



Environment Management Plan

NT-2050-15-MP-038

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BEETALOO SUB-BASIN KYALLA 117 N2 MULTI- WELL DRILLING, STIMULATION AND WELL TESTING PROGRAM

Environment Management Plan

EP117

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Executive Summary

Origin Energy B2 Pty Ltd (Origin) is a registered holder and the operator of exploration permit (EP) 117, which is located in the Beetaloo Sub-basin. This Environment Management Plan (EMP) forms the basis of Origin's application to the Northern Territory (NT) Minister for Environment for the drilling, hydraulic fracture stimulation (HFS) and well testing of two (2) additional exploration and appraisal wells (E&A wells) at the existing Kyalla 117 N2 site (Figure 1). This will increase the number of E&A wells (approved and proposed) on the Kyalla 117 N2 site to three (3).

The Kyalla 117 N2 site was constructed in 2019 following Ministerial approval of Origin's Beetaloo Sub-basin Kyalla 117 N2 Civil Construction EMP (NT-2050-15-MP-34) in June 2019. The proposed E&A wells will be drilled on Kyalla 117 N2 subject to the well testing success of the existing Kyalla 117 N2-1H E&A well, which was approved by the Minister in August 2019 under EMP N-2050-15-MP-025. Kyalla 117 N2-1H well testing results are anticipated to be obtained in April/May 2021.

The two (2) proposed additional E&A wells covered under this EMP are Kyalla 117 N2-2H and Kyalla 117 N2-3H. The drilling, stimulation and well testing of these two (2) E&A wells at the existing Kyalla 117 N2 site is considered an important step in confirming the technical and commercial feasibility of the Kyalla shale resource. The use of multi-well pads is likely to significantly reduce the environmental footprint of any potential development.

The appraisal results collected from these wells will be used to:

- validate reservoir flows from the Kyalla target formation at the Kyalla 117 N2 site with multiple wells
- optimise HFS design and spacing between adjacent horizontal wells in a multi-well pad operation
- optimise multi-well pad layout of surface operations for potential future development scenario with the core objective of minimising the environmental footprint, including minimising land clearance, maximising water reuse and reducing greenhouse gas (GHG) emissions
- determine optimal well spacing at a well pad to inform development of the Mechanical Earth Model (MEM) for a future potential Kyalla development (subject to exploration success)
- demonstrate design requirements and operability of multi-well pad operations across all seasons in the Beetaloo sub-basin
- assess the financial competitiveness in multi-well pad development scenario to inform Final Investment Decision for future development scenarios
- demonstrate no impact on groundwater quality at a well site in a multi-well pad operation
- collect additional data on flowback quality and quantity during a multi-well pad operation to assess options for minimising off-site wastewater disposal through future treatment and re-use
- provide key data as input into future production approvals, including footprint optimisation, flowback characterisation, GHG emission intensity and solid and liquid waste management

The EMP has been prepared in compliance with the *NT Petroleum (Environment) Regulations 2016*, *Code of Practice: Onshore Petroleum Activities in the Northern Territory* (referred to herein as the

The overall objective of the EMP is to ensure that the proposed activities, are carried out in a manner by which the environmental impacts and risks will be reduced to a level that is as low as reasonably practicable and are acceptable.



Description of the activity

This EMP covers the regulated activities required to enable Origin to drill, stimulate, test, maintain and potentially decommission the Kyalla 117 N2-2H and Kyalla 117 N2-3H horizontal E&A wells. To accommodate this scope, the activities described in Table 1 are proposed.

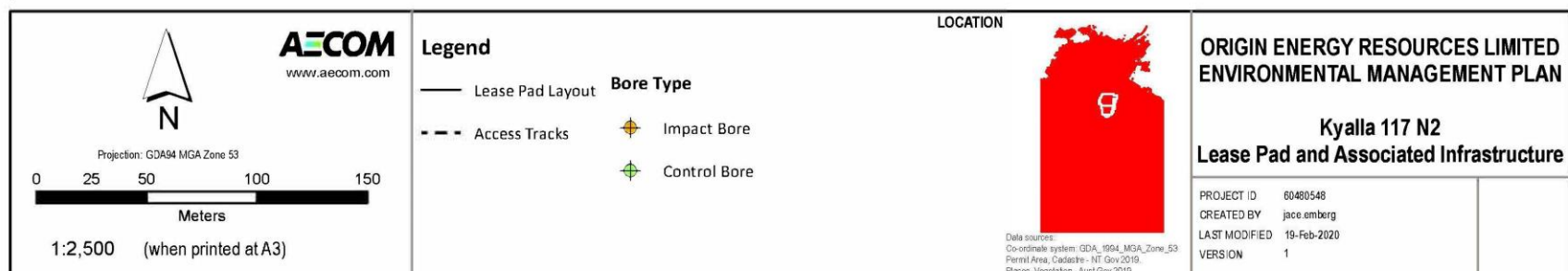
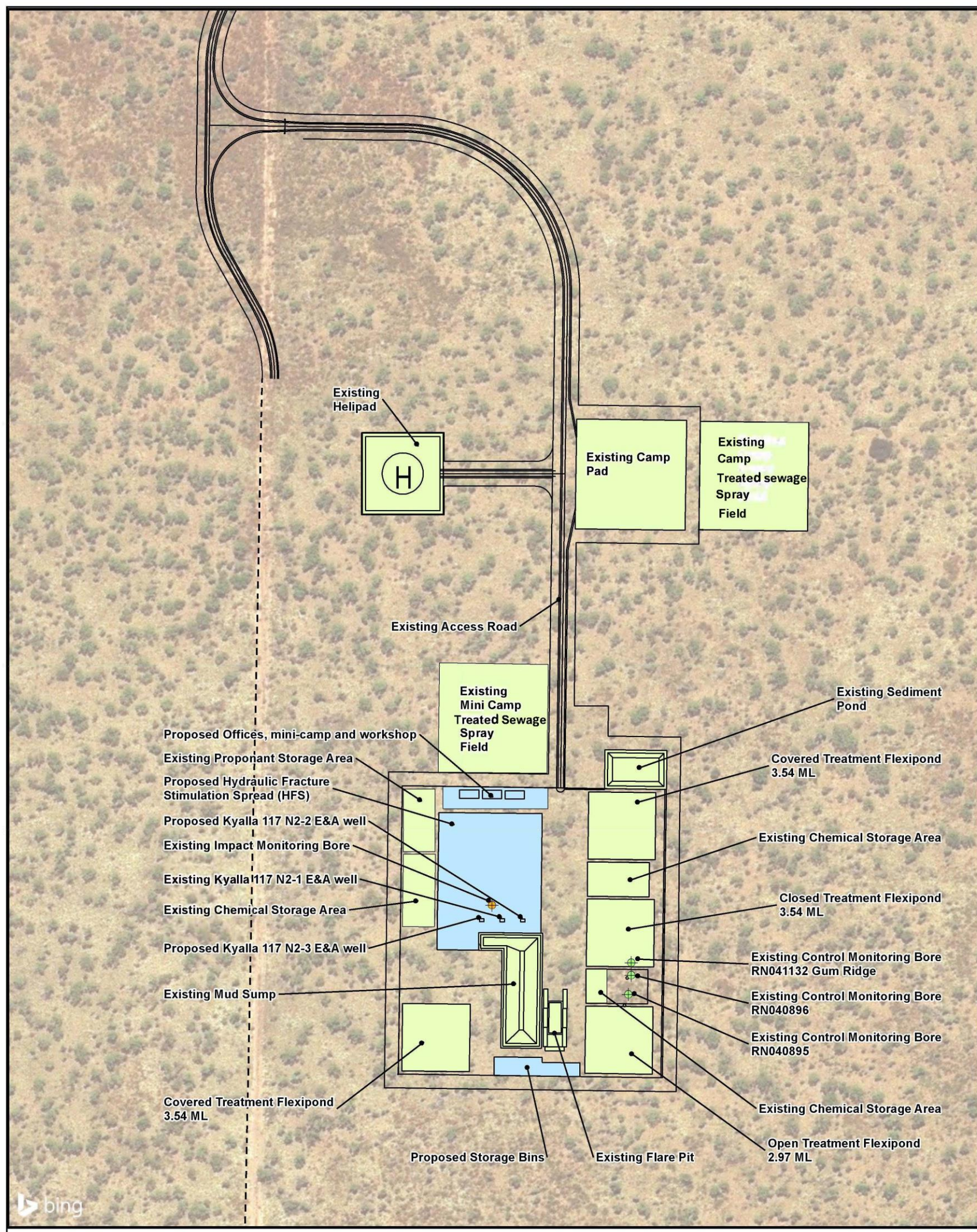
Table 1: Description of the exploration and appraisal activities for the proposed Kyalla 117 N2-2H and Kyalla 117 N2-3H horizontal wells

Activity	Description
Site set-up and mobilisation to support the Kyalla 117 N2-2H and Kyalla 117 N2-3H E&A program	• Use of existing access tracks to and from the Kyalla 117 N2 site from the Stuart Highway • Use of the existing cleared and graded Kyalla 117 N2 lease pad, including lease pad, access tracks, camp pads, stockpile storage areas and helipad • Installation of two (2) well cellars at Kyalla 117 N2 to accommodate Kyalla 117 N2-2H and Kyalla 117 N2-3H • Extension of the existing Kyalla 117 N2 drilling sump from 2,400m³ to ~3,000m³ (if required) • Set-up of two (2) temporary camps – a main camp (65 person capacity) and a drilling mini-camp (8 person capacity), both located at existing Kyalla N2 camp pads • Set up of chemical and material storage areas • Set-up of drilling rig, including blow-out preventors, fluid systems and associated equipment such as pipe racks and cementing units at Kyalla 117 N2 • Set-up of HFS equipment, completions rig and equipment, well testing equipment, and other associated equipment at Kyalla 117 N2
E&A activities at the existing Kyalla 117 N2 site including drilling, hydraulic fracture stimulation (HFS) and well testing of Kyalla 117 N2-2H and Kyalla 117 N2-3H	• Operation of two (2) temporary camps – a main camp (65 person capacity) and a drilling mini-camp (8 person capacity), both located at existing Kyalla N2 camp pads • Transportation, handling and storage of bulk chemicals, fuels and wastes • Drilling of the Kyalla 117 N2-2H and Kyalla 117 N2-3H horizontal E&A wells, including the vertical component of the well and collection of reservoir quality data • Well design in accordance with the Code of Practice and approved Well Operations Management Plan (WOMP) including isolation of freshwater aquifers • HFS of Kyalla 117 N2-2H and Kyalla 117 N2-3H • Completion and testing of Kyalla 117 N2-2H and Kyalla 117 N2-3H E&A wells • Gas flaring in accordance with Code of Practice requirements and as per US EPA 40 CFR 63.11, with a flare tip combustion efficiency of 98%

Activity	Description
	- Maintenance and monitoring works on Kyalla 117 N2-2H and Kyalla 117 N2-3H E&A wells in accordance with approved WOMP - Suspension and decommissioning Kyalla 117 N2-2H and Kyalla 117 N2-3 E&A wells (if required) in accordance with the Code of Practice - Groundwater extraction of approximately 75-110 ML under existing groundwater extraction licence (WEL GRF 10285) - Monitoring activities (including groundwater, stormwater, soils, leak detection and all other low impact ancillary data collection programs)
Onsite wastewater management to support ongoing E&A program	- On-site wastewater storage and treatment in accordance with Code of Practice - Use of the drilling sump, enclosed wastewater storage tanks and wastewater treatment tanks to manage drilling and flowback wastewater - Drill cuttings and flowback fluid quality testing in accordance with the Code of Practice - Disposal of drill cuttings within EP117 is subject to the outcomes of chemical analysis in accordance with clause C.4.1.2 of the Code of Practice - Drilling waste storage and disposal located within the existing Kyalla 117 N2 site or transported offsite - Offsite disposal of wastewater in accordance with the <i>Waste Management and Pollution Control Act</i>
Site demobilisation	- Demobilisation of exploration equipment, including camps, drilling rigs, HFS equipment, completion rigs, well testing equipment, wastewater storage tanks and various service provider equipment - Approximately 44 traffic movements per day during site demobilisation
Site rehabilitation	- Decommissioning and removal of all surface infrastructure and wastes from site including the removal of drilling sump, wastewater tanks, cellars, equipment, non-drilling waste, wastewater and all ancillary equipment - Final rehabilitation activities conducted under approved Civil Construction EMP (NT-2050-15-MP-34)

Figure 2 shows the existing Kyalla 117 N2 site and the layout of the proposed activities within the existing Kyalla 117 N2 lease pad and disturbance footprint.

The proposed activities will occur within the subject land area which has been approved by the Native Title Holders and the Northern Land Council (NLC) and covered by AAPA Certificate C2020/003. The AAPA Certificate C2020/003 allows Origin to drill, HFS and well test up to ten (10) vertical and horizontal E&A wells at Kyalla 117 N2.



