ntepa Northern Territory Environment Protection Authority

Onshore Petroleum Activity – NT EPA Advice

ORIGIN ENERGY B2 PTY LTD ORI6-3 – ENVIRONMENT MANAGEMENT PLAN (EMP) FOR THE BEETALOO SUB-BASIN KYALLA 117 N2 MULTI-WELL DRILLING, HYDRAULIC FRACTURING AND WELL TESTING PROGRAM

BACKGROUND

The Minister for Environment has formally requested under section 29B of the *Northern Territory Environment Protection Authority Act 2012* (NT EPA Act) that the Northern Territory Environment Protection Authority (NT EPA) provide advice on all Environment Management Plans (EMPs) received under the Petroleum (Environment) Regulations 2016 (the Regulations).

That advice must include a recommendation on whether the EMP should be approved or not, supported by a detailed justification that considers:

- whether the EMP is appropriate for the nature and scale of the regulated activity to which the EMP relates (regulation 9(1)(b))
- the principles of ecologically sustainable development (regulation 2(a)), as set out in sections 18 to 24 of the *Environment Protection Act 2019* (NT)
- whether the EMP demonstrates 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 as low as reasonably practicable and acceptable (regulation 9(1)(c))
- any relevant matters raised through the public submission process

In providing that advice, the NT EPA Act provides that the NT EPA may also have regard to any other matters it considers relevant.

ACTIVITY

Subject	Description
Interest holder	Origin Energy B2 Pty Ltd
Petroleum interest(s)	Exploration Permit 117 (Kyalla EP117)
Environment Management Plan (EMP) title	Environment Management Plan Beetaloo Sub-Basin Kyalla 117 N2 Multi-well Drilling, Stimulation and Well Testing Program
EMP document reference	ORI6-3

Subject	Description
Regulated activity	This EMP proposes the construction of up to an additional two exploration and appraisal (E&A) petroleum wells at the existing approved Kyalla EP117 N2 site, located approximately 300 km south-east of Katherine in the Beetaloo Sub-basin. The regulated activities include: • drilling of the Kyalla 117 N2-2H and Kyalla 117 N2-3H horizontal E&A wells (which includes the vertical component of the well) • hydraulic fracture stimulation of the two (2) horizontal E&A wells • completion and testing of the two (2) E&A wells • suspension or decommissioning of the two (2) E&A wells • stimulation and well testing of the two (2) E&A wells • ongoing routine maintenance, monitoring and minor ancillary works associated with the above regulated activity The regulated activities do not require any new ground disturbance and existing site infrastructure and campsite facilities will be used. Site decommissioning and rehabilitation will occur on or before December 2024, consistent with the existing drilling and hydraulic fracturing EMP for Kyalla well site EP117 N2-1H, approved 13 August 2019. A rehabilitation plan is included as Appendix M.
Public consultation	Public consultation on the EMP was required under regulation 8A(1)(b) was undertaken from 14 November to 12 December 2020.

NT EPA ADVICE

1. Is the EMP appropriate for the nature and scale of the regulated activity (regulation 9(1)(b))

Information relating to the nature and scale of the regulated activity is provided in the EMP in a clear format. The technical works program includes drilling, hydraulic fracture and well testing of an additional two horizontal petroleum exploration wells during 2021 – 2024 on the existing EP117 N2 well site. On completion of well evaluation (testing hydrocarbon flows), the wells will either be suspended for future re-entry or decommissioned with permanent cement plugs, in accordance with the requirements outlined in the Code of Practice: Onshore Petroleum Activities in the Northern Territory (the Code).

There is no additional land clearing proposed in this EMP. Decommissioning and rehabilitation are planned for on, or before, December 2024. A rehabilitation plan has been developed for the activity, to return the disturbed land to an environment similar to the pre-disturbance conditions. Table 1 provides an overview of the key components of the regulated activity and worst-case scenario values.

Table 1: Key components of the proposed multi-well drilling, hydraulic fracturing and well testing

Component	Approved/existing (N2-1H)	Proposed (N2-2H and N2-3H)
AAPA certificate	Existing C2020/003	
Groundwater	Existing WEL GRF 10285	
Estimated groundwater usage (kL)	20,000	110,000
Petroleum wells	1	2
Monitoring bores	2	No change
Workforce	~60 personnel during drilling and hydraulic fracturing 2 – 6 personnel during well testing	
Traffic: • Peak traffic movements (per day) • Average traffic movements per day • Average traffic movements per day for remaining 6 months	44 10 – 15 (initial 3 months) 3 – 4 (for 6 months)	No change to average traffic movements
Proppant (tonne)	2,500 (11 stages)	2,700 – 7,500[1] (per well, for 10 - 30 stages)
Sump (m^3)	2,400	3,000 (increase sump by 600 m^3)
Drilling muds/cuttings (m^3)	1,100[2]	1,500[3]
Flowback generated (ML)	4.5[4]	18[5]
Waste drilling and completion fluids (ML)	3	2
Flowback/wastewater final predicted for treatment and offsite disposal (ML)	< 3.6	~2.6[6]
Truck movements: Load-out wastewater	104	~40[7]
Greenhouse gas emissions (tCO_2-e)	77,500 (maximum 12 months testing)	25,000 – 61,000 (maximum 3 – 6 months testing)
Rehabilitation (ha)	15.68[8]	15.68[9]

A number of well evaluation techniques will be conducted prior to, during and on completion of hydraulic fracture of the lower Kyalla Shale Source Rock (SSR). Key information and data required across the phases of the activity are outlined in previous NT EPA Advice.[10] These remain relatively

[1] Based on using a maximum of 250 t of proppant per stage up to a maximum of 30 stages per well.
[2] Represents the actual volume of muds/cuttings from the existing N2-1H well compared to predicted volume of muds was 750m^3.
[3] Represents predicted volume for two wells, noting the existing volume (1,100 m^3), includes the lateral failure that occurred on N2-1H well.
[4] Reduced recovery rate based on actual data from Kyalla N2-1H well and a predicted total of 15.5 ML of hydraulic fracturing water use.
[5] Mid-case prediction.
[6] Post water treatment (evaporation).
[7] The total truck movements have been revised down based on an updated water balance.
[8] Approved under the *Beetaloo Basin groundwater monitoring bore installation program, Kyalla EP117 N2 EMP* and *Beetaloo Basin Kyalla, Civil Construction EP117 N2 EMP NT-2050-15-MP-34*. This EMP includes a rehabilitation plan as Appendix M, which covers all rehabilitation on EP117.
[9] Ibid.
[10] Refer NT EPA Advice, approved 7 August 2020.

unchanged from the information and data provided for the drilling of petroleum well N2-1H, approved 13 August 2019 and include:

1) *Basis of well design:* Critical inputs include existing geological data from the N2-1H well; identification of downhole formations that need to be isolated (i.e. freshwater aquifers), hydrocarbon-bearing zones and saline units that could be encountered during drilling operations; the subsurface well objective (e.g. production and/or reservoir evaluation); the fracture gradient; in-situ fluid pressure (pore pressure) within a reservoir; orientation and separation of the vertical and horizontal stages; and other conditions that may affect the integrity of the well (formation fluid composition, stress regime, etc).

2) *Drilling:* The vertical and horizontal separation distance for each well is 10 m and 200 – 400 m, respectively, based on well tests and an updated Mechanical Earth Model (MEM) from the N2-1H petroleum well (Figure 1).From the kick-off point, each well will be drilled horizontally for a distance of between 1,500 – 2,800 m[11] in the targeted Kyalla shale zone.

