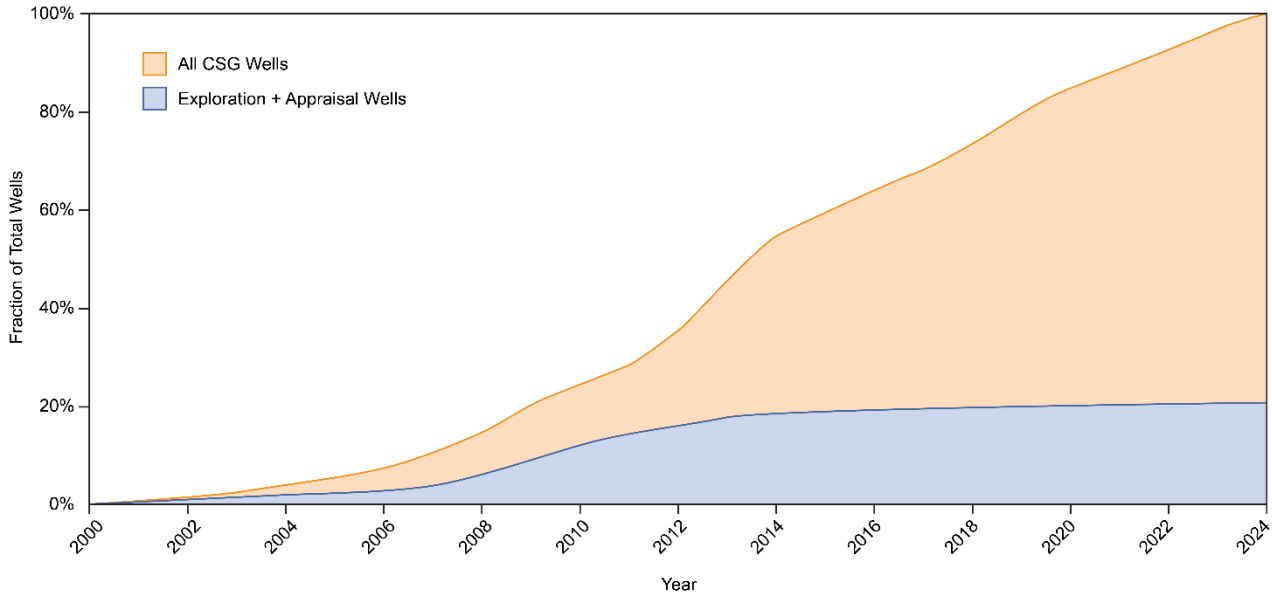

Figure 4. Exploration and appraisal wells as a fraction of total coal seam gas (CSG) wells in Queensland developed from 2000 to 2024. Data source: Queensland Spatial Catalogue.

26. The cumulative impacts of production under an MDS will likely arise from the combination of increased usage of groundwater, greater likelihood of spills and inter-aquifer leakage from well integrity failure and potential groundwater contamination (cf. Shanafield et al. 2019).

27. In addition to those impacts described in Paragraph 4, the main impacts of additional activities are likely to be potential salinisation associated with irrigated agriculture in the Beetaloo Basin, and the use of fertilisers, herbicides, fungicides and pesticides.

28. Projected climate change in the area (Paragraph 22) will likely exacerbate the following cumulative impacts: increased erosion and sedimentation associated with more intense rainfall, or recharge of groundwater that may increase or decline. Additionally, predicted changes under climate-change scenarios, particularly increasing numbers of very hot days and increasing evapotranspiration rates, may reduce the resilience of water-dependent MNES such as Gouldian Finch and species with a requirement for persistent water or climate-buffering habitats (DEPWS 2022, p.18). In general, the rate and nature of the impacts of climate change on temperatures, rainfalls and climatic variability in the region are subject to deep uncertainty, which confounds attempts to assess climate-related changes to cumulative impacts. This uncertainty is unlikely to be reduced with basin and local-scale modelling.

Question 3: Are there material gaps in the current scientific understanding of the hydrology and hydrogeology of the Beetaloo Basin that affect the IESC's ability to provide advice on potential impacts, impact pathways and risk assessment associated with exploration and appraisal activities? If so, what are these and what research is needed to address these gaps at basin and site scale?

29. Regional surveys and high-level risk assessments such as SREBA (DEPWS 2022) and the Geological and Bioregional Assessment (Huddlestone-Holmes et al. 2020, 2021) have contributed substantially to knowledge of the Beetaloo Basin. However, material gaps remain in the current scientific understanding of the hydrology, hydrogeology and other aspects of the Beetaloo Basin that affected the IESC's ability to provide advice on potential impacts, impact pathways and risks associated with exploration and appraisal activities. These gaps fall into two groups: the first where information is needed and the second where further data and research are required.

a. Information is needed on:

i. where, when and the scale of exploration and appraisal activities that are likely to occur, and their proximity to surface and subterranean water resources in the Basin;

ii. water requirements of current and future land uses, and their likely changes under projected climate change and population pressure in the Basin;

iii. planned storage, transport and treatment of flowback, drilling muds and other wastes, as well as wastewater treatment (acknowledging that there will be no controlled releases of flowback water to the environment); and

iv. which combinations of impact pathways are synergistic or antagonistic, and the conditions under which these interactions occur in the Beetaloo Basin (see response to Question 2).