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A3 size

Figure 2 Proposed Kyalla 117 N2 multi-well layout

Description of the existing environment

The Kyalla 117 N2 2H and Kyalla 117 N2-3H E&A wells will be located on the existing Kyalla 117 N2 site which includes an existing 5.2 hectare lease pad constructed in 2019 under Origin's approved Beetaloo sub-basin Kyalla 117 N2 Civil Construction EMP (NT-2050-15-MP-34). The existing Kyalla 117 N2 disturbance footprint including lease pad is shown in Figure 3.



Figure 3: Existing Kyalla 117 N2 disturbance footprint including lease pad upon which the Kyalla 117 N2-2H and Kyalla 117 N2-3H wells and associated activities will be located (image taken during drilling of Kyalla 117 N2-1H)

Kyalla 117 N2 is located on the Hayfield/Shenandoah Station, which is subject to pastoral land use. Prior to the Kyalla 117 N2 construction activities, a Land Condition Assessment was completed in August 2018 to review the physical, natural and cultural heritage environment of the Kyalla 117 N2 approved disturbance area.

Kyalla 117 N2 is located within *Corymbia* low woodland with a tussock grass understorey. This vegetation type is widespread in the tropical savannas of the Northern Territory and may provide habitat for some threatened species such as the Crested Shrike-tit (*Falcunculus frontatus whitei*) (DAWE, 2014, Ward, 2008). A summary of the existing environment in which the existing lease pad is located is provided in Table 2.

Ongoing routine field weed surveys have been completed at the location with no evidence of weeds observed since the construction of the site. The primary focus on weed management will continue to focus on preventing the introduction of weeds and detecting and managing weeds introduced/promoted during site disturbance.

The archaeology assessment did not identify culturally sensitive landforms or artefacts within the vicinity of the Kyalla 117 N2 site. In addition, a sacred site clearance survey coordinated by the Northern Land Council (NLC) and carried out by the Native Title holders in September 2018, was led by their anthropologist and included site visits and consultations with the Native Title Holders and custodians. The Sacred Site Avoidance Survey Report/Anthropological Report has been provided to the Aboriginal Areas Protection Authority and informed the issuing of AAPA Certificate C2020/003.

Table 2: Summary of existing environment and surrounds at Kyalla 117 N2

Site ID	Kyalla 117 N2	Habitat survey photos of the Kyalla 117 N2 site pre-clearance, indicative of the vegetation / habitat of the surrounding environment	
Location	-16°50' 29.01, 133°39' 0.16		
Landform and soil	Plains and rises associated with deeply weathered profiles (laterite) including sand sheets and other depositional products, sandy and earth soils		
Habitat type	<i>Corymbia</i> low woodland		
Vegetation community	<i>Corymbia</i> low woodland/ <i>Terminalia</i> (mixed) sparse shrubland/ <i>Chrysopogon</i> (mixed) low tussock grassland This vegetation community is considered regionally extensive and not subjected to extensive clearing		
Dominant flora species	Canopy dominated by <i>Corymbia dichromophloia</i> , <i>Eucalyptus setosa</i> . Shrub layer including <i>Acacia ancistrocarpa</i> , <i>Alphitonia pomaderroides</i> , <i>Brachychiton paradoxus</i> . Ground layer species include <i>Triodia bitextura</i>		
Habitat condition	No core habitat for threatened fauna identified. Good condition with evidence of recent grazing. Vegetation appeared to have been heavily burnt in recent years. No evidence of hollow bearing trees and logs. Habitat contained moderate to high refuge opportunities in the form of dense leaf litter, tussock grass cover, and woody debris. Good continuous cover adjoining adjacent woodland habitat and regionally extensive. No evidence of weeds or feral animals.		



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Potential listed threatened species	Grey Falcon, Northern Shrike-tit, Plains Death Adder, Gouldian Finch	Hydrogeology Groundwater resources and use is primarily from the Cambrian Limestone Aquifers (the Anthony Lagoon Formation and Gum Ridge Formation) with the shallower undifferentiated Cretaceous or perched alluvium systems being unsaturated.
Weeds	No <i>Weeds of National Significance</i> present	

Chemical risk assessment

A chemical risk assessment has been completed for all chemicals to be used in drilling and HFS. All chemicals were considered low concern when standard chemical handling, storage and disposal practices were utilised. The chemicals and estimated quantities that may be added to the HFS proppant (sand) are shown in Table 3.

Table 3: Chemicals that may be added to the sand proppant during stimulation activities

Material name	
Acetic Acid - 60%	DCA-19002 Crosslinker
BE-9 Biocide	DCA-23001 Friction Reducer
Caustic Soda Liquid	DCA-23003 Friction Reducer
DCA-11001 Breaker Activator	DCA-25005 Gelling Agent
DCA-13002 Breaker	DCA-30001 Scale Inhibitor
DCA-13003 Breaker	DCA-32002 Surfactant
DCA-16001 Clay Stabiliser	DCA-32014 Surfactant
DCA-17001 Corrosion Inhibitor	FE-2 Buffer
DCA-19001 Crosslinker	Hydrochloric Acid - 32%

Key environmental risks assessed in the program

The environmental, heritage and social risks associated with drilling, stimulation and well testing activities have been assessed utilising the Origin risk assessment framework. The detailed risk assessment presents the range of potential impacts, corresponding mitigation measures and residual risk ratings based on their assessed worst-case consequence and likelihood of occurrence. Key risks assessed under this EMP include:

- Protection of groundwater through sustainable use and zonal isolation
- Assessment and management of chemicals
- Generation and management of wastewater, including prevention of spills
- Generation and management of waste
- Management of erosion and sediment control
- Managing the risk of bushfire in the area
- Mitigating the introduction and spread of weeds
- Generation of greenhouse gases

It was considered that with the appropriate controls implemented to mitigate the impacts there were no residual risks above a rating of medium (Table 4).

Table 4: Summary of residual risk ratings

	Residual Environmental Risk Level			
	Low	Medium	High	Very High
Total 72	64	8	0	0

The medium risks identified were consistent with standard project and pastoral activities completed across the NT, and are related to soil erosion, spread of weeds, accidental ignition of fire/bushfires and nuisance dust generation.

The medium residual risks sources assessed under this EMP include:

1. Loss in soil productivity and viability due to soil erosion from cleared areas (existing access tracks, lease pad and camp pad)
2. Impact to fauna habitats and listed threatened flora and fauna through the introduction and spread of weeds in the area
3. Impact to fauna habitats and listed threatened flora and fauna through accidental ignition of fire from exploration activities (drilling, HFS, flaring, general access)
4. Disturbance of sacred site or culturally sensitive area and decline in environmental value of area used for cultural purposes through the accidental ignition of fire by site activities
5. Reduction in agriculture productivity through the introduction and spread of weeds in the area
6. Reduction in agriculture productivity through bushfire from accidental ignition by site activities or site personnel
7. Increased nuisance from dust emissions associated with the activities
8. Increased nuisance from dust due to accidental ignition of bushfire during the site activities

The assessment demonstrates that the risks associated with drilling and stimulation-related activities have been reduced to as low as reasonably practicable (ALARP) and are acceptable. The environmental outcomes to be achieved during the proposed activities include no significant impacts to the following aspects:

- Ecological function and productivity of soils
- Ecological function of surface water bodies
- The viability of groundwater systems to support ecological, economic and community activities
- The protection of high valued habitats and threatened flora and fauna
- The maintenance of air quality
- The minimisation of GHG emissions
- The protection and enhancement of community and cultural values, places and amenity.

At completion of E&A activities, infrastructure will be rehabilitated in accordance with the Code of Practice as described in the approved Civil Construction EMP (NT-2050-15-MP-34).



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Stakeholder engagement

Community engagement for Origin's E&A project has focused on the host Traditional Owners facilitated by the Northern Land Council (NLC) and host pastoralists directly affected by the proposed activity. Detailed community and stakeholder engagement is ongoing and covers Origin's activities on a broader level and include the information required under the *NT Petroleum (Environment) Regulations 2016*. Further information on stakeholder engagement is available in section 5.

1 Introduction

1.1 Purpose

Origin Energy B2 Pty Ltd (Origin) is a registered holder and the operator of Exploration Permit (EP) 117, located in the Beetaloo sub-basin. This Environment Management Plan (EMP) forms the basis of Origin's application to the Northern Territory (NT) Minister for Environment for the drilling, hydraulic fracture stimulation (HFS) and well testing of two (2) additional E&A wells on the existing Kyalla 117 N2 site. This will increase the total number of E&A wells (approved and proposed) on the Kyalla 117 N2 site to three (3).

The proposed E&A wells will be drilled subject to the well testing success of the existing Kyalla 117 N2-1H appraisal well. The Kyalla 117 N2-1H E&A well EMP was approved by the Minister in August 2019 (N-2050-15-MP-025), with well testing results anticipated to be obtained in April/May 2021.

The two (2) proposed additional E&A wells covered under this EMP are Kyalla 117 N2-2H and Kyalla 117 N2-3H. The drilling, stimulation and well testing of the two (2) additional E&A wells on the Kyalla 117 N2 site is considered an important step in confirming the technical and commercial feasibility of the Kyalla shale resource. The use of multi-well pads is likely to significantly reduce the environmental footprint of any potential development and significantly increase the economic viability of the resource. The appraisal results collected from these wells will be used to:

- validate reservoir flows from the Kyalla target formation at the Kyalla 117 N2 site with multiple wells
- optimise HFS design and spacing between adjacent horizontal wells in a multi-well pad operation
- optimise multi-well pad layout of surface operations for a potential future development scenario, with the core objective of minimising the environmental footprint, including minimising land clearance, maximising water reuse and reducing greenhouse gas emissions (GHG)
- determine optimal well spacing at a well pad to inform development of the Mechanical Earth Model (MEM) for a potential future Kyalla development (subject to E&A success)
- demonstrate design requirements and operability of multi-well pad operations across all seasons in the Beetaloo
- assess the financial competitiveness in multi-well pad development scenarios to inform Final Investment Decision for future development scenarios
- demonstrate no impact to groundwater quality at a well site in a multi-well pad operation
- collect additional data on flowback quality and quantity during a multi-well pad operation to assess options for minimising off-site wastewater for off-site disposal through future treatment and re-use
- provide key data as input into future Environmental Impact Statements including footprint optimisation, flowback characterisation, GHG emission intensity and solid and liquid management.

This EMP covers the regulated activities required to enable Origin to drill, stimulate, test, maintain and decommission the Kyalla 117 N2-2H and Kyalla 117 N2-3H horizontal E&A wells within the 2019-2024 period.

This EMP has been prepared in compliance with the *NT Petroleum (Environment) Regulations*, NT Code of Practice and the Exploration Agreement(s) between Origin, Native Title Holders and the Northern Land Council (NLC).

The overall objective of the EMP is to ensure that activities are carried out in a manner in which any environmental impacts and risks will be reduced to a level that is as low as reasonably practicable and acceptable.

More specifically, this EMP aims to:

- address regulatory requirements
- provide site-specific impact management strategies to assist Origin in maintaining a positive position in the local community throughout its program
- align with the principles of Ecological Sustainable Development (ESD) through the adoption of responsible development practices that are designed to maximise social benefit, while minimising the level of impact on the surrounding ecosystems
- provide a description of site-specific aspects of the existing environment (physical, biological, social and cultural)
- provide site-specific plans for monitoring and rehabilitation
- be a practical and usable document, with environmental management principles that are easily implemented and effective.

The 'site' is defined as all the work areas including the E&A camp, well pad and access tracks within the cleared subject land area approved under the Kyalla 117 N2 Civil Construction EMP NT-2050-15-MP-034. NOTE: Origin reference Kyalla 117 N2, is referred to by the NLC as Cleared Area 5 (CA5).

1.2 Background

Origin holds three (3) petroleum exploration permits in the Barkly region under the Beetaloo Joint Venture with Falcon Oil and Gas. These permits consist of EP76, EP98 and EP117, which cover 18,512 square kilometres (km²) of largely pastoral leases on the Stuart Plain, part of the Barkly Tableland, within the Northern Territory (Figure 1) and were originally granted by the NT Minister for Mines and Energy under the *Petroleum Act*.

In October 2019, Origin began drilling the Kyalla 117 N2-H1 well, the first E&A well drilled since the moratorium on hydraulic fracturing was lifted in April 2018. This E&A well has collected valuable subsurface information that confirms the potential prospectively of the Kyalla shale resource in the vicinity. The drilling of the Kyalla 117 N2-1H E&A well was completed in February 2020 with an 11-stage stimulation undertaken in September 2020. The well is currently undergoing flow back and production testing and upon cessation of these tests, an additional two (2) E&A wells are proposed to be drilled, stimulated and well tested on the existing Kyalla 117 N2 site. These additional wells will only be drilled where the results from the Kyalla 117 N2-1H E&A well indicate a technically and commercially viable shale formation.