3) *Wire logging:* Wireline logging during the drilling phase is proposed for the lower (deeper) target formations within the production hole section of the well, to provide continuous measurement of the formation properties through microseismic mapping of fracturing extent (height, length, and orientation) for each hydraulic fracture stage. Analysis of wireline logging data assists with the decision-making during drilling. Properties measured during wire line logging, include:
    - electrical properties (resistivity and conductivity)
    - aspects of the reservoir fluids and rocks, such as their natural radiation signature and porosity
    - assessment of geohazards – e.g. cave-ins, faults, water invasion
    - sidewall coring, a process that allows small cores/rock samples to be cut from the side of the hole using wireline tools.

4) *Diagnostic Fracture Injection Testing (DFIT):* A DFIT is conducted once the well is complete and the overall integrity of the well has been confirmed, to obtain information on reservoir properties to help determine subsequent hydraulic fracture design parameters in a reservoir modelling process. This test involves injecting small volumes (<10,000 L) of water, with salts (mostly NaCl) and biocide, into the formation to create small fractures, allowing the resulting pressure to fall naturally. Proppant (sand) is not used during the DFIT; hence the fracture relaxes and closes naturally when the pressure is released.

5) *Hydraulic fracture stimulation*: This will involve perforating the 5 ½" steel casing horizontal section in a series of 10 - 30 stages, for each well along the horizontal production casing. Hydraulic fracturing activities will not occur until the integrity of a well has been confirmed. Real-time continuous monitoring of the pumping pressure is conducted during hydraulic fracturing operations to ensure the Maximum Allowable Operating Pressure (MAOP) of 10,000 psi is not exceeded. In addition, anomalous pressure behaviour in the well annulus at surface is also monitored in real-time. The fracture network created in the Kyalla shale during the pumping operation is carefully monitored at the surface using pumping volume and pressure and a range of other measures in the control room of the operation. Each hydraulic fracturing stage will be plugged in the well bore prior to perforation and pumping of the subsequent stage and is anticipated to take one day to complete.

6) *Well completion and extended production test (EPT):* Subject to a successful reservoir outcome (e.g. good gas flow rates), the well will be flow tested for an EPT period of approximately 3 months to 6 months. The EPT will consist of characterising and measuring the gas qualities and quantity and any liquid hydrocarbon production as well as other "reservoir" characteristics.

[11] The maximum horizontal extent of the proposed N2-3H well is restricted subject to the conditions of the Aboriginal Areas Protection Authority (AAPA) Certificate C2020/003.

Flowback fluid wastewater will be directed through a separator at surface to capture wastewater and separate gas to flare.

7) *Well site closure operations:* On completion of technical evaluation of the results from the hydraulic fracturing activity, each exploration well will either be suspended for future re-entry, or in a non-success case, a decision made to decommission the exploration well with permanent cement plugs in accordance with the Code. At the completion of operations all surface infrastructure will be removed (excluding the well head). Each well will be suspended on completion of the test program.

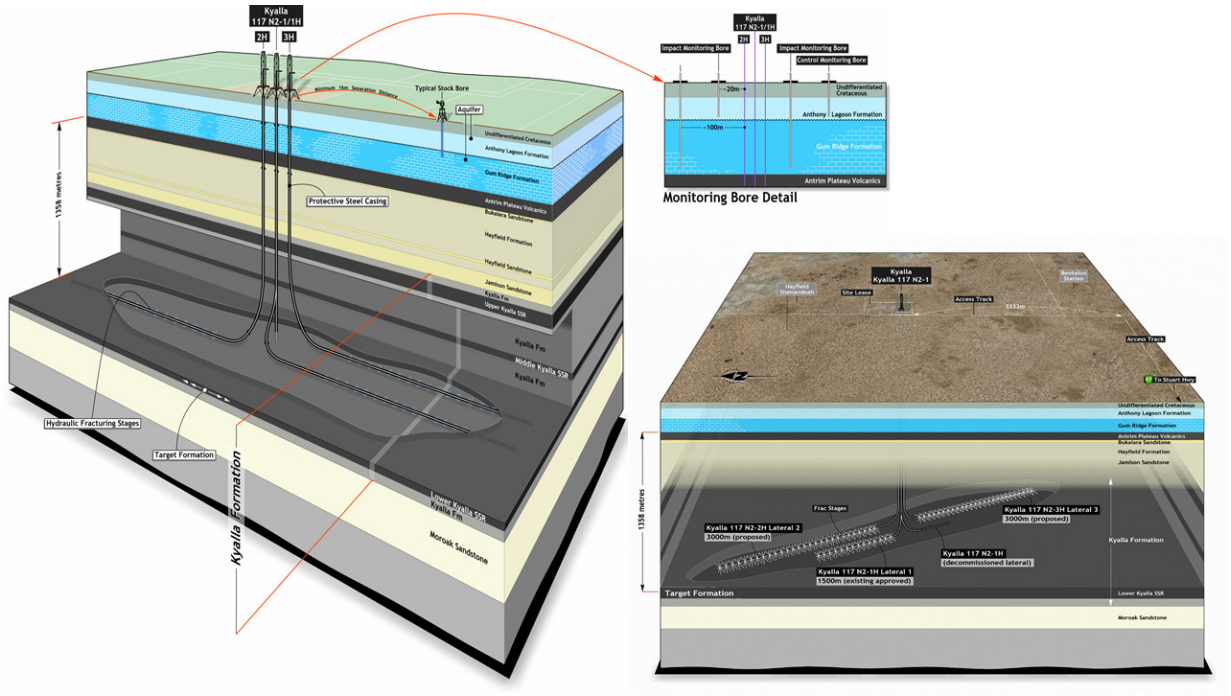

Figure 1: Kyalla EP117 multi-well configuration, including subsurface perspective

1.1 Sub-surface geology

The stratigraphic formations intersected by the petroleum wells have been adequately described in the EMP, informed by 9,500 km of 2D seismic data used to screen for large scale, regional faults or structures prior to the finalisation of any exploration well location. Current data for the broader Beetaloo exploration area and the drilling of the Kyalla N2-1H well indicates there are very few major faults present and that the strata within the Basin (i.e. away from the steep flanks) are relatively gently dipping.[12]

Planning and design of the petroleum well construction to isolate and protect the regional aquifers is informed by: data gained from stratigraphic boreholes and groundwater bores in the area; offset geological data from the control monitoring bore installed downstream of the N2-1H well; analysis of the gamma ray signature, and correlation with the basin-wide Gum Ridge Formation gamma ray signature; and, onsite analysis of the drill cuttings from N2-1H. The existing groundwater monitoring bores are installed to the base of the regional Cambrian Limestone Aquifer (CLA) system, in compliance with the Code.

[12] Scrimgeour I. (2016) *Summary of current knowledge of petroleum geology, shale gas resources and exploration in the Beetaloo Sub-basin*. Information Provided by the Northern Territory Geological Survey to the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory.

1.2 Activity scope and duration

The EMP clearly describes the scope of the activity and its duration. The duration of the drilling, hydraulic fracture stimulation and testing activities is expected to be approximately 20 months (indicative), subject to approval of the regulated activity and seasonal access. On completion of exploration well drilling and technical evaluation the exploration well will either be suspended for future re-entry, or in a non-success case, a decision made to decommission the exploration well with permanent cement plugs in accordance with the Code.

Estimations of consumables (e.g. water, sand and chemical additives) discussed in the EMP are based on a maximum 30 stage hydraulic fracturing program for each horizontal well. Water and sand make up the bulk of the materials of the hydraulic fracturing fluids per stage. The preliminary hydraulic fracturing design will involve pumping approximately 1.5 ML of fluids and 180 – 250 tonnes of proppant per stage. The final designs will be determined after the Diagnostic Fracture Injection Test (DFIT) is performed. The EMP includes a breakdown of the groundwater take, with the bulk of the water use occurring during drilling and hydraulic fracturing (70 – 100 ML total). Total volume of flowback fluid wastewater from hydraulic fracturing required for treatment and offsite disposal is estimated to be 2.6 ML (after evaporation).