30. Along with the research proposed below, there remains a need for site- and project-specific investigations including collection of baseline data and subsequent modelling. Guidelines and suggested methods for these are provided on the IESC website (https://www.iesc.gov.au/).

31. Research, including collection of relevant baseline data and other information, is needed to address material gaps in the following broad topics.

Geological framework of the basin

32. There is a need for a substantially improved geological framework of the Beetaloo Basin as this is critical to understanding the groundwater and groundwater-surface water connections as well as the risks associated with potential gas development. This requires a refined stratigraphy, including facies distribution of key aquifers and aquitards and an improved structural framework, and should include the following work.

a. To inform the improved structural framework and identify potential impact pathways, further borehole and geophysical investigations are needed. For example, there is geological uncertainty near the northern boundary with the upper Roper catchment (Jarrett et al. 2022), in the north-east near the Hot Springs Valley (Evans et al. 2020, p. 90), and in the relationship between the Bukalara and Gum Ridge strata (DEWPS 2022, Figure 4.6, p. 59).

b. The characteristics of complex fault-zones, another potential impact pathway, are uncertain near the boundaries of the Beetaloo Basin. For example, the east-west Mallapunyah fault zone near the northern boundary with the upper Roper catchment is largely undefined (Jarrett et al. 2022). Investigations are needed to map complex fault-zones (Murray and Power 2021), including the possible offset of aquitard strata that could compartmentalise groundwater. These investigations could help verify the modelling estimate that Beetaloo Basin groundwater is a small contribution to the water balance of the Tindall limestone and Mataranka springs (<10% of total groundwater in Tindall limestone, Knapton 2020).

Groundwater

33. Building from the refined geological framework (Paragraph 32), detailed characterisation is needed of aquifer and aquitard geometries, hydraulic properties, groundwater levels, hydraulic gradients and flow pathways, including their temporal variability. This information will address gaps in understand how groundwater supports GDEs (subterranean, aquatic and terrestrial), including perched systems, and will improve conceptualisation, water balances, models and site-specific evaluations of the potential impact pathways. To achieve this, the following research is recommended:

a. The regional multi-level bore monitoring network needs to be extended to better characterise basin-wide groundwater systems, fault-zones and local inter-aquifer connectivity (e.g. between the Bukalara and Gum Ridge strata). Investigations are also needed to confirm the extent and properties of aquitards that disconnect CLA aquifers from deeper shales in the Beetaloo Basin.

b. This bore monitoring network should be used to obtain site-specific values of hydraulic conductivity (e.g. Valois et al. 2023) and to identify different types of aquifers and values of groundwater storage (Chowdhury et al. 2022).

c. Site-specific geophysical surveys and tracer studies (e.g. Office of Water Science 2020) should investigate the potential for groundwater flow through preferential paths that may be undercover (e.g. karst channels without surface sinkholes, perched aquifers) and contribute to the risk of rapid migration of contaminants and their discharge to surface waters.

d. For the regional water balance (see Paragraph 36) further research is needed into groundwater recharge, particularly on its spatial and temporal variability (e.g. Lee et al. 2024), on episodic recharge events and to quantify focused recharge mechanisms through preferential paths.

e. Quantify groundwater through-flow from the south-east Beetaloo Basin to the Tindall limestone (i.e. the CLA in the Roper River catchment) using multiple lines of evidence e.g. geophysics, drilling, multi-level piezometers, environmental tracers (see Paragraph 32b).

Surface water

34. Further baseline data are needed on concurrent sub-daily rainfalls and streamflows for catchments covering a range of spatial scales, catchment types and climatic conditions. These data should include high-flow gaugings (and associated hydrodynamic modelling to help inform stage-discharge relationships) which will address material gaps in the characterisation of the high flows that contribute to surface runoff, extended inundation events and recharge of perched and near-surface aquifers.

35. Given the very flat topography, high-quality topographic data (e.g. Light Detection and Ranging (LiDAR) data) are needed to model surface runoff and flood inundation behaviour. Local-scale rainfall-runoff models will be required to address project-specific impacts.

Surface water and groundwater connectivity

36. There is the large uncertainty in how rainfall is partitioned into evapotranspiration, recharge to groundwater systems, losses to surface and depression stores, and surface runoff. To reduce this uncertainty in water balance components, data assimilation techniques should be applied that combine ground-based observations, remote-sensing data and model outputs (e.g. Doble and Crosbie 2017, Kalu et al. 2024).

37. In the flat terrain typical of much of the Beetaloo Basin, the spatial and temporal distributions of episodic runoff are governed by small differences in elevation that influence recharge to near-surface groundwaters used by terrestrial GDEs. High-quality topographic information is needed to better inform our understanding of the recharge dynamics in such areas (see Paragraph 35).