This EMP forms the basis of Origin's application to the Department of Environment, Parks and Water Security (DEPWS) for the drilling, stimulation and well testing of the Kyalla 117 N2-2H and Kyalla 117 N2-3H E&A wells at the existing Kyalla 117 N2 site. The plan provides a detailed description of how Origin proposes to manage the environmental impacts and risks associated with its activities, including how it will address its regulatory obligations and relevant Inquiry recommendations that have underpinned the Code of Practice.

The approval of the EMP forms one part of the overall activity approval application process, with the final approval granted by the Minister of Industry, Tourism and Trade (DITT) under the NT Petroleum Act.

1.3 Project boundary

Origin proposes to drill, stimulate and test up to two (2) additional petroleum E&A wells on the existing Kyalla 117 N2 site within Exploration Permit (EP) 117. These wells will target the Kyalla shale resource.

The boundary of this EMP is defined as the area which may be affected by E&A activities. This includes:

- Existing access tracks to and from the Kyalla 117 N2 site from the Stuart Highway
- Existing Kyalla 117 N2 lease pad, camp pad, helipad and associated infrastructure (water bores, chemical storage areas, wastewater tanks and drilling sump)
- Proposed Kyalla 117 N2-2H and Kyalla 117 N2-3H petroleum E&A wells

The proposed locations of the infrastructure and associated regulated activities are provided in Table 5, Figure 1 and Figure 4.

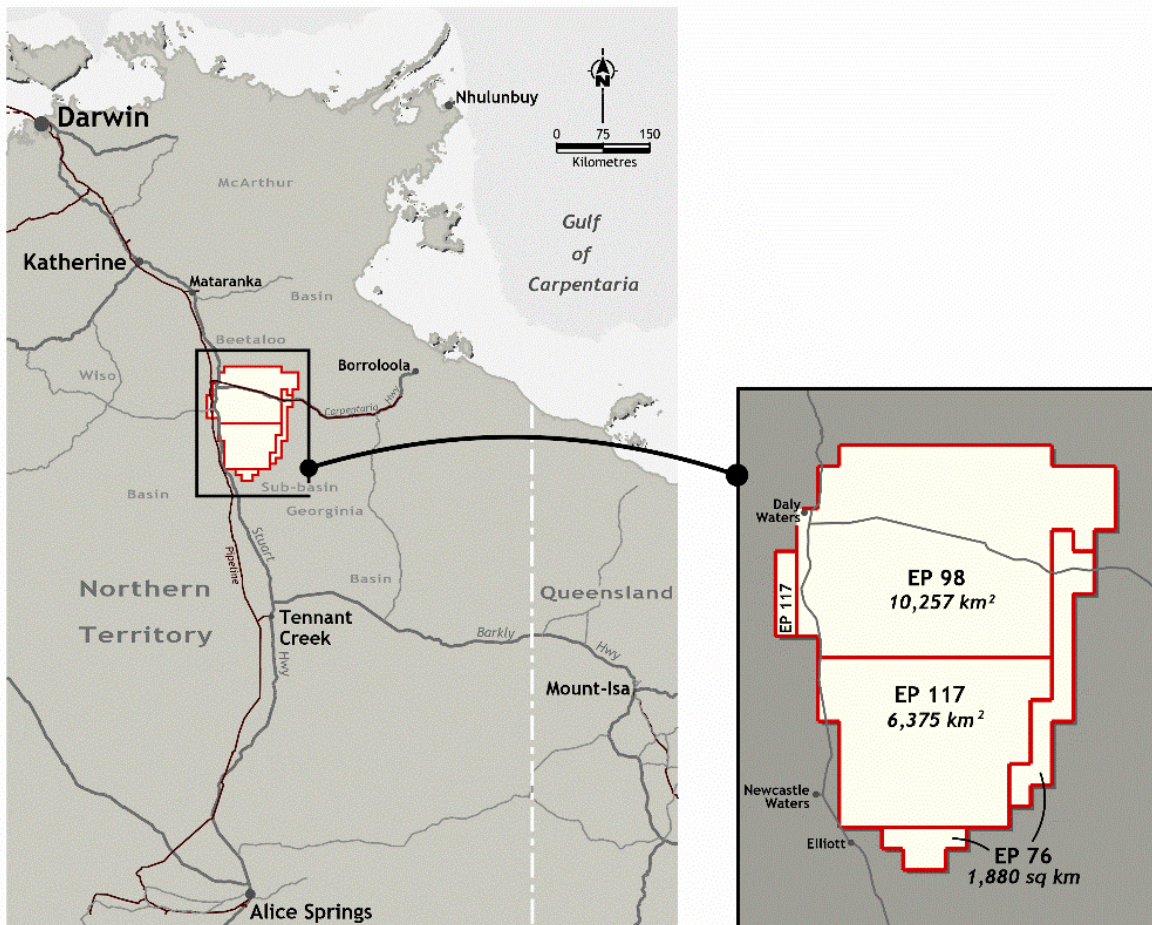


Figure 4: Location of Origin permit area

Table 5: Kyalla 117 N2-2H and 3H and associated infrastructure covered under this EMP

Exploration Permit	Infrastructure Name	Station	Zone*	Approx. Easting	Approx. Northing
EP117	Existing approved Kyalla 117 N2 Lease Pad	Hayfield/Shenandoah	53	356511	8137498
EP117	Proposed Kyalla 117 N2-2H E&A well	Hayfield/Shenandoah	53	356361	8137493
EP117	Proposed Kyalla 117 N2-3H E&A well	Hayfield/Shenandoah	53	356350	8137493
EP117	Existing Temporary main drilling camp	Hayfield/Shenandoah	53	356448	8137813
EP117	Existing Helipad	Hayfield/Shenandoah	53	356278	8137820
EP117	Existing access tracks	Hayfield/Shenandoah	Not Applicable		

*Universal Transverse Mercator (UTM) geographic coordinate system is Geocentric Datum of Australia (GDA) 94.

1.4 Project proponent

The proponent for the project is Origin Energy B2 Pty Ltd as the Operator. Origin representatives can be contacted at origin_nt_beetaloo@originenergy.com.au.

1.5 Broader exploration project

Origin is part way through its nine (9) well exploration and appraisal program, having drilled six (6) exploration wells. The drilling of nine (9) E&A wells is a tenure commitment that must be fulfilled by Origin to comply with the tenure work program requirements. Once the nine (9) E&A well commitment has been achieved, Origin will submit to the DITT for approval of a new work program designed to further assess the prospectively of the shale resources in the region.

To provide an understanding of how the Beetaloo exploration and appraisal program may evolve in the future, a project conceptual road map is provided in Figure 5. As demonstrated in this conceptualisation, the Beetaloo project is in the early appraisal phase, which aims to assess whether hydrocarbons from a prospective shale formation identified during exploration can be successfully and commercially ‘produced’. The conceptualisation also illustrates the reality of E&A programs, with multiple avenues for appraisal failure that may result in some or all prospective resources being assessed as unviable.

Given the high level of uncertainty about the future viability of the project beyond the exploration and appraisal phase, the cumulative impact assessment has been restricted to the current approved three (3) exploration wells remaining on the tenure commitment program. This boundary of the cumulative impact ensures an assessment can be made about what is reasonably known and planned, rather than what could eventuate, if a successful result was achieved. The cumulative impact of the project will be continuously refined as a part of subsequent project approvals.

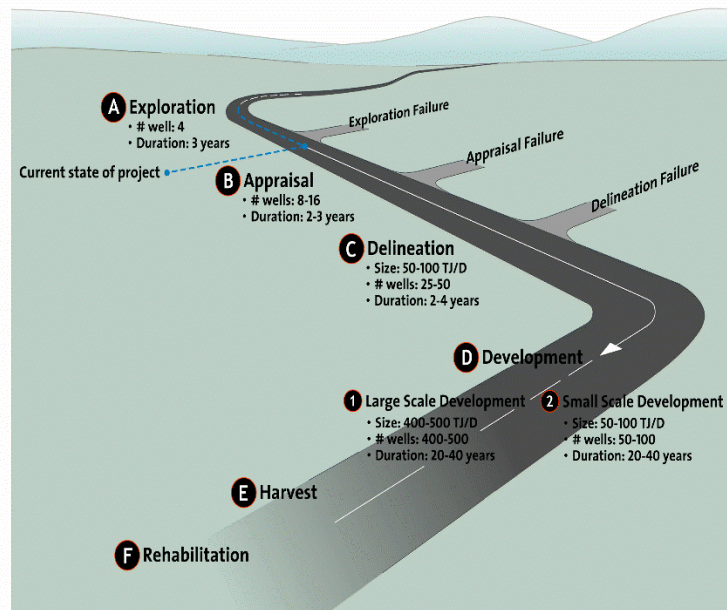


Figure 5: Conceptual Beetaloo sub-basin project pathway from exploration to development

1.6 Multi-well lease pads

The additional two (2) E&A wells covered under this EMP are a natural evolution in the Beetaloo sub-basin E&A project to provide a proof-of-concept for a multi-well pad use within the Kyalla shale resource. The installation of additional wells on the existing lease pad will obtain critical subsurface and surface information used to understand the potential productivity of the reservoir and minimise the environmental impact of a future development. The information collected under this program will be used to:

- validate reservoir flows from the Kyalla target formation at the Kyalla 117 N2 site with multiple wells
- demonstrate HF design is sufficiently developed to ensure isolation between adjacent wells in the target formation in a multi-well pad operation
- demonstrate operability and design of multi-well pad drilling in the Beetaloo to reduce extraction cost and environmental impact
- determine optimal well spacing at a well pad to inform development of the Mechanical Earth Model (MEM) for a future potential Kyalla development (subject to exploration success)
- optimise multi-well pad layout of surface operations for a potential future development scenario with the core objective of minimising the environmental footprint, including minimising land clearance, maximising water reuse and reducing greenhouse gas (GHG) emissions
- demonstrate design requirements and operability of multi-well pad operations across all seasons in the Beetaloo
- assess the financial competitiveness in multi-well pad development scenarios to inform Final Investment Decision for future development scenarios
- demonstrate no impact on groundwater quality at a well site in a multi-well pad operation

- determine optimal requirements for management and removal of drilling wastes and flowback wastewater in a multi-well pad operation
- collect additional data on flowback quality in a multi-well pad operation to assess options for minimising off-site wastewater for off-site disposal through future treatment and re-use
- provide key data as input into future Environmental Impact Statements, including footprint optimisation, flowback characterisation, GHG emission intensity and solid and liquid management.

1.7 Kyalla 117 N2 activity summary

The Kyalla 117 N2-1H E&A well EMP was approved by the Minister in August 2019 (N-2050-15-MP-025) and completed drilling in February 2020. The proposed additional two (2) E&A wells for the Kyalla 117 N2 site (Kyalla 117 N2-2H and Kyalla 117 N2-3H) covered under this EMP will increase the well count at the Kyalla 117 N2 site from one (1) to three (3). The additional E&A wells will result in an increase in the activity intensity at the Kyalla 117 N2 site, as summarised in Table 6. It should be noted that some figures, such as water use, stimulations stages and proppant usage, are anticipated levels and may be higher or lower depending on operational requirements.