The existing campsites will be used for the activity. A smaller crew will be required during the longer well completion and testing stage. Peak projected vehicle movements is 44 vehicles per day during the demobilisation of equipment from site.

Information on the location and scale of the proposal is provided in the EMP. The existing environment has been adequately described through previous baseline surveys and is sufficiently understood. There are no areas of high conservation value or cultural significance in proximity of the regulated activity. The EMP includes an impact and risk assessment (Appendix K) based on information gathered during environmental baseline surveys and experience drilling and hydraulic fracturing petroleum well N2-1H (72 total risks). Mitigations outlined in the risk register, Appendix K, are classified based on the hierarchy of controls, and the impacts and risks should be reduced to an acceptable level through the proposed mitigation and management measures. The potential impacts and risks of the regulated activity have been identified and relevant environmental outcomes, performance standards and measurement criteria have been provided in the EMP. Where appropriate the NT EPA has also provided advice relating to Ministerial conditions at the end of this advice.

1.3 Wastewater Management

The EMP identifies wastewater as water generated mainly from drilling, hydraulic fracture stimulation, well testing, dust suppression and camps. A large proportion of the volume of wastewater generated will be evaporated during operations. At the end of operations, the remaining predicted 2.6 ML of wastewater will be removed offsite to a licensed facility for treatment and disposal (after evaporation). Enclosed tanks will be used as the primary wastewater storage facility, with enough enclosed tank capacity to store all wastewater on-site. The EMP includes contingencies to transport wastewater offsite prior to the onset of the wet season or to management onsite storage capacity.

Flowback fluid generated during hydraulic fracturing and well testing will be held on site and involves the use of two above ground enclosed tanks of 3.5 ML capacity each, and one 2.9 ML above ground open evaporation tank to reduce the amount of wastewater feasibly required to be disposed of off-site. Estimated recoverable flowback based on the EP117 N2-1H well is 30 % (~ 4.5 ML – 13.5 ML per well). This is necessary during the early stages of exploration when onsite treatment and recycling is unfeasible. Large pumps will be installed, capable of transferring the entire volume of a single open tank to closed tanks within eight hours. Pumping capacity is approximately 16,000 L per minute (up to 23 ML per day). All flowback fluid will be transferred to enclosed/covered tanks within 72-hours when a significant rainfall event is predicted.

Flowback fluid that is not evaporated during operations will be stored in enclosed above-ground, double-lined tanks with leak detection. DEPWS reports on laboratory analysis of a suite of more

than 60 analytes tested in flowback fluid from two previously hydraulically fractured petroleum exploration wells in the Beetaloo sub-basin are available at the DEPWS Onshore Petroleum webpage. Contaminants of potential concern in the flowback fluid, due to their persistence and higher toxicity in the environment, including heavy metals (such as arsenic, cadmium, chromium and mercury), polyaromatic hydrocarbons (such as benzo-a-pyrene) were all below limits of reporting. The results are similar to those reported in major studies of flowback from shale plays in North America (Hayes, 2009; Gandhi *et. al*, 2018).[13] These studies concluded that spills of flowback to ground were unlikely to pose a significant risk to aquatic ecosystems provided they were contained and cleaned up promptly. Offset distances to protected or conservation areas from the EP117 N2 site are over 65 km. The residue following evaporation of flowback fluid is considered a listed waste and therefore must be managed under listed waste provisions of the *Waste Management and Pollution Control Act 1998*.

Consistent with the Code, all wastewater will be treated via an evaporation tank to reduce the amount of water stored in covered tanks and the subsequent impacts of transporting large volumes offsite for treatment and disposal.

1.4 General compliance with Code

The EMP demonstrates how the interest holder will comply with relevant requirements of the Code in undertaking this regulated activity. This includes a list of applicable ISO/API standards that have been adopted for the selection of materials for use in well construction; hydraulic fracturing program environmental controls and related engineering controls contained in the Well Operations Management Plan (WOMP); a summary of which is provided in the EMP (Appendix G). The risk assessment provided in the EMP (Appendix K) cross references relevant sections of the Code that apply to the mitigation and management measures to enable the reviewer to identify and confirm that the proposed drilling, hydraulic fracturing and well testing activities comply with the Code. The EMP also provides the following plans, which are compliant with the Code:

- Chemical Risk Assessment of chemicals to be used in the hydraulic fracturing activity
- Wastewater Management Plan – including management of flowback wastewater
- Spill Management Plan – including spill risk assessment and response strategy
- Emergency Response Plan
- Methane Emissions Management Plan
- Weed Management Plan
- Bushfire Management Plan
- Stakeholder Engagement Plan

All groundwater monitoring data is available from the DEPWS website.[14] Water is sampled on a quarterly basis and analysed at a NATA accredited laboratory for an array of analytes, including Total Dissolved Solids, chloride, electrical conductivity, boron, strontium, barium, naturally occurring radionuclide material (NORM) and dissolved methane. As required in the Code and the Preliminary Guideline: Groundwater Monitoring Bores for Exploration Petroleum Wells in the Beetaloo Sub-basin, the interest holder must undertake ongoing groundwater monitoring for three years from the approval date of the EMP, to demonstrate 'no change' to groundwater quality.

The level of detail and quality of information provided in the EMP is sufficient to inform the evaluation and assessment of potential environmental impacts and risks, and meets the EMP approval criteria under Regulation 9(1)(b).

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[13] Hayes, T. 2009. *Sampling and Analysis of Water Streams Associated with the Development of Marcellus Shale Gas*, Final Report, 31 December 2009
Gandhi, H, Sadiq, R, Hu, G, and Hewage, K. 2018. Ecological Risk Assessment of Accidental Release of Flowback Water: A Conceptual Framework. *Human & Ecological Risk Assessment* 24(2): 398-426.

[14] Refer https://denr.nt.gov.au/onshore-gas/onshore-gas-in-the-northern-territory/industry-compliance-and-reporting/groundwater-monitoring-results

2. Principles of ecologically sustainable development (regulation 2(a))

2.1 Decision-making principle

The EMP adequately assesses the environmental impacts and risks associated with the regulated activity and outlines appropriate avoidance and mitigation measures. The regulated activity will increase activity intensity at the Kyalla EP117 N2 site, while constraining the exploration to one location. In this context, environmental considerations have been considered through the use of the existing well site to minimise impacts. The outcomes of this regulated activity will continue to inform decision-making about longer-term petroleum activities in the Beetaloo Sub-basin.

The impacts and risks associated with the drilling and hydraulic fracturing program have been assessed. Of the 72 risks identified, 64 are assessed as "low" if carried out in accordance with the mitigations and controls proposed in the EMP. Wet season contingencies and controls are proposed to mitigate potential erosion and sediment impacts associated with wet season transport and traffic impacts on major arterial roads. These controls have been assessed by NT Government agencies and deemed adequate.

The increased drilling sump design and capacity to 3,000 m^3 (if required) complies with the Code to conservatively accommodate a 1:1,000 year rainfall occurrence during the wet season. A wet season and dry season freeboard is applied to all waste storage infrastructure of 1,300 mm and 300 mm, respectively.

The interest holder has demonstrated ongoing stakeholder engagement in the EMP as required by the Regulations with identified, directly affected stakeholders. The EMP was also made available for public comments (14/11/2020 – 12/12/2020).

2.2 Precautionary principle

The NT EPA considers there is a low threat of serious or irreversible damage from the regulated activity. The interest holder's investigations into the physical, biological and cultural environment provide a satisfactory scientific basis to assess potential environmental impacts and risks, and to identify measures to avoid or minimise those impacts and risks and address scientific uncertainty.