38. To better understand the connectivity and hydrological pathways between groundwater and surface water systems, data are needed to develop a range of suitable trigger values for maintaining groundwater discharge to the surface at major springs such as those in Hot Springs Valley. This needs to be done in conjunction with geophysical studies and tracers (e.g. Campbell

et al. 2025) to ensure that potential contamination pathways are identified and incorporated into environmental risk assessments.

Water quality

39. Further baseline groundwater and surface water quality monitoring across the Beetaloo Basin is required to assess impacts from any accidental chemical or flowback wastewater spills and from which site-specific criteria may need to be developed if production goes ahead (Golding et al. 2022). Monitoring should include background physico-chemical parameters, nutrients, dissolved methane, naturally occurring radioactive materials and organic and inorganic contaminants in both surface and groundwaters prior to and during exploration and appraisal activities. Baseline groundwater monitoring should also include environmental isotopes (Office of Water Science 2020) to characterise groundwater and dissolved gases.

40. Recent research (Golding et al. 2022) has shown that concentrations of naturally occurring radioactive materials, such as radium, in flowback may exceed guidelines. These isotopes may precipitate at the surface, with potential increases in daughter isotopes. Information on these isotope species and concentrations are required to ensure appropriate protection of aquatic ecosystems in the Basin (Lauer et al. 2018, Campin 2019, p. 260).

Ecology

41. Although Question 3 asks specifically about material gaps in hydrology and hydrogeology, there are several gaps in the current scientific understanding of ecology of water-dependent biota that constrained the IESC's advice and where research is needed. These gaps include:

    a. Species composition, distribution, degree of groundwater-dependence and current condition of aquatic and terrestrial GDEs in different parts of the Basin, and what and how native species (especially MNES) are supported by them. Survey techniques for assessing these GDEs are well-established (e.g. Doody et al. 2019) and include remote-sensing methods (e.g. Brim Box et al. 2022) that can be used in a multiple-lines-of-evidence approach (e.g. Fildes et al. 2023) appropriate for site- and Basin-scale assessments. In some areas where diverse GDEs occur (e.g. the Roper River discharge area) or where perched aquifers may be at risk (e.g. Lake Woods catchment), detailed field assessments of seasonal groundwater use and potential sources of groundwater are needed to confirm suspected impact pathways.

    b. Species composition and distribution of subterranean GDEs (stygofauna and microbial assemblages). The initial studies by Oberprieler et al. (2021) and DEPWS (2022) need to be extended to fully describe the components and processes that characterise the subterranean GDEs of the Basin. Determination of the spatial and temporal variability exhibited by the groundwater biota is needed to develop thresholds indicating irreversible change and to provide a baseline for future monitoring.

    c. Species composition, distribution and current condition of water-dependent native plants and animals (especially MNES) that may be affected by unconventional gas development (including production), climate change and other existing and future water-uses in the Basin. Appropriate methods (e.g. Geological and Bioregional Assessment Program 2021, DEWPS 2022) should be used to provide further baseline data, supplemented by targeted research assessing water use and seasonal dependency so that thresholds (see next point) can be assessed.

    d. Thresholds ('tipping points') for the vulnerability of different GDEs to changes in groundwater drawdown and water quality across the Basin. Field and laboratory research is needed to quantify these thresholds to identify whether they may be exceeded by maximum

unconventional gas development (including production), informing assessment of cumulative impacts due to climate change and other ongoing water-uses in the Basin.

Date of advice	16 December 2024
Acknowledgement	We thank Belinda Cale for drafting the figures in this advice.
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Responded At: Dec 15, 2025 14:41:09 pm
Last Seen: Dec 14, 2025 20:27:56 pm
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Q1.	**Given name**	Jaemie
Q2.	**Family Name**	Page
Q3.	**Location**	JINGILI, NT
Q4.	**Stakeholder type**	Community member
Q5.	**Email address**	jaemie.one@gmail.com
Q6.	**Interest area**	Social and cultural Flora and fauna Water Waste management Climate change Human health Regulation and compliance Well integrity

Q7. **Please provide your comments**

Fracking is a terrible idea bad for the environment and adds to climate change. Don’t do it.

Q8.	**Add an attachment - Max file size: 5MB**	not answered
Q9.	**Tick this box if you wish for your name and contact details to be confidential**	not answered

Respondent No: 6
Login: Anonymous
Email: n/a

Responded At: Dec 16, 2025 23:17:09 pm
Last Seen: Dec 16, 2025 23:17:09 pm
IP Address: n/a

Q1.	**Given name**	Melissa
Q2.	**Family Name**	Ball
Q3.	**Location**	FANNIE BAY, NT
Q4.	**Stakeholder type**	Community member
Q5.	**Email address**	mellie.81@hotmail.com
Q6.	**Interest area**	Social and cultural Flora and fauna Water Waste management Climate change Human health Chemicals Regulation and compliance Well integrity
Q7.	**Please provide your comments**	Please see attached submission.
Q8.	**Add an attachment - Max file size: 5MB**	https://s3-ap-southeast-2.amazonaws.com/ehq-production-australia/096ff5bace8d180064e34bba086fd21e8f763777/original/1765892784/03fb545eaba9445709a207ed31faf2a1_EP%20161%20Submission_Melissa%20Ball_%2016.12.2025.docx?1765892784
Q9.	**Tick this box if you wish for your name and contact details to be confidential**	not answered

Reply to: Melissa Ball
E: mellie.81@hotmail.com

16 December 2025

Submission: STO8-1: EP161 Beetaloo Basin Appraisal Pilot EMP

Thank you for the opportunity to make a submission on this referral.