Table 6: Kyalla 117 N2 site activity summary table

Component	Approved existing Kyalla 117 N2-1H scope	Additional scope proposed under this EMP (Kyalla 117 N2-2H & 3H)	Total site activity summary (approved and proposed)
AAPA certificate	All works covered under C2020/003 with installation of up to 10 E&A wells per site approved		
Groundwater extraction license	All take covered under existing WEL GRF 10285		
Total area of new disturbance	N/A well site is already established		
Number of E&A wells	1 exploration well: Kyalla N2-1H	2 additional E&A wells: Kyalla 117 N2-2H and Kyalla 117 N2-3H	3 E&A wells in total
Kyalla 117 N2-2H and 3H lateral length	1500m	<2,800m	<2,800m
Number of monitoring bores	2	0	2
Number of gravel pits approved under EMP	0	0	0
Operational workforce	~60 people during drilling and hydraulic fracturing	No Change – ~60 people during drilling and hydraulic fracturing	~60 people during drilling and hydraulic fracturing

Component	Approved existing Kyalla 117 N2-1H scope	Additional scope proposed under this EMP (Kyalla 117 N2-2H & 3H)	Total site activity summary (approved and proposed)
	2-6 people during well testing	2-6 people during well testing	2-6 people during well testing
Main camp capacity	50-60 people	An additional 5 people (camp capacity up to 65 people)	Approximately 65 people
Drilling mini-camp	8 people	No change	8 people
Helipad	50x 50m Helipad	No change	50x 50m Helipad
Peak traffic movements for all Kyalla activities (per day)	44	No change – 44 during rig demobilization	No change – 44
Average traffic movements per day for first 6 months	10-15 (for 3 months)	10-15 (for 6 months)	10-15 (for 6 months)
Average traffic movements per day for the remaining 6-month period	~3-4 (for 6 months)	3-4 (for 6-months)	3-4 (for 6 months)
Truck load-out: wastewater transport	Up to 104 truck movements	~40 truck movements	~40 truck movements ¹
Estimated groundwater usage for Kyalla 117 N2 drilling, stimulation and well testing	~20ML (based on actual water use data)	50ML-110ML	75ML -130ML
Proppant usage (total)	2,500t (actual proppant volume used)	2,700-7,200t (for 20 stages, or 180t -250t of proppant per stage per well)	8,000 to 16,900t
Water storage tank capacity (both make-up and flowback water)	Up to 13.4ML (10.5ML of enclosed and 2.9ML of open capacity)	3.5ML (enclosed tanks capacity)	16.9ML (14ML of enclosed and 2.9ML of open capacity)
Bunded tank pad containment capacity	~9.6ML	No change	~9.6ML

¹ The total truck movements associated with Kyalla 117 N2-1H have been revised down based on an updated water balance

Component	Approved existing Kyalla 117 N2-1H scope	Additional scope proposed under this EMP (Kyalla 117 N2-2H & 3H)	Total site activity summary (approved and proposed)
Flowback/wastewater volume generated onsite	~4.5ML ²	18 (9ML per E&A well) ³	22.5ML
Flowback/wastewater volume (final predicted for treatment and off-site disposal)	<3.6ML	~2.62ML	~2.62ML
Sump capacity	2,400m ³	Capacity increased to 3,000m ³	3,000m ³
Total volume of drilling mud and cuttings generated	~1100m ³ ⁴	~1,500m ³	~2,600m ³
Total volume of waste drilling and completion fluid	3ML ⁵	~1.5-2ML	~5ML
Residual drilling wastewater required for offsite disposal	0ML	0ML	0ML
Transfer pumps	6x 6 inch- up to 23 ML/day	No change	6x 6 inch- up to 23 ML/day
Flares	Vertical and horizontal flare	No change	Vertical and horizontal flare
tCO ₂ -e emissions	~77,501.6 tCO ₂ -e (12 months testing)	24,525 to 60,795tCO ₂ -e (maximum 3-6 months testing)	47,155 to 84,425tCO ₂ -e ⁶ (maximum 3-6 months testing) ⁷
Sediment basin	~20x 20m	No change	~20x 20m
Rehabilitation	15.68ha (approved under the Kyalla 117 N2 water bores and civil construction EMPs)	No change proposed under this EMP	15.68ha (approved under the Kyalla 117 N2 water bore and civil construction EMPs)

² The total flowback produced for Kyalla 117 N2-1H has been revised down based on actual stimulation volumes. A 15.5ML stimulation was executed on the Kyalla 117 N2-1H well, reducing anticipated flowback recovery rates to ~4.5ML

³ This figure represents the mid-case

⁴ Actual data- includes additional cuttings and muds from a small horizontal well section (within the shale formation) that was plugged and abandoned as it did not pass the Well Acceptance Criteria.

⁵ 2ML of additional drilling wastewater was produced due to operational issues (requirement to suspend a section of the Kyalla 117 N2-1H well). This is not anticipated to occur during the drilling of the subsequent wells

⁶ It is anticipated that a range of GHG emissions scenarios could result from exploration well tests. This variation is based upon a) the productivity of each well and the duration of the well test completed on each well. The emissions from the activity will be materially reduced where production rates are or well test days are less than anticipated.

⁷ The emission profile of the Kyalla 117 N2-1H exploration well is anticipated to be significantly lower than expected. This is based on the reduced horizontal length (and associated production rates) and expected reduced well testing time of 3 to 6 months. Greenhouse gas emissions are anticipated to reduce from 77,501.7 tCO₂-e to 22,630 tCO₂-e.

2 Environmental legislation and other requirements

Key Northern Territory and Commonwealth legislation, agreements, operating consents, guidelines and Codes of Practice relevant to the activities described in this EMP are summarised in Table 7. This EMP has been prepared in relation to these requirements.

Table 7: Key legislation

Legislation	Requirement	How Origin meets the requirement	Administered by
Northern Territory			
<i>Petroleum Act 1984</i>	Petroleum exploration licences are required in the areas where activities are proposed	- Exploration permits obtained - Minister provides the final sign off authorising Petroleum activities.	Department of Industry, Tourism and Trade (DITT)
	Compensation to be paid to native title holders and owners/ occupiers of land where petroleum activities are proposed	- Exploration Agreements obtained with Native title holders - Compensation paid to Pastoralists for all activities proposed under this EMP	
	The NT Schedule of Onshore Petroleum Exploration and Production Requirements (' NT Schedule'), should be listed. It covers key regulatory requirements for operational management of well activities in conjunction with the NT Code of Practice for Petroleum Activities.	Requirements addressed in the WOMP	
NT Petroleum (Environment) Regulations 2016	Ensuring all regulated activities have an approved EMP	This EMP has been developed to satisfy this requirement	Department of Environment, Parks and Water Security (DEPWS) <i>NT Petroleum (Environment) Regulations 2016</i>
	That the EMP is developed in accordance with the <i>NT Petroleum (Environment) Regulations 2016</i>	Origin has developed this EMP in accordance with the Petroleum (Environment) Regulation requirements	
	That stakeholder engagement for the regulated activities is undertaken	Origin has completed stakeholder engagement in accordance with the <i>NT Petroleum (Environment) Regulations 2016</i> , as summarised in section 5 of this EMP	

Legislation	Requirement	How Origin meets the requirement	Administered by
	That activities are conducted in accordance with the <i>Code of Practice: Onshore petroleum activities in the Northern Territory</i>	The EMP outlines how the activities will be conducted in accordance with the Code of Practice	
	Reporting requirements for incidents and hydraulic fracturing	The EMP summarises how incidents and flowback monitoring results will be reported	
Bushfires Management Act 2016 and associated regulations	Compliance with total fire bans and fire permitting	Origin will not undertake flaring or the lighting of fires during periods of total fire bans and will obtain a permit where flaring occurs during declared fire danger periods	Bushfires NT
	Requirements for occupiers to prevent and control fires	Addressed through Origin's Bushfire Management Plan (appendix D) which includes bushfire preventative and response measures	
	Aerial burning permits	Origin will acquire permits where aerial burning to manage fuel loads is proposed as a part of its ongoing bushfire management activities. Origin does not consider that aerial burning will be required	
Control of Roads Act 1953 and Northern Territory Traffic Act 1987	Any proposed development which may affect the Territory road network, including traffic, operation, management, capacity or safety, or result in the construction or installation of new infrastructure within the NTG road network, requires assessment and Road Agency Approval	Origin has completed engagement with the Department of Infrastructure, Planning and Logistics (DPIL) regarding proposed and ongoing traffic management	Department of Infrastructure, Planning and Logistics
Environmental Protection Act 2019	Activities which have the potential to cause a significant impact to the environment are required to be referred	Origin has completed a self- assessment in Appendix A. The level of	Northern Territory Environment

Legislation	Requirement	How Origin meets the requirement	Administered by
	to the NT EA for assessment under the EP Act	potential environmental impact is not considered significant	Protection Authority (NT EPA) DEPWS
Heritage Act 2011	Requirements to avoid impacts to heritage places and objects	Origin completed desktop studies and field scouts to confirm the presence/absence of heritage places and objects within the vicinity of the proposed activities	Heritage Branch, Department of Tourism and Culture
Northern Territory Aboriginal Sacred Sites Act 1989	The legislation establishes a procedure for the protection and registration of sacred sites and the issuing of sacred site clearance certificates. Access and work within sacred sites require authorisation	- All areas of Origin's proposed activities have had sacred site clearances completed by Traditional Owners. - AAPA certificates for all exploration activities have been obtained for all activities proposed in this EMP	Aboriginal Areas Protection Authority (AAPA) Minister for Environment
Public and Environmental Health Act 2011	Requirements for camp kitchens and wastewater (sewage and greywater) management and permitting in the NT	Origin's camps are registered and a wastewater works design approval for the main camp and mini-camp sewage treatment plan irrigation area has been obtained	Department of Health
Radiation Protection Act 2004	Requirements for the management of radiation for the health and safety of community and protection of the environment	Origin complies with the Act proper handling of and disposal of drill cuttings.	Department of Health
Territory Parks and Wildlife Conservation Act 1976	Prohibits impacts to protected places, impacts to threatened flora and fauna and interference with protected wildlife	Origin complies with the Act through the avoidance of impacts to protected places (essential habitat, sanctuaries, parks etc.) and flora and fauna. This is completed through ecological surveys and the	Parks Wildlife and Heritage Division of the Department of Tourism Sport and Culture

Legislation	Requirement	How Origin meets the requirement	Administered by
		controls implemented to limit the impact on wildlife	
Transport of Dangerous Goods by Road and Rail (National Uniform Legislation) Regulations 2011	Regulations stipulating the transportation requirements for dangerous goods by road and rail. This includes implementing all required signage, spill management, reporting and licencing requirements for chemical transportation during drilling and stimulation activities.	Any chemical transported and stored for exploration activities is undertaken in a manner that will comply with these requirements.	NT Worksafe, Department of the Attorney-General and Justice
Waste Management and Pollution Control Act 1998	Requirements covering general environmental duty, waste management, including waste management hierarchy, waste transportation and waste disposal requirements.	- The storage, transportation and disposal of wastes will comply with the requirements of this Act. - The transportation and disposal of listed wastes will only be completed by a licenced contractor and at a licenced disposal facility - Any interstate disposal will be completed with an approved consignment authority	NT EPA
	S12 General environmental duty-Applies to activities outside of the lease area, or if a spill or leak occurs that leaves the lease area, or 1 km from the centreline of a pipeline	Origin will conduct all activities outside the approved disturbance area (camp area, lease pad, access tracks authorised in the EMP) in a manner that prevents environmental harm	
	S14 Duty to notify of incidents causing or threatening to cause pollution: Applies if an incident occurs outside of the lease area, or if a spill or leak occurs that leaves the lease area, or 1 km from	Origin will report all incidents that causes or threatens to cause pollution beyond the boundary of the	

Legislation	Requirement	How Origin meets the requirement	Administered by
	the centreline of a pipeline, that causes or threatens to cause material or serious environmental harm.	authorised activity (beyond the lease or camp pad), in accordance with Section 14 of the WMPCA	
Water Act 1992 and Water Regulations 1992	The Act requires that all groundwater take in the Beetaloo sub-basin must have obtained a Water Extraction Licence (WEL)	Origin has obtained a Water Extraction Licence (WEL) GRF 10285 covering water usage required to complete exploration activities (Appendix E). Water extraction licences will be renewed periodically as required to support operational activities.	Water Resources Division, Department of Environment, Parks and Water Security (DEPWS)
	The take of surface water for petroleum activities is prohibited	No surface water take is proposed under this activity	
	Prohibits wastewater releases to surface water bodies or reinjection	No wastewater release to surface water proposed	
Weeds Management Act 2001	- Requires the occupier of the land (in this case Origin) to - prevent the land being infested with a declared weed - prevent a declared weed or potential weed on the land spreading to other land - notify the weeds officer of the presence of the declared weed - comply with any declared weed management plans	Origin will comply with the requirement of this Act through the implementation of weed prevention, detection and eradication controls through its approved weed management plan (Appendix J)	Weed Management Branch, Department of Environment, Parks and Water Security (DEPWS)
Work Health and Safety (National Uniform Legislation) Act 2011	Provides for a nationally consistent framework to secure the health and safety of workers and workplaces. Includes requirements for hazardous chemical assessments, hazardous chemical register, access to safety data sheets, labelling, and the use, handling, generation and storage of hazardous chemicals at a workplace.	Origin has a Safety Management Plan that outlines how the requirements of the Act are achieved. This includes the management of chemical storage dossiers, safety data sheets (SDS) and appropriate procedures and controls to prevent worker exposure to hazards.	NT WorkSafe, Department of the Attorney-General and Justice

Legislation	Requirement	How Origin meets the requirement	Administered by
Commonwealth			
Environment Protection and Biodiversity Conservation Act 1999	Requires approvals for any activity likely to have an impact on a Matter of National Environmental Significance (MNES)	A self-assessment was completed as a part of this EMP to determine whether a MNES is likely to be impacted by the proposed activities within this EMP. Impacts to MNES are not anticipated to occur.	Department of Agriculture, Water and Environment
National Greenhouse and Energy Reporting Act 2007	An Act that requires operators who generate emissions over a threshold to report information related to greenhouse gas emissions, greenhouse gas projects, energy consumption and energy productions of corporations	All energy consumption and greenhouse gas data used/generated as a result of this activity will be reported in accordance with this act	Department of Industry, Science, Energy and Resources
National Environment Protection Council Act 1994 (National Environment Protection (Assessment of Site Contamination) Measure 1999) (NEPM)	This Act provides a nationally consistent approach to the assessment of site contamination to ensure sound environmental management practices to protect human health and the environment	Origin uses the NEPM to assess risk of contamination and for the assessment of the drilling fluids for disposal.	Department of Agriculture, Water and Environment
Native Title Act 1993	Legislation that provides for ways in which future dealings affecting native title may proceed and the recognition and protection of native title. The Right to Negotiate requirements are the most relevant provisions applying to Origin's exploration activities.	The Right to Negotiate process was applied to the grant of Origin's permits, resulting in Section 31 Agreements and Exploration (Ancillary) Agreements covering Origin's permits. The Traditional Owners were and continue to be represented by the Northern Land Council (NLC)	Prime Minister and Cabinet

Legislation	Requirement	How Origin meets the requirement	Administered by
		- Origin continues to implement the Exploration Agreements, in collaboration with the NLC, with all work programmes being reviewed and approved by Traditional Owners - Origin has the consent of the Traditional Owners for activities proposed in this EMP, evidenced by the Section 31 Agreements and the implementation of the relevant Exploration Agreement	

2.1 Alignment with the principles of Ecologically Sustainable Development

This EMP is consistent with the principles of Ecologically Sustainable Development (ESD) through the adoption of responsible practices that are designed to maximise social benefit, while minimising the level of impact on the surrounding ecosystems.