The risk assessment clearly classifies the hierarchy of controls for the mitigations applied to each risk (e.g. eliminate, substitute, engineering, administrative, personal protective equipment). Uncertainty in relation to the environmental features was assessed, with no areas of environmental uncertainty identified. The EMP outlines the interest holder's investigations into the physical, biological and cultural environment and demonstrates a sound understanding of the environment at the location, providing a satisfactory scientific basis to assess potential environmental impacts and risks for the activity, and to identify measures to avoid or minimise those impacts and risks.

The risks of drilling and hydraulic fracturing over the wet season are well understood. The EMP demonstrates adherence to the Code that establishes best practice management measures for operations, as set out in the risk assessment and revised Wastewater Management and Spill Management Plans. The EMP includes the assessment of impacts and risks for wet season operations and management strategies, including measures such as halting activities and ongoing inspection of erosion and sediment control measures and access roads, if there is significant rainfall.

There are internationally recognised standards and established management measures in well design, operation and well integrity monitoring to ensure aquifer protection; these are reflected in the mandatory requirements of the Code. The surface separation distance (10 m) is calculated from the hole centre to hole centre and is selected to accommodate the rig package and future well interventions. Sub-surface separation distances will be determined based on the Kyalla N2-1H well test results and updated MEM to ensure the stimulated zones between wells are not connected during stimulation. During drilling, specialised Global Positioning System (GPS) drill bits monitor the downhole position and trajectory of the well to eliminate the risk of sub-surface collision between wells.

Measures for managing risks during wet season operations include commitments to daily inspections of chemical and waste storages to ensure any leaks or spills from chemical and waste storage are prevented or promptly identified; 1,300 mm freeboard on evaporation wastewater tanks and the sump to accommodate a 1:1000 year Average Recurrence Interval (ARI) for the duration the sump is in operation (i.e. sufficient freeboard for an entire wet season; weekly update of wastewater balance and storage curves to ensure sufficient freeboard in compliance with the Code; bunding of all chemical storage areas, including covers (where safe and appropriate) to prevent rain ingress and bund overflows; use of enclosed tanks as the primary wastewater storage with sufficient capacity to store all wastewater on-site; no transportation of wastewater or chemicals will be undertaken during the wet season unless a risk assessment is undertaken that demonstrates the risk is ALARP and acceptable (as per the Code); stormwater will be retained on-site via the sediment retention pond prior to release; fully bunded well pad area with containment capacity of approximately 9.6 ML.

The NT EPA is of the view that the precautionary principle has been considered in assessing the regulated activity and has not been triggered due to the low threat of serious or irreversible damage existing and the presence of a satisfactory scientific basis to assess potential impacts and risks. In addition, the existing wide-wide environmental monitoring commitments contained in the EMP are compliant with the Code and should provide measureable performance measures to ensure that the environmental outcomes are met.

2.3 Principle of evidence-based decision-making

The EMP includes additional Tier 2 toxicity screening of the cumulative risks to workers from chemicals of potential concern through exposure pathways such as aboveground storage and handling of flowback water. The information in the EMP confirms that the calculated risks associated with chemicals of potential concern in flowback water, drilling fluids, chemical tracers and combination hydraulic fracturing fluid systems are considered low and acceptable. The information in EMP further indicates there are no potentially complete exposure pathways from hydraulic fracturing chemicals to impact potable groundwater sources in proximity to the regulated activity. Environmental mitigation controls include:

- physical vertical separation distances between the aquifer and target formation to prevent any migration of stimulation fluid to aquifers (approximately 1,400 m)
- 11.4 km horizontal separation distance between the exploration well and the closest groundwater extraction bores
- use of double lined wastewater tanks with leak detection
- implementation of spill management plan
- use of enclosed wastewater tanks with wet and dry season freeboard
- mandatory secondary containment

The EMP aligns with the requirements of the Code, including tracking of water use and wastewater generation and movement. The NT EPA has assessed the potential for spills from chemicals and hydrocarbons (e.g. diesel) stored in designated bunded areas at each location. The mitigations described in the EMP include existing bunding around chemical storage areas, existing well/lease pad bunding with a holding capacity of 9.6 ML, containment of hydrocarbons in double-lined diesel storage tanks and spill prevention and response procedures for hazardous spill prevention, monitoring, assessment, response and clean-up. The NT EPA has recommended the interest holder provide DEPWS with a written report of any contaminant incidents exceeding 200 litres, within 24 hours of the incident being detected.

The proposed environmental outcomes are likely to be achieved based on the best available information on the nature and scale of the activity, and the environment in which the regulated activity will be conducted. The studies undertaken by the interest holder to inform the EMP affords the interest holder with a detailed and reliable knowledge of the potential environmental impacts and risks and the most appropriate measures for mitigation of those impacts and risks.

The NT EPA is of the view that the evidence-based decision-making principle has been considered in assessing the regulated activity and that in the circumstances, decisions can be based on best available evidence that is relevant and reliable.

2.4 Principle of intergenerational and intra-generational equity

The potential environmental impacts and risks associated with the regulated activity can be adequately avoided or managed through the management measures and ongoing monitoring programs proposed in the EMP.

Cumulative GHG emissions generated by the regulated activity are not considered significant when considering the regulated activity will result in an overall increase in NT GHG emissions of approximately 0.4%, based on six (6) months flaring. The EMP includes an assessment of the maximum combined cumulative greenhouse gas emissions from the regulated activity and previously approved regulated activities, which are approximately 184,000 tCO_2-e over a 2 – 3 year period. This represents approximately 1.2% increase in annual Northern Territory emissions reported for 2018-19.[15]

Protection of cultural interests is achieved through compliance with the requirements of Authority Certificates issued by the Aboriginal Areas Protection Authority under the *Northern Territory Aboriginal Sacred Sites Act 1989* (NT) and the previously completed archaeological assessment at the site to avoid archaeological heritage impacts. The regulated activity is subject to requirements of the AAPA Certificate C2020-003. Appropriate measures are in place for the management of items of heritage value should they be discovered through implementation of the "unexpected heritage finds procedure".

The NT EPA considers that environmental values will be protected in the short and long term from the activities outlined in the EMP and that the health, diversity and productivity of the environment will be maintained for the benefit of future generations.

2.5 Principle of sustainable use

Exploration activities are necessary to enable commercial appraisal of resources. In the absence of reliable data regarding the shale resource, exploration will take a number of years to complete, in order to assess the viability of the resource prior to production.

Cumulative impacts of groundwater extraction have been assessed. The interest holder has a groundwater extraction licence GRF10285 with a maximum water entitlement of 175 ML per annum from the Gum Ridge Formation. The anticipated water demand for this regulated activity is 75 – 110 ML per annum, which is less than the interest holder's maximum water entitlement. Annual cumulative groundwater extraction from the Gum Ridge Formation from all licenced bores (approximately 850 ML) is currently well below the storage ranges of 1,766,000 to 3,532,000 GL.[16]

A conservative estimate of greenhouse gas emissions likely to be generated by the regulated activity is approximately 25,000 – 61,000 tCO_2-e. The bulk of the predicted emissions are generated during the 3 – 6 months of flaring from well testing. Flares will be designed and operated in compliance with the US EPA 40 CFR § 63.11 to achieve a 98% combustion efficiency. The NT EPA notes that the Government has committed to implementing all recommendations of the Hydraulic Fracturing Inquiry, including that the NT Government seeks to ensure there is no net increase in the lifecycle GHG emissions emitted in Australia from any onshore petroleum produced in the NT.

To support the NT Government's commitment, the NT EPA has provided advice that the interest holder provide to DEPWS annual actual scope 1 and scope 2 greenhouse gas emissions reported under the National Greenhouse Energy Reporting Scheme (NGERS) versus predicated emissions in the EMP.

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[15] DISER 2020. State Greenhouse Gas Inventory. https://ageis.climatechange.gov.au/SGGI.aspx.