My name is Melissa Ball, and I live in Fannie Bay. I am writing to you to share my strong belief that this project should not proceed without further oversight.

My connection to this issue is:

- I am a proud Territorian, deeply invested in the preservation of our iconic natural environment and biodiversity, in perpetuity, for the benefit of current and future generations.
- I am an Australian citizen with firsthand experience of the adverse environmental and social consequences of hydraulic fracturing (fracking).
- I am a global citizen who is deeply concerned about the ramifications of gas expansion in terms of accelerating climate change.

My primary concerns regarding the contents of this EMP are:

Climate change

According to Santos Beetaloo Basin Appraisal Pilot Environmental Management Plan (EMP) dated November 2025, the projected scope 1 greenhouse gas emissions are 27,741 tCO2-e.

Whilst this figure is well below the 100,000 tonnes of carbon dioxide equivalent per year that would be required to apply the Safeguard Mechanism, it fails to account for the majority of a company's total carbon footprint through scope 2 and 3 emissions.

Gas expansion is not compatible with avoiding a climate catastrophe. This is a fact that has been verified in scientific literature published by the International Energy Agency and Intergovernmental Panel on Climate Change.

The Northern Territory Government (NTG) would have Territorians believe gas expansion is necessary to "keep the lights on" however, educated Territorians are not content to swallow propaganda.

As cited by the Australian Institute, Australia's "gas crisis" is self-inflicted. Companies such as Origin and Shell have existing gas surpluses and a simple tax on gas imports would raise sufficient revenue to cut energy bills and ensure ample domestic supply.

Company integrity/transparency

Santos has demonstrated a reckless disregard for the environment and health of Territorians. This is exemplified in the recent revelation of Santos Liquefied Natural Gas (LNG) plant leaking methane into Darwin Harbour since prior to their takeover of the facility in 2020. Santos attempt to prevent the release of documents in relation to the leak under a Freedom of Information request submitted by Environment Centre NT and Santos rejection of the Environment Centre's call for more accurate monitoring of the leak does not instil confidence in their integrity or transparency as a company.

Groundwater implications

The implications of fracking, with respect to the impact on groundwater, are significant. The Griffith University study 'Tracking freshwater depletion in Northern Australia: A multi-satellite approach', found the Cambrian Limestone Aquifer (CLA) has experienced significant water loss since 2014 and has raised concerns about the sustainability of groundwater regulation in the NT, with respect to the expansion of agriculture and gas developments.

Santos EMP is proposing an estimated total groundwater usage of 2350 ML, in a location that will require drilling through the CLA. It is therefore reasonable to conclude that the risks of fracking, in terms of water loss, are considerable with respect to the vital importance of the CLA to sites of ecological significance including the Roper River, Bitter Springs, and Flora River National Park.

Biodiversity/cultural considerations

According to Santos' EMP, there are no Threatened Ecological Communities or threatened flora listed under the Environmental Protection and Biodiversity Act (EPBC) and/or Territory Parks and Wildlife Conservation Act, known to occur within 10 km of the project area.

This assertion is misleading and fails to account for groundwater loss and the potential for substantial reduction in spring and dry season river flows, and subsequent deleterious impacts on groundwater dependent ecosystems.

The scientific literature also attests to leaks and improper disposal of fracking effluents as significant factors contributing to groundwater and soil pollution.

The 10km radius referred to in Santos EMP is therefore inadequate, in terms of failing to consider downstream impacts.

The CSIROs Gas Industry Social and Environmental Research Alliance (GISERA) is currently conducting an environmental baseline characterisation of the springs in Hot Springs Valley, an area located on the boundary of the eastern Beetaloo Sub-basin.

GISERAs Progress Report documents the fact there is currently limited understanding of the source aquifer of geothermal springs in the Hot Spring Valley and their connections to, or isolation from, gas reservoirs existing at present. It would therefore be prudent to ensure rigorous oversight of Santos EMP, prior to approving a project with the potential to impact the springs. Presently there is limited understanding regarding their ecological and cultural significance to First Nations Australians.

Recommendation

With consideration to the above, no less than a precautionary approach is required in assessing Santos EMP and therefore it is recommended for further oversight under the Environmental Protection and EPBC Act.

Further assessment is required to:

- Analyse the full scope of emissions and climatic impact.
- Analyse the downstream impact in terms of sites of ecological significance and biodiversity.