Principles of Ecologically Sustainable Development (as defined in the *NT Petroleum (Environment) Regulations 2016*)

1. Decision making principle – decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations
2. Precautionary principle – if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation
3. Principle of evidence-based decision making – decisions should be based on the best available evidence in the circumstances that is relevant and reliable
4. Principle of intergenerational and intragenerational equity – that the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations
5. Principle of sustainable use – natural resources should be used in a manner that is sustainable, prudent, rational, wise and appropriate

6. Principle of biological diversity and ecological integrity – the conservation and maintenance of biological diversity and ecological integrity should be a fundamental consideration in decision-making
7. Principle of improved valuation, pricing and incentive mechanisms – improved valuation, pricing and incentive mechanisms should be promoted including market based environmental incentives, the polluter pays principle, life cycle analyses, and the inclusion of environmental factors in the valuation of assets and services

Origin's exploration activities align with the principles of ESD.

- Exploration activities are an essential step in defining a potential future commercial resource which can generate sustainable, long-term benefits to the local community, to the Barkly region generally and more broadly into the rest of the NT (Principles 1 and 5)
- Complying with the Petroleum Code of Practice and industry best practice to reduce the risk to the environment and communities to an acceptable level. Noting the Inquiry Panel's Final Report Statement that "provided that all of the recommendations made in this Report are adopted and implemented in their entirety, not only should the risks associated with an onshore shale gas industry be minimised to an acceptable level, in some instances, they can be avoided altogether." (*Scientific Inquiry into Hydraulic Fracturing in the Northern Territory 2018*) (All principles)
- The activities that are the subject of the EMP do not constitute threats of serious or irreversible environmental damage and there is no impact on the conservation of biological diversity and ecological integrity (Principles 4 and 6)
- Beyond royalty payments to the NT Government (as owner of the natural resource), and payments to Native Title Holders (as per Exploration Agreements) and host pastoralists (as per Access and Compensation Agreements), Origin seeks to maximise broad-based local participation in education, training, employment and enterprise opportunities engendered by its presence (Principles 1 and 5)
- Prioritising the use of local employment to deliver exploration activities (Principles 1 and 5)
- Obtaining sacred site clearances from host Traditional Owners through open engagement with custodians, the Statutory Representative body – the Northern Land Council (NLC) and the Aboriginal Land Protection Authority (AAPA) (Principles 1, 4 and 5)
- Obtaining Land Access Agreements with host pastoralists (Principles 1 and 5)

3 Description of regulated activities

This EMP covers the regulated activities required to enable Origin to drill, stimulate, test, maintain and decommission the Kyalla 117 N2-2H and Kyalla 117 N2-3H horizontal E&A wells within the 2021-2024 period. To accommodate this scope, the activities summarised in Table 8 are proposed to be executed under this EMP.

Additional land clearing is not proposed under this EMP. All activities will be undertaken in existing disturbed areas approved under the Kyalla 117 N2 Civil Construction EMP NT-2050-15-MP 026.

Table 8: Description of the exploration and appraisal activities for the proposed Kyalla 117 N2-2H and Kyalla 117 N2-3H horizontal wells

Activity	Description
Site set-up and mobilisation to support the Kyalla 117 N2-2H and Kyalla 117 N2-3H E&A program	• Use of existing access tracks to and from the Kyalla 117 N2 site from the Stuart Highway • Use of the existing cleared and graded Kyalla 117 N2 lease pad, including lease pad, access tracks, camp pads, stockpile storage areas and helipad • Installation of two (2) well cellars at Kyalla 117 N2 to accommodate Kyalla 117 N2-2H and Kyalla 117 N2-3H • Extension of the existing Kyalla 117 N2 drilling sump from 2,400m to ~3,000m³ (if required) • Set-up of two (2) temporary camps – a main camp (65 person capacity) and a drilling mini-camp (8 person capacity), both located at existing Kyalla N2 camp pads • Set up of chemical and material storage areas • Set-up of drilling rig, including blow-out preventors, fluid systems and associated equipment such as pipe racks and cementing units at Kyalla 117 N2 • Set-up of HFS equipment, completions rig and equipment, well testing equipment, and other associated equipment at Kyalla 117 N2
E&A activities at the existing Kyalla 117 N2 site including drilling, hydraulic fracture stimulation (HFS) and well testing of Kyalla 117 N2-2H and Kyalla 117 N2-3H	• Operation of two (2) temporary camps – a main camp (65 person capacity) and a drilling mini-camp (8 person capacity), both located at existing Kyalla N2 camp pads • Transportation, handling and storage of bulk chemicals, fuels and wastes • Drilling of the Kyalla 117 N2-2H and Kyalla 117 N2-3H horizontal E&A wells, including the vertical component of the well and collection of reservoir quality data • Well design in accordance with the Code of Practice and approved Well Operations Management Plan (WOMP) including isolation of freshwater aquifers • HFS of Kyalla 117 N2-2H and Kyalla 117 N2-3H • Completion and testing of Kyalla 117 N2-2H and Kyalla 117 N2-3H E&A wells • Gas flaring in accordance with Code of Practice requirements and as per US EPA 40 CFR 63.11, with a flare tip combustion efficiency of 98% • Maintenance and monitoring works on Kyalla 117 N2-2H and Kyalla 117 N2-3H E&A wells in accordance with approved WOMP

Activity	Description
	- Suspension and decommissioning Kyalla 117 N2-2H and Kyalla 117 N2-3 E&A wells (if required) in accordance with the Code of Practice - Groundwater extraction of approximately 75-110 ML under existing groundwater extraction licence (WEL GRF 10285) - Monitoring activities (including groundwater, stormwater, soils, leak detection and all other low impact ancillary data collection programs)
Onsite wastewater management to support ongoing E&A program	- On-site wastewater storage and treatment in accordance with Code of Practice - Use of the drilling sump, enclosed wastewater storage tanks and wastewater treatment tanks to manage drilling and flowback wastewater - Drill cuttings and flowback fluid quality testing in accordance with the Code of Practice - Drilling waste storage and disposal located with the existing Kyalla 117 N2 site or transported offsite - Offsite disposal of wastewater in accordance with the Waste Management and Pollution Control Act
Site demobilisation	- Demobilisation of exploration equipment, including camps, drilling rigs, HFS equipment, completion rigs, well testing equipment, wastewater storage tanks and various service provider equipment - Approximately 44 traffic movements per day during site demobilisation
Site rehabilitation	- Decommissioning and removal of all surface infrastructure and wastes from site including the removal of drilling sump, wastewater tanks, cellars, equipment, non-drilling waste, wastewater and all ancillary equipment - Final rehabilitation activities conducted under approved Civil Construction EMP (NT-2050-15-MP-34) in accordance with the approved rehabilitation plan (Appendix M).

3.1 Timeframes

The anticipated key activity dates for the drilling, stimulation and well testing program are detailed in Table 9 and illustrated in Figure 9. The drilling, stimulation and well testing of the two (2) proposed additional wells (Kyalla 117 N2-2H and Kyalla 117 N2-3H) is contingent on the well testing results of the existing Kyalla 117 N2-1H E&A well. These additional wells will likely be drilled if the well test results confirm the potential viability of the shale resource through sustained gas and condensate flow rates.

It should be noted that the below timeframes are indicative, with final dates and decision to complete activities dependent on a range of additional considerations, including access, commercial and joint venture constraints. An update on the project will be provided to DEPWS on a monthly basis.

Table 9: Anticipated activity dates

Activity	Estimated dates
Existing approved exploration activities	
E&A well drilling Kyalla 117 N2-1H	February 2020 (completed)
E&A well stimulation Kyalla 117 N2-1H	October 2020 (completed)
Work instruction finalised and issued to contractors	March 2021
E&A well testing Kyalla 117 N2-1H	October 2020 to January 2021
E&A well suspension Kyalla 117 N2-1H	February 2021
Proposed scope covered under this EMP	
Kyalla 117 N2 site preparation – sump extension, cellar installation and drilling rig commissioning	March/April 2021
E&A well drilling Kyalla 117 N2-2H & 3H	April-August 2021
E&A well stimulation Kyalla 117 N2-2H & 3H	August-September 2021
E&A well testing Kyalla 117 N2-2H & 3H	October 2021-October 2022*
E&A well suspension Kyalla 117 N2-2H & 3H	October/November 2022
Full site demobilisation and stabilisation	November 2022
Well decommissioning	November 2024 (dependent on the success of the exploration well)
Rehabilitation of site	December 2024 (contingent on well decommissioning and covered under Kyalla 117 N2 Civil Construction EMP NT-2050-15-MP 026.)

*worst case assumes 6-month well test

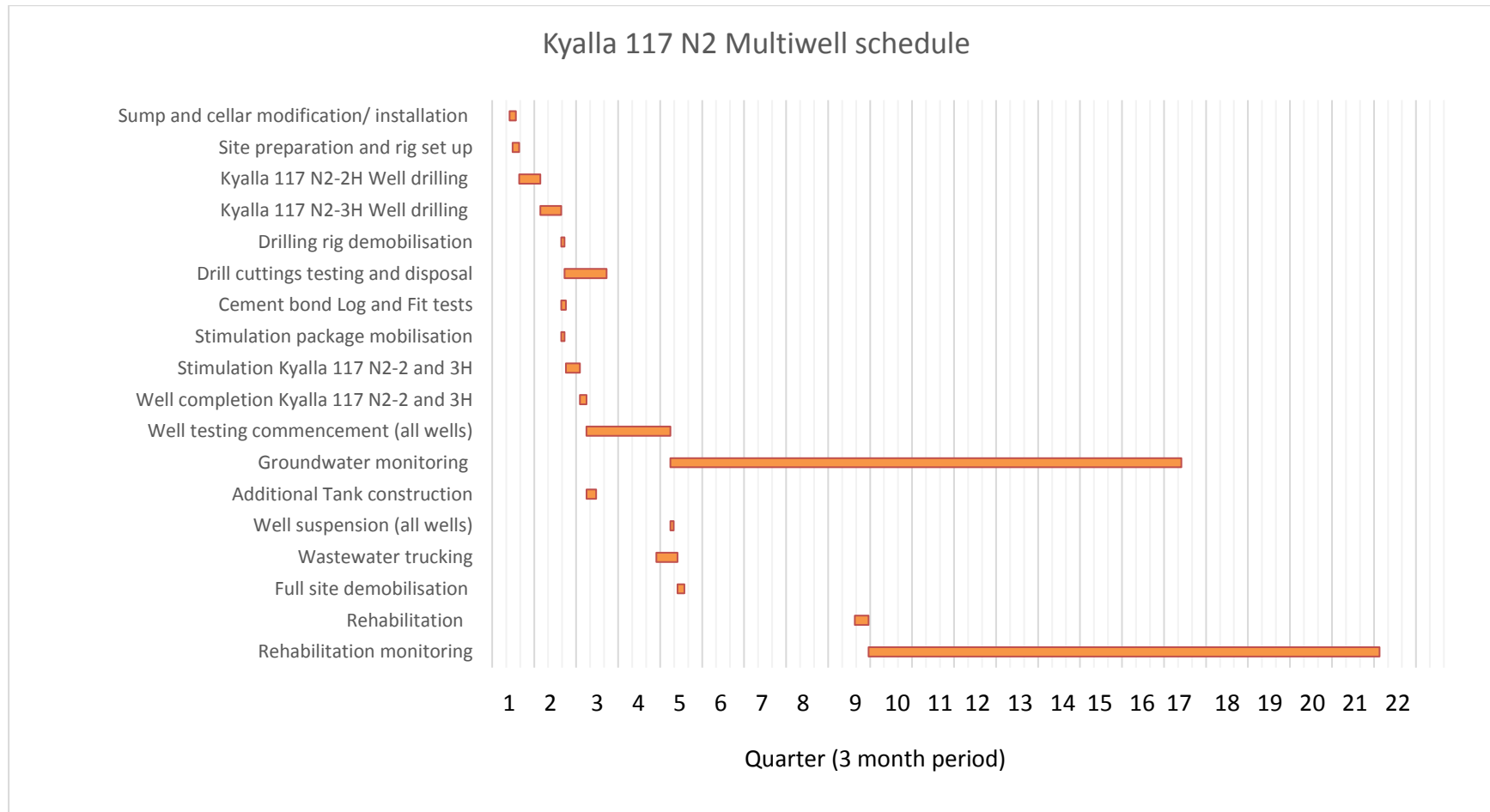


Figure 6 Timeline of Kyalla multiwell activities

3.2 Kyalla 117 N2 site setting

The Kyalla 117 N2 site (including the lease pad, helipad, camp pad, drilling sump and well cellars) is an existing disturbed area that was constructed under the approved Kyalla 117 N2 Civil Construction EMP NT-2050-15-MP 026 (https://depws.nt.gov.au/_data/assets/pdf_file/0006/706155/ep117-origin-betaloo-basin-kyalla-emp.pdf) .