[16] Tickell, SJ & Q Bruwer, 2019. *Georgina Basin Groundwater Assessment: Daly Waters to Tennant Creek.* Water Resources Division, Report 17/2017 (Version 2, April 2019).

The NT EPA is of the view that the sustainable use principle has been considered in assessing the regulated activity.

2.6 Principle of conservation of biological diversity and ecological integrity

Site selection for conduct of the regulated activity was informed by a previous detailed ecological assessment, which covered a much larger area than that required to be cleared of vegetation, thereby enabling the interest holder to establish one lease pad to support a multi-well configuration and minimise impacts from additional land clearing.

The proposed location for the regulated activity does not include groundwater dependent ecosystems; nor is it within proximity to a declared ecological community under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*.

The regulated activity poses a low risk to the ecosystem within the Sturt Plateau bioregion. Given the relatively small area of impact (approximately 16 ha), and the very large area of similar habitat within the region, the regulated activity does not pose a significant risk to any regional populations of threatened species. This EMP does not address land clearing or other civil works which have already been approved via a separate EMP (Origin Beetaloo Basin Civil Construction EP117 N2 EMP, approved 6 June 2019). Three threatened species were identified as having a 'medium' likelihood of occurrence within the regulated activity area. Due to the management strategies outlined in the EMP and the relatively small area of impact, it is unlikely that the regulated activity will pose a risk to the identified threatened species. Impacts and risks to flora, fauna, and ecosystems have been mitigated to an acceptable level.

The DEPWS Flora and Fauna Division is satisfied the proposed activities do not pose a significant risk to threatened species or significant habitats and vegetation types. Further, that avoidance and mitigation measures identified in the EMP are adequate to reduce risks from, for example, vehicle-strike, dust, erosion and/or spills to as low as reasonably practicable, in relation to potential impacts on biodiversity.

The EMP outlines measures to minimise impacts on affected environmental values, including the management of threatening processes such as erosion, weeds and fire through implementation of existing management plans, monitoring and corrective actions. Where relevant, management measures for the aforementioned threatening process are consistent with the requirements of the Code, the *NT Land Clearing Guidelines*, the *Weed Management Planning Guideline: Onshore Petroleum Projects* and Commonwealth threat abatement plans and advice. Specific precautions to ensure interaction with wildlife is avoided are included in the EMP, including installation of fencing around the flare pits, appropriate storage of waste, implementation of a fauna interaction log, ongoing remote camera monitoring around the well/lease pad and use of speed limits and avoidance of driving on unsealed roads after significant rainfall.

The NT EPA considers that implementation of, and compliance with, the EMP will ensure the conservation of biological diversity and ecological integrity is not impacted by the regulated activity.

2.7 Principle of improved valuation, pricing and incentive mechanisms

The interest holder is required to prevent, manage, mitigate and make good any contamination or pollution arising from the regulated activity, including contamination of soils, groundwater and surface waters through accidental spills.

All stages of the regulated activity, including disposal of waste, commercial purchase of groundwater, and progressive rehabilitation of all disturbed areas to an acceptable standard, are at the cost of the interest holder. The interest holder is required to provide an adequate environmental rehabilitation security bond to indemnify the NT Government. This is based on an assessment by DEPWS of the estimated rehabilitation cost, to be supported by independent contractor quotes' submitted by the interest holder.

The NT EPA is of the view the principle of improved valuation, pricing and incentive mechanisms has been considered in assessing the regulated activity and is based on the interest holder bearing any environmental costs for the activity.

3. Environmental impacts and risks reduced to a level that is as low as reasonably practicable (ALARP) and acceptable (regulation 9(1)(c))

The interest holder has undertaken identified measures to avoid impacts on environmental values, informed by a baseline studies, surveys and data derived from the drilling and hydraulic fracturing of Kyalla petroleum well N2-1H.

The EMP demonstrates a systematic identification and assessment of environmental impacts and risks associated with the regulated activity. The key potential environmental impacts and risks considered in the EMP are:

- loss in long-term soil productivity and viability from cleared areas (e.g. access tracks, lease pads and camp pads) from contamination or physical disturbance of soils
- impacts to surface waterways causing changes in water quality and decline in ecological function from failure of a flowback storage tank, overtopping of waste storage facilities or a transportation accident resulting in a release of contaminants
- groundwater contamination and over-extraction from exploration activities degrades environmental value(including GDE's) and impacts pastoralist water extraction
- impacts to high valued habitats and threatened flora and fauna from, for example contamination, vehicle strikes, entrapment, etc
- impact on local air quality predominantly from dust and particulate matter generated from accidental fires
- environmental nuisance and impacts to communities and pastoralists, from, for example, noise, light pollution, the introduction and spread of weeds in the area, or particulate matter generated from accidental fires
- decline in environmental values and disturbance of sacred sites, from, for example, unauthorised access to sacred sites, accidental fires, or structural failure of a flowback tank

The EMP also considers cumulative impacts to groundwater, flora and fauna, and greenhouse gases and concludes the cumulative impacts are not significant.

The EMP has considered the hierarchy of controls (elimination, substitution, engineering, administration) and provided demonstration of why the controls to be implemented are considered ALARP and acceptable. Of the 72 environmental risks identified by the interest holder, 64 are considered 'low' risk, and therefore are ALARP and acceptable. The remaining 8 risks are considered 'medium' and the interest holder has included mitigations that can/will be implemented such that the risks will therefore be managed at levels that are ALARP and acceptable.

Key risk mitigations include:

1. *Impacts to soils resulting in loss of ecological function and soil productivity:* the interest holder has committed to, for example, secondary containment of all chemicals, fuels and hazardous materials; well/lease pad bunding to a capacity of 9.6 ML (equivalent to the loss of containment of two wastewater storage tanks); concrete lining of each well cellar to contain drilling fluids, including pumps to prevent overflow; impermeable secondary containment liners (including the drilling sump) with a permeability of less than 6×10^{-14} m/s; containment of drilling fluids in wastewater tanks (and sumps) designed and engineered to AS3990, AS 1170.1 and AS1170.2; condensate storage tanks compliant with AS1692 and double-lined; drilling sump designed to management multi-well inventories; wastewater tank liner with impermeable membrane with coefficient of permeability of less than 10^{-9} m/s, 120N puncture resistance and 49N tear resistance; flare pit lined with earthen cover and freeboard maintained to prevent loss of containment/overflows; enclosed tanks to have vents and ignition exclusion zones to eliminate the build-up of explosive gasses; access track maintained to allow periodic wet weather access.

The ‘medium’ risk ranking is based on the likelihood being considered ‘likely’, but the consequence of the event occurring being considered ‘minor’ and localised.

2. *Impacts to surface waterways causing changes in water quality and decline in ecological function:* in addition to the mitigations outlined in 1 above, the interest holder has committed to flowback wastewater storage within enclosed tanks to prevent rain ingress; wastewater stored in open treatment tanks and the sump to have a 1:1000 ARI wet season freeboard of 1,300 mm and dry season freeboard 300 mm, (which are conservative freeboard estimates, as no allowance has been made for evaporation); the transfer and storage of wastewater within enclosed tanks 8 hours prior to a significant rainfall event occurring (i.e. greater than 300 mm falling in 4 days); erosion and sediment controls in place, maintained and fully functional. Due to the lack of major water courses, the impact is likely to "minor", locally restricted and reversible. The ‘low’ risk ranking is based on the likelihood being considered ‘remote’, but the consequence of the event occurring ranging from ‘minor’ to ‘serious’.

3. *Groundwater contamination and over-extraction:* the interest holder has committed to adhere to the requirements of the Code, and use low toxicity, water-based drilling fluids; quaternary casing barriers and specifically engineered cement to protect aquifers informed by the drilling of the Kyalla N2-1H well; continuous collision protection using GPS tracking of the drill bit to detect and respond to vertical and horizontal well deviations during drilling; cement plugs to isolate hydrocarbon zones from aquifers as a part of well abandonment; monitoring of the casing annuli pressure post well abandonment to ensure formation isolation; geomechanical modelling from the Kyalla N2-1H well stimulation to manage and contain fracture propagation; 1 km mandatory separation between exploration wells and water extraction bores; and continuous flow meters to monitor take and water balance implemented to ensure compliance with water extraction licence.