Yours sincerely,

Melissa Ball

Respondent No: 7
Login: Anonymous
Email: n/a

Responded At: Dec 18, 2025 14:09:42 pm
Last Seen: Dec 18, 2025 14:09:42 pm
IP Address: n/a

Q1.	**Given name**	Martin
Q2.	**Family Name**	Jackson
Q3.	**Location**	RAPID CREEK, NT
Q4.	**Stakeholder type**	Community member
Q5.	**Email address**	me@MartinJackson.au
Q6.	**Interest area**	Social and cultural Flora and fauna Water Waste management Climate change Human health Chemicals Regulation and compliance Well integrity

Q7. **Please provide your comments**

Thank you for the opportunity to make a submission on this referral. I work as a software author. I am writing to you to share my strong belief that this project should not proceed. Fracking is a high energy dirty method of extracting natural gas that is increasingly not needed. The resultant CO2 emissions will continue to make Darwin, Australia and the planet, hotter. This is not a contentious issue. All rational ethical people can see this. This will produce few local jobs, little income for the state and serious profits to Santos. Hence Santos spend millions lobbying and feeding disinformation. It is dirty and dangerous for the environment. Theoretical procedures to prevent spills, contamination of the ground and aquifers continue to fail. So far there has been numerous spillages that we know about. How many others? Our aquifers are precious in an often dry state such as ours and should not be risked for this unnecessary activity. The countryside of our NT is often pristine and untouched by agriculture or industry and is an asset now and in the future. Why spoil it for such unnecessary climate damaging fuel? This development will lead to demands to process on Middle Arm and further pollute Darwin air. Already we have terrible pollution from leaking methane tank of Santos and the VOCs and dirty air emanating from the Impex plant. This is damaging workers and residents health. The future for burning fossil fuels is now very limited as renewables and batteries continue to get better and cheaper. It is now much cheaper to build renewables than fossil burners. Demand for the fracked gas will dimmish quite quickly over the next decade as testified by leading business economists. This will lead to stranded assets and well pads that need clearing and lots of poisoned land, water and air. A clean sustainable future is within the grasps of out decision makers, if they would listen. Otherwise Darwin will become too hot, parts of Australia will be uninsurable from fire and flooding, dirty air will damage our children and ourselves.

Q8.	**Add an attachment - Max file size: 5MB**	not answered
Q9.	**Tick this box if you wish for your name and contact details to be confidential**	not answered

Respondent No: 9
Login: Anonymous
Email: n/a

Responded At: Dec 18, 2025 19:19:31 pm
Last Seen: Dec 18, 2025 19:19:31 pm
IP Address: n/a

Q1.	**Given name**	[redacted]
Q2.	**Family Name**	[redacted]
Q3.	**Location**	[redacted]
Q4.	**Stakeholder type**	[redacted]
Q5.	**Email address**	[redacted]
Q6.	**Interest area**	Social and cultural Flora and fauna Water Waste management Human health Chemicals Regulation and compliance
Q7.	**Please provide your comments**	Please see attached submission.
Q8.	**Add an attachment - Max file size: 5MB**	https://s3-ap-southeast-2.amazonaws.com/ehq-production-australia/27152f953c26c781e3c907412ebe68648601a866/original/1766051346/d2fe8b13ac8d5603606c333bf9df9cc8_251217%20Submission%20EMP%20EP161.docx.pdf?1766051346
Q9.	**Tick this box if you wish for your name and contact details to be confidential**	Make my name and contact details private

[redacted]

ABN: 32 608 508 769

ICN: 9392

17 December 2025

Department of Lands, Planning and Environment
Petroleum Regulations Unit
PO Box 3675
Darwin NT 0801

cc: DEPWS Petroleum Operations unit (by email: santos.ep161@nt.gov.au)

Response to EP161 Beetaloo Basin Appraisal Pilot Environment Management Plan

[redacted] 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 "[redacted]" 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.

[redacted] is a way 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 [redacted] 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 area of Exploration Permit EP161.

Previous engagement with NTG and Santos regarding EP161

[redacted] members have had ongoing communications with Santos and the Northern Territory Government regarding proposed fracking activities on EP 161.

As we originally communicated in 2019, our members who hold native title interests in the area of EP 161 have had inadequate engagement with the Northern Land Council (NLC) and Santos about this project. As a result, there is widespread confusion amongst affected native titleholders about what Santos is proposing to do and what risks are involved.

[redacted]

Impact on water

We have significant concerns about the impact this proposal will have on water. The two proposed well pads are located in the middle of a flood plain, and water modelling shows that in a flood event, water would flow into the Tanumbiruni Creek and then onto the Limmen River.

These waterways are important to our culture, help our plants and animals to survive and give drinking water. We cannot put this at risk. Water is life. Once this water is damaged or depleted, there is no going back.

The EMP does not provide any information about the impact of drawing down from the aquifers, or the potential for pollution to escape into them. These underground aquifers lie like lungs under our country and are vast and interconnected. Their recharge is slow, and the behaviour of water in them is largely unknown, which means the impacts of water depletion are uncertain.