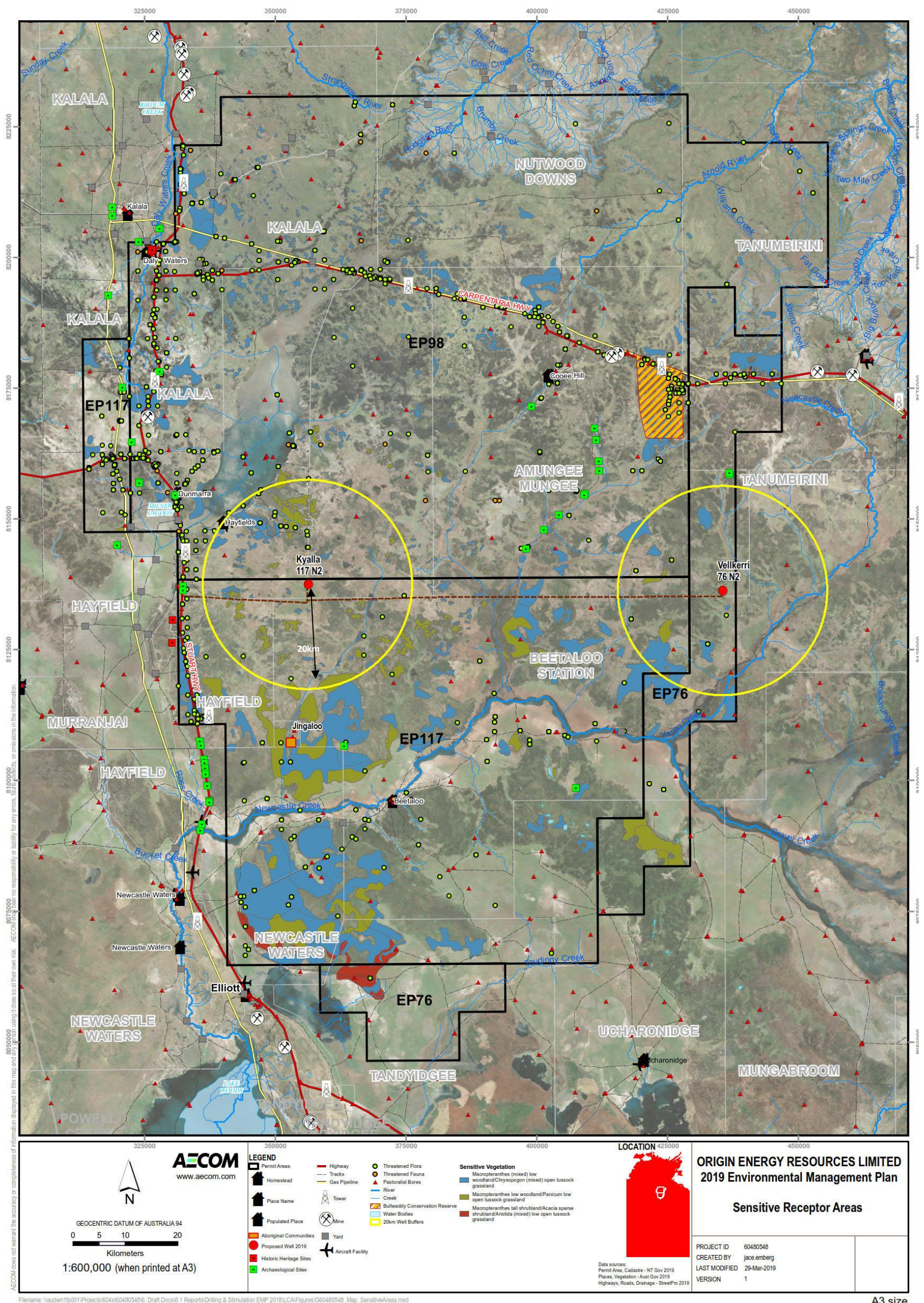
The site was chosen using a multi-criteria analysis based on the geological, environmental, cultural and social suitability of the site. Field ecological, cultural heritage and Native Title clearances were obtained to ensure avoidance of the following areas:

- High conservation value
- High habitat value
- Water courses or major overland flow paths
- Areas of cultural significance
- Sensitive receptors (homestead and communities)
- Existing pastoralist groundwater extraction bores
- Major roads

A description of the existing environment is provided in section 4. The site is located in *Corymbia* low woodland/*Terminalia* (mixed) sparse shrubland/*Chrysopogon* (mixed) low tussock grassland. This vegetation community is regionally extensive, not threatened and in good condition.

Approximate separation distances to the nearest environmental and community receptors is illustrated in Figure 7 and includes:

- 16km from the closest pastoralist bore
- 20km from the Stuart Highway
- 21km from the nearest homestead
- 28km from Frew Ponds
- 29km from the nearest community (Dunmarra)
- 71km from the closest conservation area (Bullwaddy Conservation reserve)
- 50 km from the closest major watercourse (Newcastle Creek) and 12km from the closest stream order 1 unnamed watercourse (refer Figure 7 and the Land Condition Assessment report (AECOM 2018) provided in the [Beetaloo Basin Kyalla, Civil Construction EP117 N2 EMP](#), approved 6 June 2019, Appendix C
- 92 km from Lake Woods (direct)



A3 size

Figure 7: Kyalla 117 N2 proximity to sensitive receptors

3.2.1 Existing Kyalla 117 N2-1H exploration well

The existing Kyalla 117 N2-1H well was spudded on 8 October 2019, following Ministerial approval in August 2019. The Anthony Lagoon and Gum Ridge was successfully isolated through casing and cement on 25 October, with the final verification report submitted to DEPWS on 7 November.

Drilling of the Kyalla 117 N2-1H well successfully reached the Total Depth (TD) of 1,865m for the vertical section after 35 days of drilling. Data was collected on reservoir properties to further evaluate the potential prospectively of the encountered upper and lower Kyalla shale resource. This included:

- Collecting gas composition data during drilling and sampling using isotubes – initial gas composition results confirm the presence of liquids rich gas, with further evaluation of gas composition to be undertaken during well testing
- Successfully obtaining core from various intervals within the upper and lower Kyalla shale, which were sent for further diagnostic testing at an international test
- Performing open hole Diagnostic Fracture Injection Tests (DFIT) from the upper and lower Kyalla shale– which were then used to select the direction of the horizontal well.

Drilling of the horizontal section of the Kyalla 117 N2-1 was successfully completed on 20 February 2020. Following this milestone and with the onset of the global COVID-19 pandemic, Origin made the decision to suspend all exploration activities for a period of five (5) months.

In September 2020, work recommenced on the Kyalla 117 N2 site under an approved COVID management plan. An 11-stage hydraulic fracture stimulation was successfully executed on the Kyalla 117 N2-1H well, with no technical difficulties encountered. The Kyalla 117 N2-1H well is currently undergoing well testing activities, with insufficient information available at this stage to determine the success of the exploration well.

A schematic of the existing Kyalla 117 N2 lease pad is provided in Figure 2.

3.3 Cellar construction and drilling sump modification

The existing well cellar for the Kyalla 117 N2-1 and drilling sump has been constructed under the Kyalla 117 N2 Civil Construction EMP NT-2050-15-MP 026. To accommodate an additional two (2) E&A wells, an additional two (2) cellars will be installed and the existing drilling sump modified.

The two (2) 8m³ cellars will be constructed on the proposed lease to accommodate the wellhead equipment and blow-out preventer (BOP). The cellars are concrete lined and will be prefabricated off-site. The cellars are transported to the site in one (1) piece and lowered into an excavated pit. A conductor casing is installed within the cellar to approximately 20m using an auger. The conductor casing is designed to prevent the upper sections of the exploration well from caving in when drilling through the unconsolidated sediments. The cellar itself will be fenced at all times to exclude fauna ingress. A picture of a cellar is provided in Figure 8.

The existing drilling sump is 77m long x 23m wide x 4.8m deep. Depending on operational requirements (such as final length of both proposed lateral well sections), the existing drilling sump may require expansion to manage the additional drill cutting, muds and fluids under this program. Where such an expansion is required, the sump will be expanded to increase its storage volume from 2,400m³ to 3,000m³.

The new section of the sump will be located adjacent to the existing sump. The new section will be excavated, lined with a coletanche liner and then joined (welded) into the existing sump liner. The new addition is proposed to be shallower than the existing sump, which will allow for some waste drilling material to be kept in-situ during the activity. This is designed to minimise waste handling and keep the existing sump liner weighed down to prevent any tears or damage. To accommodate this activity,

the drilling waste levels will be reduced below the liner tie-in point, with an allowance made for a seasonal freeboard (as dictated in the Code of Practice). The waste fluids, muds and cuttings will be removed to an onsite wastewater storage tank or disposed of in accordance with section 3.9.1.3.

Further information on the coletanche liner is provided in section 3.9.1.1.



Figure 8: Picture of a cellar prior to installation

3.4 Exploration well drilling

3.4.1 Well design

Well design is the first step in ensuring the integrity for each proposed well. Origin's subsurface team, (geologists, geophysicists and petroleum engineers) summarise the key information and data required by the drilling engineers to design each E&A well. This forms the Basis of Well Design (BOWD).

Critical inputs into the BOWD

- Existing geological data available for the site (such as geological data obtained from the existing Kyalla 117 N2-1H well)
- 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 (production and/or reservoir evaluation)
- The fracture gradient, which describes how much pressure is required to fracture a specific formation
- The pore pressure, which is the in-situ fluid pressure within a reservoir
- The orientation and separation of each vertical and horizontal well
- Other conditions that may affect the integrity of the well (formation fluid composition, stress regime, etc.)

The BOWD is used in combination with the requirements outlined in the Code of Practice, *NT Petroleum (Environment) Regulations 2016* and Origin's internal standards to develop an appropriate well design that ensures well integrity is maintained throughout the life of the well and addresses all regulatory and risk management requirements.

The design process includes the definition of Well Acceptance Criteria (WAC). WAC are critical thresholds that are tested during well construction and typically form components of the well barrier

envelope. The barrier envelope is the combination of one (1) or more well barrier elements that are combined to prevent uncontrolled flow of fluids and hydrocarbons into another formation, or to escape at surface. The isolation and protection of aquifers is a critical component of the WAC. The WAC must be met or exceeded to confirm well integrity before proceeding to the next phase of well construction or operation. If a well WAC is not achieved, an approved remedy and/or risk assessment must be in place prior to moving forward with operations.

The well design and WAC form a critical part of the Well Operations Management Plan (WOMP), which is a regulatory document that summarises how each well will comply with the required standards from the design to decommissioning of a well. This document is prepared and submitted to DITT for approval prior to the commencement of any drilling and stimulation activities. Where required, any deviation from the approved WOMP will need to be reviewed and approved by DITT prior to proceeding.

To accommodate multiple wells, each well is separated on surface by a minimum of 5-10m. This separation distance is calculated from the hole centre to hole centre and is selected to accommodate the rig package and future well interventions. Petroleum wells on a multi well pad (both within Australia and internationally) are typically separated by a distance of 8-10m, but may be located in closer proximity where safe to do so (for example Coal Seam Gas Wells are shallower, need smaller drilling rigs to drill and may be separated by 3-5m). Well deviations from the vertical plane during drilling are monitored through the use of standard survey tools as discussed in section 3.4.3.