   Through the adoption of the mandatory controls in the Code for well construction, aquifer isolation, well integrity verification, monitoring and reporting, the likelihood of groundwater contamination is considered ‘highly unlikely’ to ‘remote’. The ‘low’ risk ranking is based on the likelihood being considered ‘highly unlikely’ to ‘remote’, but the consequence of the event occurring ranges from ‘minor’ to ‘serious’.

4. *Exploration activities cause impacts to high valued habitats, and threatened flora and fauna:* in addition to the mitigations outlined in 1 and 2 above, the interest holder has committed to daily monitoring of bushfires in the region during periods of high fire danger; no flaring during periods of total fire ban; 45 m separation distances between flares and surrounding vegetation; horizontal flaring into a lined pit, enshrouded by shipping containers and operation of a water curtain during flaring; a fenced sump to reduce fauna access; lease pad fenced to prevent stock access; ongoing remote camera monitoring of the well/lease pad and reporting of results to DEPWS; vehicle movements to avoid driving at night; storage and disposal of camp wastes to prevent scavenging by fauna; progressive rehabilitation in those areas not required for future use, inclusive of deep ripping to reduce the effects of compaction and preservation of topsoil and cleared vegetation for respreading (including rehabilitation monitoring to track rehabilitation progress); equipment and vehicles to be washed-down and to have a Biosecurity Declaration Certificate prior to access to site. The ‘medium’ risk ranking is based on the likelihood being considered ‘unlikely’, but the consequence of the event occurring being considered ‘serious’.
5. *Impact on local air quality:* the interest holder has committed to, for example, using flares designed and operated in compliance with the US EPA 40 CFR § 63.18 to achieve a volatile organic compound combustion efficiency of 98%; reporting all greenhouse gas emissions from venting under the NGERS; drilling overbalanced to reduce the inflows of hydrocarbons; blow out prevention to manage well failure and uncontrolled gas influxes; preferential offsite transport of condensate; installation of multiple barriers during well suspension/operation, including downhole suspension plugs, suspension fluid and surface valves; weekly inspection of flares to rectify excessive smoke production; annual fire frequency mapping using the Northern Australia Fire Information fire history database; dust suppression using water carts. The ‘medium’ risk ranking is twofold based on a) the likelihood from fire being considered ‘unlikely’, but the consequence of the event occurring being considered ‘serious’; and b) the likelihood from dust being considered ‘likely’, but the consequence of the event occurring being considered ‘minor’.

6. *Environmental nuisance and impacts to communities and pastoralists:* the interest holder has committed to ignition sources being placed outside of the hazardous areas; firebreaks have been constructed around the lease pad and camp site; busses and charter flights used to minimise light vehicle traffic; the site is located 20 km away from the Stuart Highway and the nearest homestead, reducing noise, dust and light pollution; helicopter movements are undertaken in consultation with the landholder and restricted to the wet season when landholder activities are minimal; existing weed management plan implemented, including corrective actions. The 'medium' risk ranking is based on the likelihood being considered 'unlikely', but the consequence of the event occurring being considered 'serious'.
7. *Decline in environmental values and disturbance of sacred sites or culturally sensitive areas:* the interest holder has committed to ignition sources being placed outside of the hazardous areas; firebreaks have been constructed around the lease pad and camp site; wastewater tanks and sumps designed and engineered to AS3990, AS 1170.1 and AS1170.2; enclosed tanks have vents and ignition exclusion zones to eliminate the build-up of explosive gasses; all wastewater tanks to have non-return valves to prevent multiple tank draining in the case that one tank fails; weekly tank and sump integrity inspections; inductions to prevent unauthorised access to sacred sites. The 'medium' risk ranking is based predominantly on the outcome of a fire event. Although likelihood is considered 'highly unlikely', the consequence of the event occurring is considered 'serious'.

The NT EPA considers that all reasonably practicable measures will be used to control the environmental impacts and risks, considering the level of consequence and the resources needed to mitigate them, and the nature, scale and location of the regulated activity. The NT EPA considers that the environmental impacts and risks will be reduced to a level that is ALARP and acceptable, considering the sensitivity of the local environment, relevant standards and compliance with the Code.

4. Relevant matters raised through public submissions

Public consultation on the EMP was required under regulation 8A. The EMP was made available for public comment for 28 days from the 14 November to 12 December 2020, on the DEPWS website, in the NT News and the Katherine Times. A total of 364 public submissions were received with 359 (99%) of the submissions originating from the advocacy website Do Gooder. A total of 126 submission (35%) originated from the NT, noting 86 submissions (24%) did not identify their origin. In summary, the submissions received did not identify new issues that have not already been addressed in this, or previously approved EMPs. All submissions were opposed to onshore petroleum development and raised substantially similar issues as those addressed through the *Scientific Inquiry into Hydraulic Fracturing in the Northern Territory* (HFI) and subsequent implementation of the 135 HFI recommendations.

Table 1: Issues raised in public submissions

Theme	Overview of issue raised
Flora and fauna (environment)	• toxicity of hydraulic fracturing chemicals to aquatic life • ingestion of contaminated wastewater/materials impacting, for example, reptiles, birdlife in general and threatened species – e.g. Gouldian Finch • potential ignition sources and flaring on total fire ban days
Social and cultural	• impacts to public and tourism from increased traffic • concerns as to the extent of stakeholder engagement • damage to cultural heritage sites, land and waters
Climate change	• greenhouse gas emissions
Water	• potential impacts to Lake Woods downstream from the site from spills and/or loss of containment, particularly during the wet season resulting in contamination of soils • contamination of groundwater caused by well corrosion • impacts to the Moroak Sandstone

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Waste	• use of open tank wastewater storages • transportation of toxic waste interstate, as opposed to treatment options in the NT
Human health	• toxicity of chemicals including: acute toxicity, respiratory irritation, tissue damage, burns, and cancer
Regulation and compliance	• fragmented, piecemeal approvals • development by stealth • lack of transparent and scientific scrutiny

1. *Flora and fauna:* Submissions raised concerns with animal welfare, increased bushfire risk and interactions with various aspects of the regulated activity, including for example, contaminated water, open tanks and flaring. The EMP appropriately identifies the risks and potential impacts raised in these submissions. The interest holder has implemented routine remote camera monitoring to log fauna interactions with wastewater tanks and the drill cuttings sump, and is committed to implementing additional controls if required. Preliminary results of the remote camera monitoring indicate minimal impacts fauna resulting in long-term impacts to populations of general or listed threatened species. The EMP has considered the potential of increased feral pest species impacting native fauna, as well as the threat that open wastewater facilities pose to general and listed threated fauna species. Potential pathways that would lead to an increase in the number of feral pest species, such as access to food and semi-permanent open water sources have been assessed in the EMP as 'low' based on the mitigation controls currently implemented on site and discussed previously in section 3.

   The EMP includes mitigations for ignition sources such as, horizontal flaring into a lined pit, enshrouded by shipping containers and operation of a water curtain during flaring. The distance between the bunded flare pit and vegetation is over 45 m. The interest holder has committed to not flaring or lighting fires during periods of total fire bans in accordance with the *Bushfires Management Act 2016*.

2. *Social and cultural:* Public submissions raised concerns about social aspects such as stakeholder engagement, especially the adequacy of the stakeholder engagement with neighbours, local businesses and tourism; and, damage to cultural heritage sites, land and waters. The EMP provides details of stakeholder engagement that meets regulation 7 and Schedule 1, Clause 9 of the Regulations (Section 5 and Appendix P). Stakeholder and community engagement logs (Appendix Q and Appendix R) demonstrate that stakeholders did

not raise objections about environmental impacts of the proposed activity that required specific changes from the interest holder.