We also understand that a new underground aquifer (the Inacumba aquifer) was discovered after the original EMP was approved in 2019, and this aquifer is not mentioned at all in the new EMP documentation. We also note that the referenced water modelling is not recent. We are requesting more information about the impact of Santos' proposed development on this water source, as well as the nearby hot springs.

Given limited knowledge of the aquifers in this area, we are asking that a full Environmental Impact Statement be required that properly investigates the hydrological properties of the aquifer and the other waterways, its cultural and ecological values and the impact of this water removal on those values.

Waste water and monitoring

It is not acceptable that Santos not be required to undertake appropriate groundwater or surface water monitoring, and we note that the reports mentioned rely on desktop assessments rather than on-ground truthing of how water flows on our country.

We know that the wastewater from fracking is poisonous and must not be allowed to leach into our country. In the EMP the company says that the wastewater tanks will be open, which means birds can land on the tanks, and there is a risk of spills or overflow, particularly during the wet season.

The proposed monitoring activities in this new EMP are not sufficient. We have seen the impact of spills and other incidents from fracking already in the Northern Territory, and we

do not want this to happen here. We know that these incidents go largely unreported, and Traditional Owners never find out. If there is an accident or a spill, how will people know if there is no good and transparent monitoring?

Cultural heritage and sacred sites

Traditional Owners have had concerns about the impact of fracking on cultural heritage for a long time. Just because the desktop search did not find any sites does not mean that they do not exist. We know that many sites in this area have not been registered yet. Only doing a ground search on areas that have been identified as moderate or higher means that things will get missed.

In addition, we think it is important that a cultural heritage management plan for the entire EMP area be put in place before any works take place. We are aware that this has been done for other areas in the Beetaloo Basin region where fracking is proposed to occur, and it should be standard practice.

The report seems to have some inaccuracies about dates, which does not give us confidence about the accuracy of the broader report (for example, December 2025 being quoted as the date that Traditional Owners provided comment to AECOM that the area has a low number of sites, but the document was submitted to the NT Government in October 2025).

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 there is a significant impact of large-scale fracking that could poison our country and the life that it supports. None of the information we have received since the Pepper Inquiry has allayed our concerns about fracking, yet now it is permitted again.

Under the EMP, Santos intends to carry out a range of activities that 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. We continue to have cultural responsibilities across the region for the protection of waterways.

Country will be damaged, and cultural heritage 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 and not approve this new EMP.

We are also aware that significant legislative and policy changes have occurred, particularly to NT petroleum laws, since the original EMP was approved in 2019. We are interested in how Santos has incorporated these changes into this review process, particularly as they relate to emissions, human health, cultural heritage and environmental risk.

We have also heard people talking about the sale of fracked gas and are requesting clarity from Santos about any plans to sell appraisal gas from wells on EP161.

We ask that Santos 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
- work with Traditional Owners and the Land Council to ensure there is a cultural heritage management plan for the area

Yours sincerely,

[redacted]

Respondent No: 14
Login: Anonymous
Email: n/a

Responded At: Dec 19, 2025 17:34:34 pm
Last Seen: Dec 19, 2025 17:34:34 pm
IP Address: n/a

Q1.	**Given name**	[redacted]
Q2.	**Family Name**	[redacted]
Q3.	**Location**	DARWIN, NT
Q4.	**Stakeholder type**	Community member
Q5.	**Email address**	[redacted]
Q6.	**Interest area**	Social and cultural Flora and fauna Water Waste management Climate change Human health Chemicals Regulation and compliance Well integrity
Q7.	**Please provide your comments**	please refer attached
Q8.	**Add an attachment - Max file size: 5MB**	https://s3-ap-southeast-2.amazonaws.com/ehq-production-australia/8d834e6e47dc843b8bb05659feab5326319df509/original/1766131468/fea9e1bbc7d25393b58207bd730d9551_EMP161%20Submisson%20Response.pdf?1766131468
Q9.	**Tick this box if you wish for your name and contact details to be confidential**	Make my name and contact details private

Department of Lands, Planning and Environment
Petroleum Regulations Unit
PO Box 3675
Darwin NT 0801

Santos.ep161@nt.gov.au

Re: EMP STO8-1 – EP161 Beetaloo Basin Appraisal Pilot Environment Management Plan

I make this submission as an individual concerned about the cumulative environmental, climate and cultural impacts of the Beetaloo Basin gas program and the weakening of safeguards that were supposed to govern it. In my view, EMP STO8-1 for EP161 is being assessed in a regulatory environment that has shifted sharply away from the Pepper Inquiry's precautionary framework towards accelerated approvals with reduced oversight.

Since the Pepper Inquiry reported, the Northern Territory Government has:

- Introduced the Territory Coordinator role with a mandate to fast-track major projects, including gas, which risks sidelining transparent, independent environmental scrutiny and community input.
- Gutted key elements of the Fracking Code of Practice, weakening enforceable standards on issues such as chemical disclosure, containment, monitoring and community protections that were central to public acceptance of any onshore gas development.
- Removed renewable energy targets and
- Removed emissions reduction targets, signalling a policy shift away from a planned transition to clean energy and emissions reduction, and towards expanded fossil fuel production without a credible climate framework.