Each horizontal well is drilled at a sub-surface separation distance of at least 200-400m (with the final separation distance determined from the Kyalla 117 N2-1H well test results and updated mechanical earth model) to ensure the stimulated zones between wells are not connected during stimulation. If two (2) stimulation zones within the target reservoir were connected, this could reduce the productivity of each of the wells. It would not represent an environmental risk, as the stimulated zones are within the Kyalla shale formation.

A series of schematics of the Kyalla 117 N2 multi-well pads and typical well design are provided in Figure 9 to Figure 14.

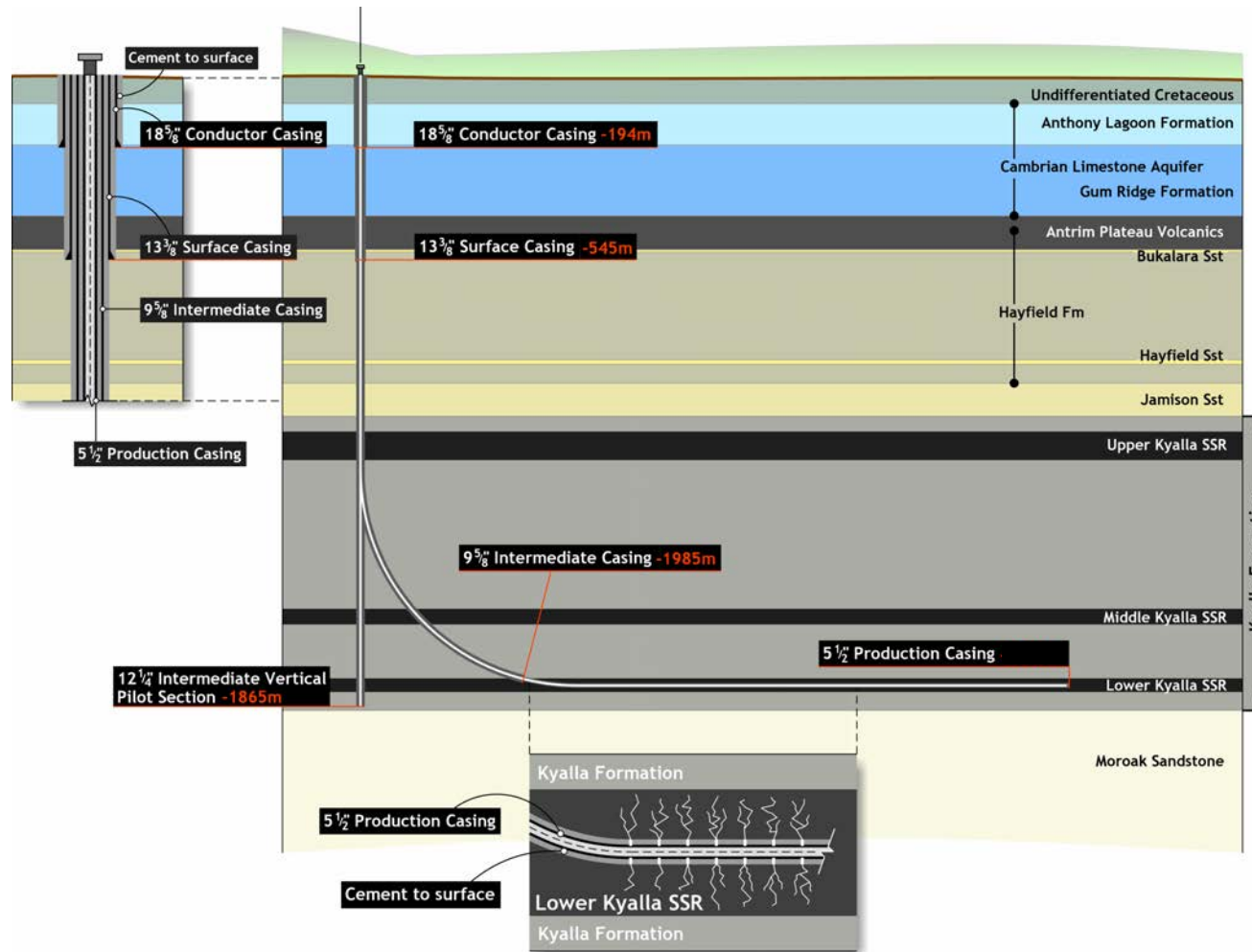


Figure 9: Typical Kyalla 117 N2 well section design schematic

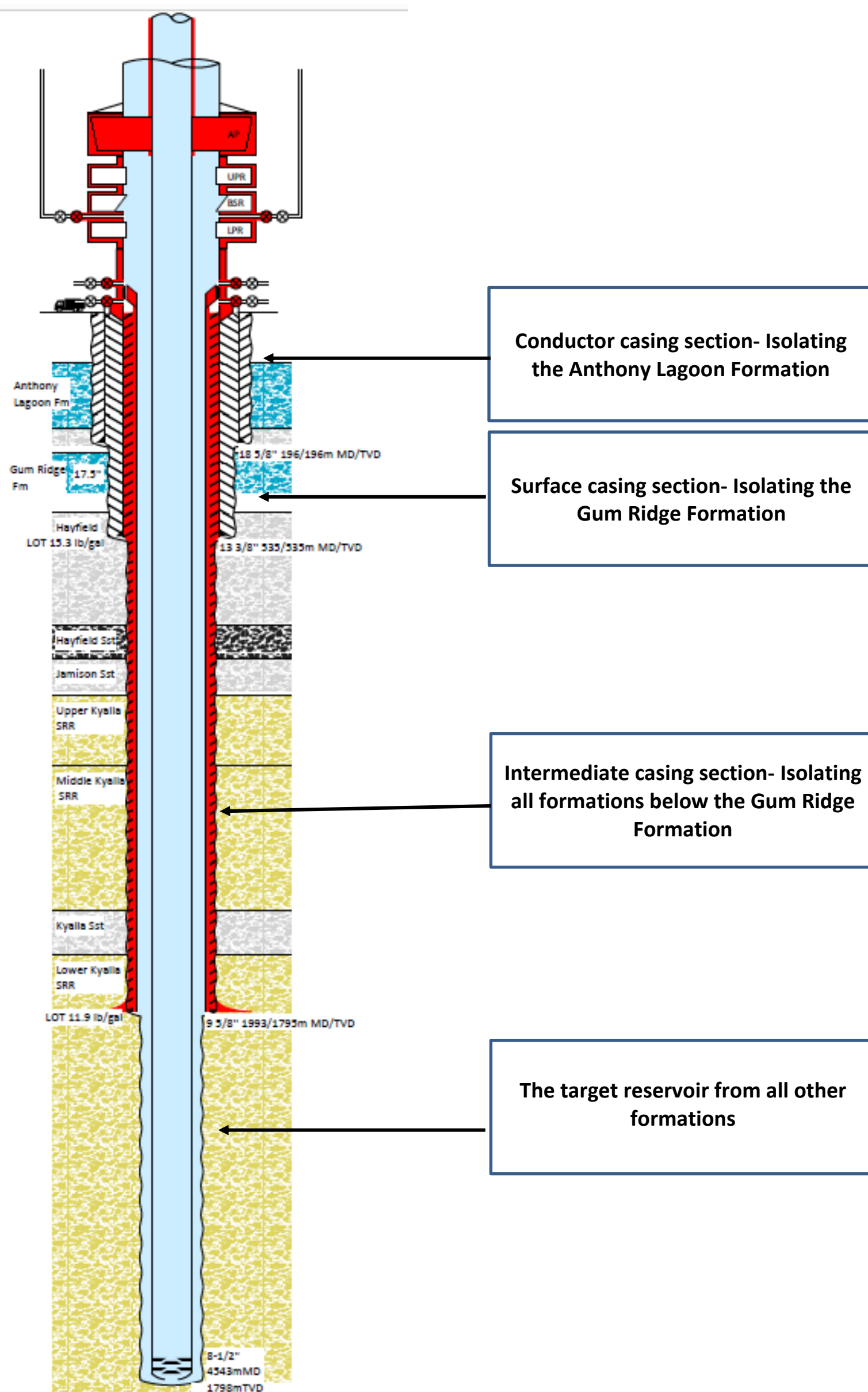


Figure 10: Proposed typical Kyalla 117 N2 well sections – conductor and surface, intermediate and production casing strings of each exploration well

Kyalla 117— HFS Emergency Response Equipment Layout & Hazardous Zoning

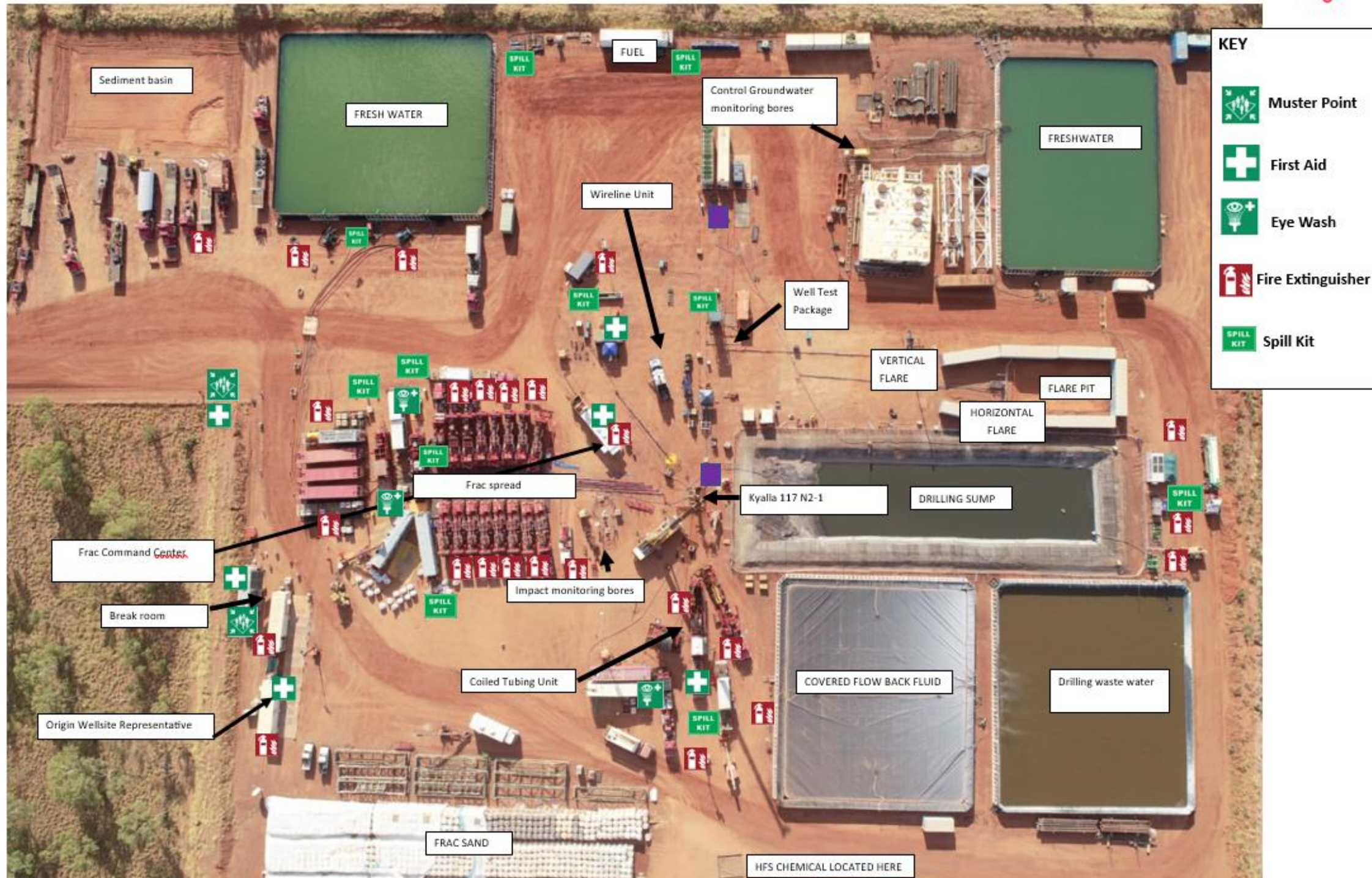


Figure 11: Top-down view of the Kyalla 117 N2 lease pad on the Hayfield/Shenandoah Station