There is no additional land clearing proposed in this EMP and appropriate measures are in place for the management of items of heritage value should they be discovered through the existing "unexpected heritage finds procedure". The EMP adequately identifies how the potential impacts and risks associated with land and water will continue to be mitigated. The risk assessment in the EMP details the potential environmental impacts of the activity and proposed environmental outcomes to manage impacts on social and cultural surroundings.

3. *Climate change (emissions):* The EMP provides details of predicted emissions for this regulated activity and cumulative greenhouse gas emissions from existing and proposed regulated activities being undertaken by the interest holder. The EMP also provides details of cumulative greenhouse gas emissions from regional developments. The EMP commits to the greenhouse gas emission mitigation and monitoring requirements of the Code and the NT EPA has recommended the interest holder provide to DEPWS annual actual greenhouse gas emissions generated by the regulated activity from all sources.

4. *Water:* Public submissions raised concerns about potential impacts to soils, aquatic ecosystems (e.g. Lake Woods) from spills and/or loss of containment, particularly during the wet season and contamination of groundwater. Impacts to soil and surface waters have been identified and existing mitigations and controls are in place to prevent downstream impacts to, for example, Lake Woods, (located approximately 90 km south of the Kyalla EP117 N2 well site) and soils through loss of containment or spills, including bunding around the well/lease pad that has a holding capacity of 9.6 ML. Primary and secondary containment is in place on the site for all chemical, hydrocarbon and wastewater storage/containment. In accordance with the Code clause B.4, all onshore shale gas wells (including exploration wells constructed for the purposes of production testing) are to be constructed to international standards, with cementing extending up to at least the shallowest problematic hydrocarbon-bearing, organic carbon rich or saline aquifer zone. The EMP outlines the controls identified in the Well Operations Management Plan (WOMP) that will be implemented for the drilling program design to ensure isolation of the Gum Ridge Formation, aquifer protection and overall petroleum well integrity is achieved. These include:

   - development of critical controls and hold points throughout the well construction process that will need verification by a competent person prior to proceeding to the next operation
   - barrier verifications and monitoring throughout well construction, maintaining primary and secondary well control measures
   - a cemented production casing string that will provide an additional barrier between producing hydrocarbon bearing zones and shallow aquifers, with pressure testing once the cement is set to ensure overall integrity of the production casing
   - multiple strings of steel casing with each casing string cement grouted to the surface and multiple engineered and system mitigations to adequately detect water quality threats to the Cambrian Limestone Aquifer (and the deeper, saline Moroak Sandstone, which lies beneath the lower Kyalla SSR Formation)
   - well barrier integrity validation testing for each well with a report demonstrating compliance with the Code to be provided to the regulator (DITT) for approval

   Development of the N2-1H well at Kyalla EP117 has verified the distances between aquifers and hydraulic fracturing are greater than 1 km minimising groundwater pathways/contamination. The well design and construction method described in the EMP surpasses the requirements of the Code for protection of aquifers. The interest holder has installed control and impact groundwater monitoring bores in the vicinity of the exploration wells, with monitoring results made public. A Well Integrity Management Plan and a Well Operations Management Plan (WOMP) is provided separately to this EMP and sent to DITT for review and acceptance prior to works commencing. These plans will only be accepted if they comply with the requirements detailed in the Code. As per the Code, the interest holder must demonstrate that they have a system or process for managing well integrity throughout the whole well life cycle that complies with *ISO 165301:2017 Well integrity -Part 1: Life cycle governance*.

It is noted that the concerns raised in relation to the Moroak aquifer and corrosion of wells have previously been addressed in a letter to the same member of the public in November 2020. In accordance with clause B.4 of the Code, all onshore shale gas wells (including exploration wells constructed for the purposes of production testing) have mandatory requirements for well construction. Top of cement in each casing string must comply with barrier requirements set out in section B.4.3 of the Code.

The interest holder must have a WOMP reviewed and accepted by DITT prior to commencement of the activity, that will be implemented for the hydraulic fracturing program design to ensure isolation of the Gum Ridge Formation and overall petroleum well integrity continues to be achieved. These measures to be implemented, as specified in the Code, include:

- development of critical controls and hold points throughout the well construction process that have verification by a competent person prior to proceeding to the next operation
- barrier verifications and monitoring throughout well construction, maintaining primary and secondary well control measures
- a specified maximum allowable operating pressure in the Kyalla N2-2H and N2-3H wells for hydraulic fracturing pumping operations
- multiple strings of steel casing with surface casing string cement grouted to the surface and multiple engineered and system mitigations to adequately detect water quality threats to the Cambrian Limestone Aquifer
- well barrier integrity validation testing for the well with a report demonstrating compliance with the Code provided to the regulator (DITT).

Increasing salinity and temperature with depth below surface is a general feature of all sedimentary basins including the Beetaloo Sub-basin. In conventional petroleum reservoirs a salt “top seal” is a common feature of the stratigraphic trap that causes hydrocarbons to accumulate. The risk of corrosion as a result of increased salinity and temperature is therefore not unique to unconventional (e.g. shale) petroleum exploration and production. However, petroleum wells are designed with multiple barriers, as required by the Code, so that a single barrier failure will not lead to a loss of containment or in this case aquifer contamination. As such, petroleum wells are highly engineered underground “pressure vessels”. Complete well integrity failure where all well barriers fail is an extremely rare occurrence in contemporary petroleum wells, including shale wells. International failure rate is estimated at less than 1 in 10,000 wells.[17] Moreover, a recent study on well integrity of coal seam gas wells in Queensland, Australia, covering the period 2010 – 2015 concluded that the risk of a subsurface breach of a well integrity was assessed to be “very low to near zero”.[18] The article cited in the submission in relation to coal seam gas wells in Queensland dates back to 2016 and is not a new issue arising since the NT Hydraulic Fracturing Inquiry.

The lower Kyalla SSR (the target formation for this regulated activity), lies above the Moroak Sandstone and Velkerri Formation. The fracture propagation zone is constrained within the lower Kyalla SSR, informed by geomechanical modelling validated from Kyalla 117 N2-1H stimulation results (see EMP Figure 13).

The necessary ingredients for upward flow from the Moroak is an upward head gradient (pressure) or driving force and a leakage pathway. In order for upward flow to occur, the head gradient must be large enough to overcome density gradients associated with increasing salinity with depth and these upward head gradients would need to be sustained over thick sequences (typically >1,000 m) to drive a significant amount of brine from the Moroak into shallow fresh groundwater. The Moroak must also have sufficient fluid existing in the pore space (porosity) and also be permeable enough to provide a driving force in a potential leakage pathway. Rate of

[17] Wu B, Doble, R, Turnadge, C and D Mallants, 2016. *Well Failure Mechanisms and Conceptualisation of Reservoir-Aquifer Failure Pathways*. SPE Asia Pacific Oil & Gas Conference and Exhibition, 25-27 October, Perth, Australia. (CSIRO).

[18] Mallants, D, Jeffrey, R, Zhang, X, Wu, B, Kear, J, Chen, Z, Wu, B, Bekele, E, Raiber, M, Apte, S and B Grey, 2018. Review of plausible chemical migration pathways in Australian coal seam bas basins. *International Journal of Coal Geology* 195; 280 – 303.

progress during drilling through the Moroak formation at, for example, the Carpentaria-1 well, was extremely low, as reported elsewhere in the Beetaloo, indicating a very high degree of cementation in the Moroak and supports the fact that it acts as barrier to any upward migration of hydrocarbons from the Velkerri shale over millions of year. The high degree of cementation (extremely low porosity) evident in the Moroak due to difficulty in drilling through it, also precludes likelihood of any significant water production from the Moroak. In addition, there was no evidence of over-pressure during drilling through the Moroak sandstone at, for example, the Carpentaria-1 well; evidenced by the drilling and mud logs for Carpentaria-1 well. Overpressure is necessary for upward flow. The likelihood pollutants will be moved to other aquifers is therefore considered remote.