Each of these policy changes has contributed to a reckless rollback of environmental oversight and regulation, leaving EMPs like STO8-1 to be assessed under looser, more pro-development settings than the community was promised. Against that backdrop, it is even more critical that this EMP is not waved through on the basis of narrow, company-authored risk assessments, but is refused, and at minimum referred to the NT EPA and the federal environment ministers for full, independent scrutiny of its cumulative impacts on water, climate, biodiversity and cultural values.

In this context, it is important to recall that the NT's current approach to Beetaloo gas is occurring against the history of the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory. Following the 2016 moratorium on onshore hydraulic fracturing and DFIT, the Inquiry ran for around 15 months, received 1,257 submissions, held 52 community forums and 151 public hearings, and consistently recorded that a significant majority of participants saw onshore shale gas fracking in the NT as not safe, not trusted and not wanted. The Inquiry's 2018 final report was explicit that the risks of developing an onshore shale gas industry may only be mitigated or reduced if all 135 recommendations are adopted and implemented in full, yet subsequent policy changes – including weakening the Fracking Code of Practice and removing renewable energy and emissions-reduction targets – have moved the NT further away from, not closer to, that full-implementation safeguard.

1. Request and overall position

I request that:

- EMP STO8-1 for EP161 (Beetaloo Basin Appraisal Pilot) is refused approval.
- The proposal is referred to the NT Environment Protection Authority (NT EPA) for a full environmental impact assessment.
- The proposal is referred to the federal environment ministers for assessment under the EPBC Act, due to likely significant impacts on Matters of National Environmental Significance (MNES), on water resources and on climate from an already-fracked Beetaloo appraisal field.

This EMP does not adequately assess or manage cumulative impacts of past and proposed activities on Tanumbirini/Mount Brown, does not demonstrate that risks to land, water, biodiversity and cultural values are reduced to ALARP, and treats major climate and contamination risks as minor local issues.

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2. Why the EMP is not fit for approval

Already-fracked, cumulatively impacted landscape (Appendices A–C, G, J)

- Appendix A shows EP161 Tanumbirini/Mount Brown is already heavily disturbed, with multiple wells drilled and fracture-tested, seismic lines, borrow pits, pads, an airstrip and long-standing rehabilitation debt, so this is not a small, new proposal but an escalation in an already scarred landscape.
- The EMP rolls several earlier EMPs into a single “Appraisal Pilot”, normalising a long-term basin-style appraisal phase while still assessing impacts at an activity level, with no robust cumulative assessment of the combined footprint, groundwater drawdown, erosion, fire and weed interactions, or pastoral and cultural disruption across decades.

Inadequate protection of water resources (Appendices A, D–F, G, I)

- The project draws heavily on the Cambrian Limestone Aquifer and existing GRF10280 bores, with up to 750 ML/year water use and large new storages, but performance standards are framed as “no reduction to groundwater availability” without clear drawdown thresholds, trigger levels or basin-scale limits, failing to protect other users and groundwater-dependent ecosystems.
- Appendices D, E and F assume that large spills (up to 12 ML from a tank, 2.5 ML from pits) will mostly infiltrate a shallow soil profile and are “extremely unlikely” to affect groundwater, yet they do not model realistic wet-season flooding, bund overtopping, drainage line transport, or long-term leaching from shallow burial of drilling wastes and flowback residues.

Dangerous waste and chemical handling, with open ponds (Appendices D–F)

- Appendix D expands the inventory of fracking and drilling chemicals, including high-hazard surfactants, biocides, oxidants and tracers, while relying on consultant Tier-2 assessments that only examine a narrow set of receptors (workers and some birds) and idealised containment; there is no robust evaluation of risks to cattle, native fauna, soil biota or downstream water users under failure scenarios.

- Appendices D and E show that large volumes of frack fluids and flowback (around 145 ML stimulation fluid and 28 ML flowback per horizontal well) are stored for up to 300 days in open tanks or pits, creating prolonged exposure risks for people, birds, stock and wildlife, including inhalation of aerosols and direct ingestion, which is inconsistent with Pepper Inquiry expectations and modern best practice.

Climate and methane: scope-limited and misleading (Appendix H, J)

- Appendix H deals only with fugitive methane and flaring from this appraisal campaign and omits any quantification of full scope 1 emissions (diesel, flaring, leaks), scope 2 emissions (electricity) and scope 3 emissions from combustion of produced gas, which are by far the largest climate impact.
- Appendix J repeatedly uses the "small footprint, temporary activity" framing to argue that significant impacts are unlikely, while ignoring that Beetaloo EP161, EP167 and neighbouring tenements together constitute a large new gas province whose cumulative emissions are incompatible with Australia's climate goals and should be assessed as a single integrated action at both NT and Commonwealth level.