Regardless of the driving mechanism, flow rates are low and timescales for transport are long (often $>10^6$ years). The effective hydraulic isolation of these formations is demonstrated by the fact that fluids have been trapped at depth for tens to hundreds of millions of years.[19]

5. *Waste:* The interest holder is required to ensure all waste is classified and ensure that all listed waste is only disposed of through licensed waste contractors, under the *Waste Management and Pollution Control Act 1998* (NT). The Code mandates that all backflow be recycled and re-used to maximum potential and the off-site transport and disposal of fluids should be minimised. Offsite (interstate) treatment is an interim solution while the NT Government works with industry to implement a long term solution to water management including recycling and disposal. With regard to the use of open tanks, the outcome intended by the Inquiry's recommendation (7.12) was that the use of enclosed tanks was to prevent the risk of open wastewater ponds overflowing during significant rainfall events. This outcome has been maintained in the Code. Wastewater will be allowed into evaporation ponds (open above ground tanks) to reduce the amount of wastewater stored in tanks and the impacts of transporting large volumes offsite for subsequent treatment and disposal. This is necessary during the early stages of exploration when on-site treatment and recycling is unfeasible. The EMP does not propose to dispose of hydraulic fracturing flowback wastewater in-situ. Volume reduction of the wastewater and trucking to an authorised facility in Queensland by a listed waste transporter is proposed at this pilot exploration stage.

   The NT EPA has recommended the interest holder provide to DEPWS a laboratory analysis and risk assessment report of hydraulic fracturing wastewater contained in wastewater tanks following flowback from the well.

6. *Regulation and compliance:* Concerns were raised about the separation of different regulated activities across EMPs; that it leads to development by stealth and lacks public transparency and consultation. All EMPs that relate to drilling or hydraulic fracturing are subject to 28-day public consultation. All EMPs undergo assessment based on the nature and scale of the regulated activity, including cumulative impacts. Regulation 8 (5) allows for more than one regulated activity to be included in an EMP. The regulation does not preclude interest holders submitting EMPs for separate regulated activities; however, the NT EPA encourages interest holders to submit a consolidated EMP.

7. *Human health:* Public submissions were concerned with impacts of the regulated activity on human health, particularly arising from the chemicals used during hydraulic fracture stimulation and potential contamination of groundwater and surface water sources. A chemical risk assessment to evaluate the potential human health and environmental health effects of all compounds to be used during drilling and stimulation has been completed. All chemicals were considered low concern when standard chemical handling, storage and disposal practices are implemented.

   The EMP provides a Wastewater Management Plan, Spill Management Plan, compliance with an existing Erosion and Sediment Control Plan, Emergency Response Plan, Methane Emission Management Plan and Chemical Risk Assessment, and specific petroleum well integrity criteria and monitoring programs that meet the requirements of the Code. These plans adequately

[19] Flewelling S and M Sharma, 2014. 'Constraints on upward migration of hydraulic fracturing fluid and brine'. *Groundwater,* 52(4); 492-4.

identify how the potential impacts and risks associated with chemical use, waste storage and waste disposal will be mitigated.

The EMP demonstrates how the interest holder will comply with relevant requirements of the Code in undertaking the regulated activity. This includes reference to applicable Australian and international standards that have been adopted for the regulated activity, as applicable. The EMP cross references relevant sections of the Code that apply to the mitigation and management measures to enable the reviewer to identify and confirm that the proposed regulated activity complies with the Code, as applicable. The EMP provides management plans that meet the requirements of the Code.

5. Other relevant matters

Regulation 9 requires that an EMP provides a comprehensive description of the regulated activity, including provision of a detailed timetable for the activity. The EMP includes an estimate of duration of the regulated activity, but at the time of preparation the exact timing of each activity is not known. To meet this requirement, the NT EPA has provided advice that the interest holder be required to submit an updated timetable for the regulated activity prior to commencement. The timetable should address all aspects of the activity and include, but not be limited to, dates for the implementation of commitments and should be updated quarterly or as other constraints, such as seasonal weather forecasts or travel restrictions emerge.

CONCLUSION

The NT EPA considers that, subject to the consideration of the recommended EMP approval conditions, the EMP:

- is appropriate for the nature and scale of the regulated activity
- demonstrates that the regulated activity can be carried out in a manner that potential environmental impacts and environmental risks of the activity will be reduced to a level that is as low as reasonably practicable and acceptable.

In providing this advice the NT EPA has considered the principles of ecologically sustainable development.

RECOMMENDATIONS

The NT EPA recommends that should the EMP for Origin Energy B2 Pty Ltd be approved, the following conditions be considered:

Condition 1: The interest holder must submit to the Department of Environment, Parks and Water Security (DEPWS):

i. a timetable (including time-bound commitments) for the regulated activity prior to the commencement of the activity and each quarter thereafter; and

ii. daily on-site reports indicating the status and progress of drilling, hydraulic fracturing and the freeboard available in drilling sumps and wastewater tanks during operations; and

iii. a five-day activity forecast for the duration of the activity during the wet season (1 October – 30 April each year); and

iv. written notification of any halt to the activity due to wet season conditions, within 24 hours of the halt; and

v. immediate written notification of any fires potentially threatening the activity from external or internal sources.

Condition 2: In the event of any accidental release of contaminants that exceeds 200 litres (for liquids), the interest holder must provide a written report to DEPWS within 24 hours of the incident being detected. The report must include:

i. details of the incident specifying material facts, actions taken to avoid or mitigate environmental harm; and

ii. the corrective actions taken including the volume and depth of impacted soil removed for appropriate disposal if required; and

iii. any corrective actions proposed to be taken to prevent recurrence of an incident of a similar nature.

'Contaminant' is defined in section 117AAB(1) of the *Petroleum Act 1984* (NT).

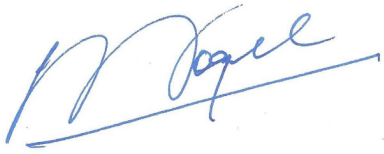
Condition 3: The interest holder must provide an annual report to DEPWS on its environmental performance, in accordance with item 11(1)(b) in schedule 1 of the Petroleum (Environment) Regulations 2016 (NT). The first report must cover the 12 month period from the date of the approval, and be provided within three calendar months of the end of the reporting period. The annual environmental performance report must align with the template prepared by DEPWS for this purpose.

Condition 4: An emissions report must be provided to DEPWS by 30 September each year, which summarises actual annual greenhouse gas emissions reported under the Commonwealth *National Greenhouse and Energy Reporting Act 2007*[20] versus predicted emissions in the EMP.

Condition 5: The interest holder must provide to DEPWS within 6 weeks of completion of well flowback operations at the Kyalla N2 well site on EP117, a report on the risk assessment of flowback wastewater from the hydraulic fracturing phase. The risk assessment must be:

i. prepared by a suitably qualified person[21]; and

ii. prepared in accordance with the monitoring wastewater analytes specified in Section C.3 of the Code of Practice: Onshore Petroleum Activities.



PAUL VOGEL AM

CHAIRPERSON

NORTHERN TERRITORY ENVIRONMENT PROTECTION AUTHORITY

15 FEBRUARY 2021

[20] Clause D.6.2(b) of the Code requires annual actual greenhouse gas emissions to be provided even where emissions are below the NGERs threshold of 25 ktCO_2-e for scope 1 and scope 2 emissions reporting.

[21] As classified in the Definitions table in the Code.