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3. Grounds for NT EPA referral

Significant, complex, cumulative impacts across A–P

- Taken together, Appendices A–P show an already-fracked, multi-EMP field where new pads, up to 12 hydraulically fractured appraisal wells, new roads, camps, pits and dams will compound existing disturbance, erosion, altered drainage, weed infestations and changed fire regimes over a large area of Tanumbirini Station.
- The EMP relies on a suite of narrow, compliance-oriented subsidiary plans (erosion, weeds, fire, groundwater, chemicals, wastewater, methane, emergency response, rehabilitation) and a consultant environmental assessment (Appendix J) that consistently downplays cumulative risk and leans on assumptions of perfect containment and effective rehabilitation without independent verification.

Inadequate assessment of risks to water, land and pastoral operations

- Groundwater and surface-water monitoring (Appendix I) is sparse and focused on verifying model predictions, not on early detection of failure; analyte suites are limited, and there is no explicit, routine monitoring for PFAS and other highly persistent organics that may be present in drilling and frack additives or in imported inputs.
- Erosion and sediment controls (Appendix G) are standard IECA measures applied to large new disturbed areas in the headwaters of sensitive drainage lines; they do not integrate chemical spill risks, wet-season flood routing, long-term legacy of tracks and pits as drainage features, or cumulative sediment and contaminant loads off-lease.

Santos safety and compliance record

- The EMP's risk characterisation assumes high levels of compliance and self-reporting by Santos, despite documented safety and leak issues at other Santos operations nationally, including long-running methane and condensate leaks and delayed disclosure at Darwin LNG, which are not addressed in this EMP or used to tighten conditions.

- In the context of existing conflicts and legal disputes on Tanumbirini and other Beetaloo leases, reliance on a “no unresolved complaints” metric as an indicator of social performance is inappropriate; Appendix A itself acknowledges a history of complaints and disputes, yet this is not used to strengthen monitoring, enforcement or independent oversight in the current EMP.

Given the scale, complexity and cumulative nature of impacts, the dependence on company-authored plans, and Santos’s wider safety and compliance record, the proposal easily meets the threshold for NT EPA referral for a full environmental impact assessment.

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4. Grounds for federal EPBC referral

Threatened species and MNES (Appendix J and related appendices)

- Appendix J acknowledges potential habitat for MNES species such as Gouldian finch, yellow-spotted monitor and plains death adder, as well as migratory birds, but systematically concludes “no significant impact” by treating disturbance as small, habitat as marginal and existing threats as a reason to discount additional loss.
- The assessment relies on limited field surveys and desktop reviews in an already disturbed, heavily burned and grazed landscape, without a rigorous cumulative analysis of how additional clearing, roads, pits, weeds, fire and contamination will interact over the life of the appraisal program and any subsequent production phase.

Water resources and groundwater-dependent ecosystems (D–F, G, I, J)

- The project poses material risks to MNES water resources through large-scale groundwater extraction from the Cambrian Limestone Aquifer, long-term storage of hazardous fluids in open facilities, and potential spill pathways into headwater drainage lines, yet does not quantify or map risks to specific creeks, rivers or groundwater-dependent ecosystems down-gradient.
- The EMP’s approach (relying on localised modelling, minimal monitoring and generic references to “ephemeral watercourses”) does not meet EPBC expectations for assessment of significant impacts on water resources associated with coal seam gas and large coal mining developments, which should be extended by analogy to large unconventional gas developments like Beetaloo.

Climate impacts

- By omitting scope 3 emissions and treating appraisal emissions in isolation from the broader Beetaloo build-out, the EMP fails to provide the Commonwealth with the information required to assess whether this action contributes significantly to greenhouse emissions and associated impacts on MNES, including listed species, ecosystems and World Heritage/National Heritage values.
- Approving this EMP without a full lifecycle greenhouse assessment, including cumulative EP161/EP167/Tamboran emissions, would be inconsistent with Australia’s climate commitments and with the precautionary principle that underpins the EPBC Act.

For these reasons, the proposal should be referred and assessed as a controlled action under the EPBC Act, on the grounds of likely significant impact on listed threatened species and ecological

communities, listed migratory species, and water resources, and because of its substantial contribution to greenhouse gas emissions.

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5. Requested decision and conditions if not refused

- On the evidence in Appendices A–P, EMP STO8-1 does not demonstrate that environmental risks are reduced to ALARP or that cumulative impacts on land, water, biodiversity, climate and cultural values are acceptable, and should therefore be refused.
- If the NT Government nevertheless considers approval, it should at minimum:
    - **Refer** the proposal to the NT EPA for full environmental impact assessment.
    - **Recommend and support** EPBC referral to the Commonwealth.
    - **Prohibit** open evaporation ponds and long-term open storage of flowback and wastewater, require covered/closed systems, and require independent, publicly reported monitoring for the full suite of frack and drilling chemicals, including PFAS, in groundwater and surface water.

These steps are necessary to protect Tanumbirini's water, land, cattle, cultural values and biodiversity, and to ensure that decisions about Beetaloo gas are made transparently, on the basis of full and cumulative environmental and climate impacts.