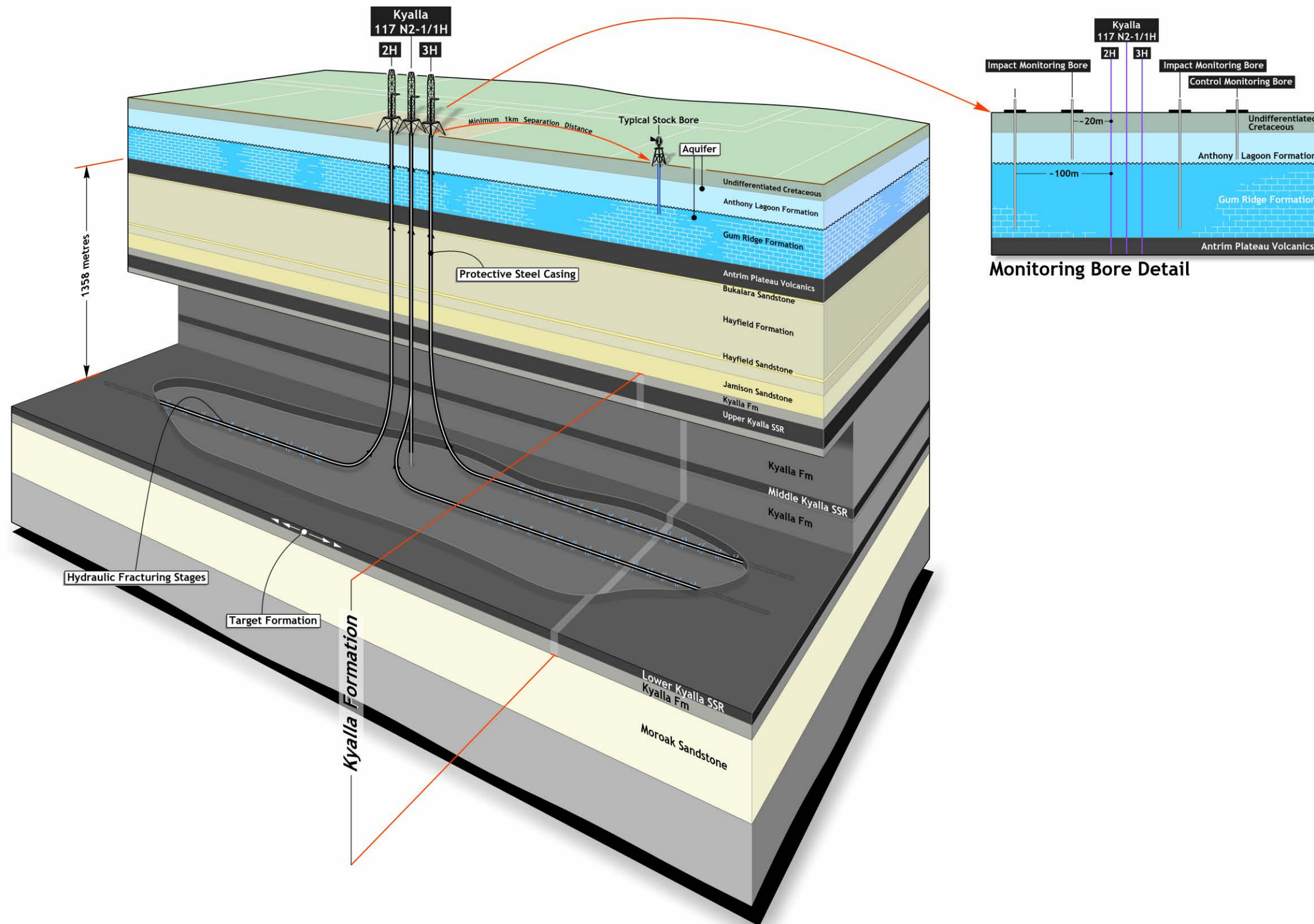


Figure 12 Kyalla 117 multi-well schematic

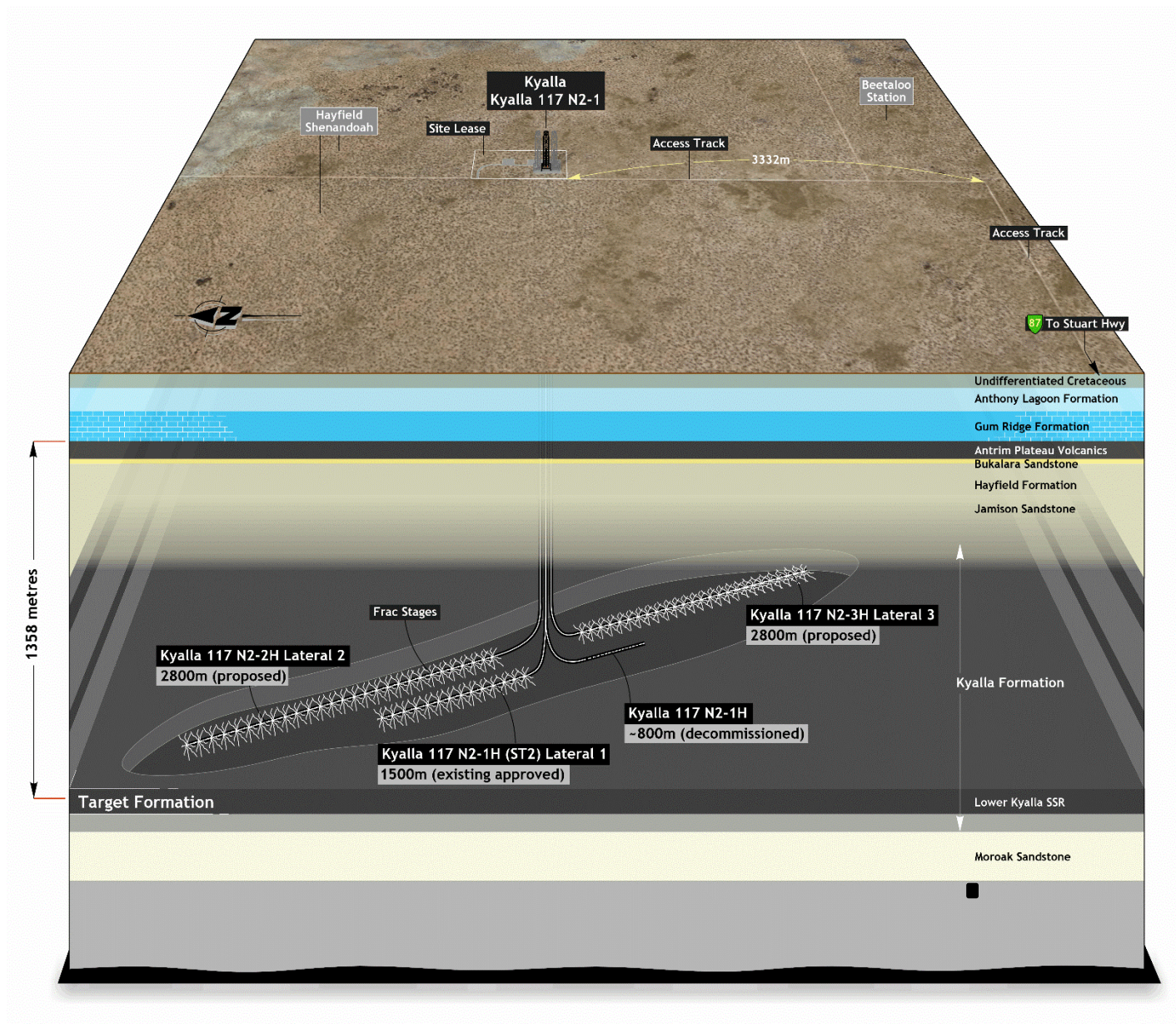


Figure 13: Sub-surface schematic of the Kyalla 117 N2 site with current approved and proposed E&A wells

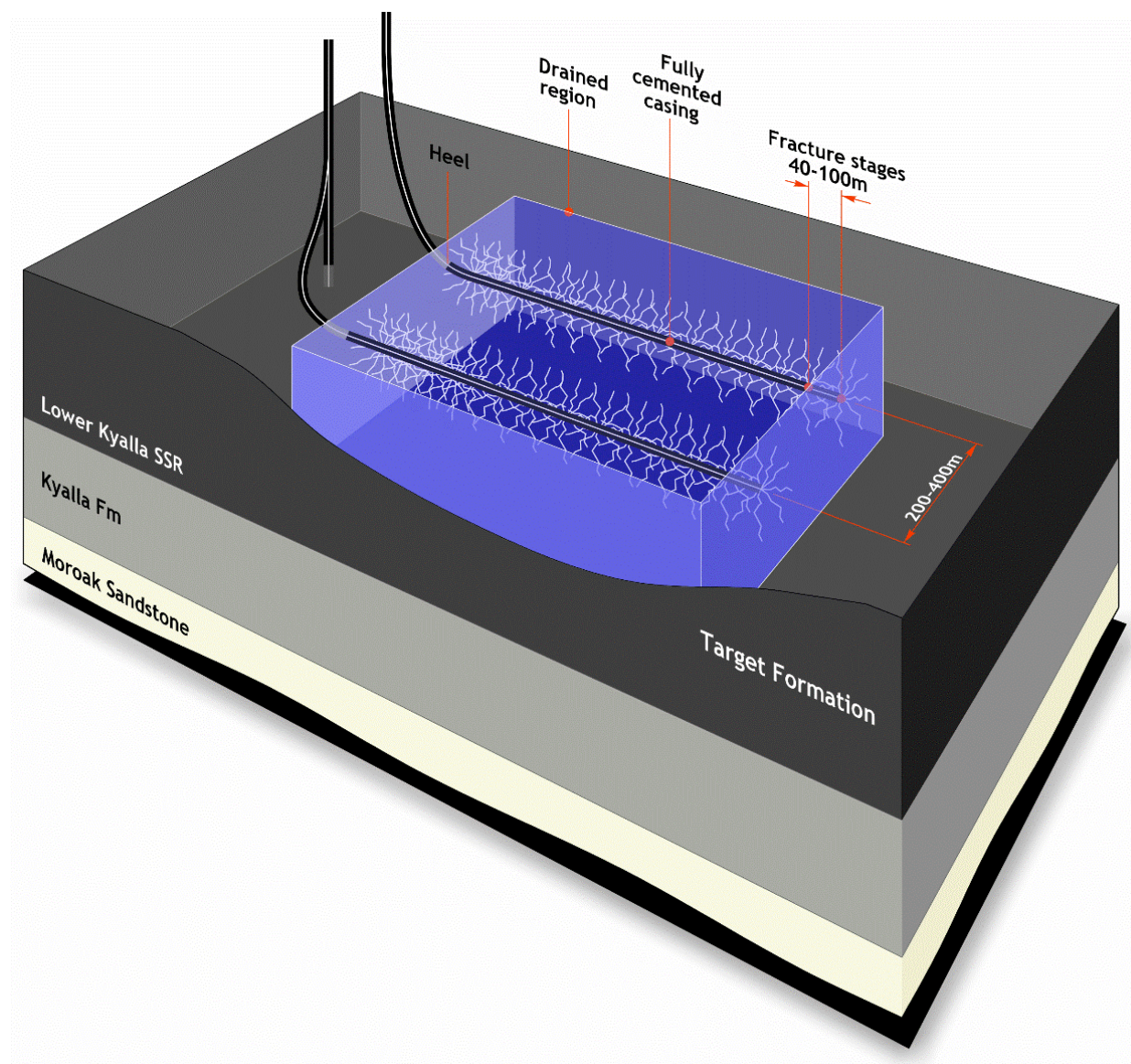


Figure 14: Kyalla 117 N2 multi-well subsurface schematic – well separation and fracture propagation zoom in

3.4.2 Site preparation

A drilling rig package will be mobilised to site and constructed to prepare for the commencement of drilling activities. The rig package comprises the main rig, as well as the supporting vehicles, equipment and facilities outlined below.

- Rig mat, an impermeable liner containing all spills from the drilling rig
- Drilling rig, comprising a rig floor, a mast or derrick, rig engine, Blow Out Preventer (BOP) system and catwalk
- Pipe rack for storing drill pipe and casing and potentially a pipe arm, which is a piece of equipment designed to bring the pipe and casing up to the drill floor
- Rig fluid system, including tanks (water and mud), shakers, mud treatment system and pipes for storing and pumping fluids down the drill string
- Storage trailers and racks for equipment
- Bunded chemical storage areas for mud chemicals, diesel and wastes
- A workshop
- Portable on-site offices
- Rig mini-camp, wastewater treatment system and irrigation area
- Temporary accommodation housing approximately 65 people
- Diesel power generators
- Third-party equipment such as cementing trucks, fuel trucks and wireline evaluation units.

It is anticipated that the drilling rig will be located on the existing Kyalla 117 N2 site, with no additional rig movements required. Throughout drilling operations there will be ongoing vehicle movements, from the initial rig mobilisation to the interchange of drilling support services or delivery of equipment (a discussion of traffic is provided in section 3.22). Drilling operations are generally a 24-hour per day operation.

An overview of the drilling rig lease layout is provided in Appendix B, Figure 2 and Figure 15.

3.4.3 Drilling

Up to two (2) additional E&A wells are proposed to be drilled on the existing Kyalla 117 N2 site. The two (2) new proposed E&A wells, Kyalla 117 N2-2H and Kyalla 117 N2-3H, will be drilled once the existing approved Kyalla 117 N2-1H well has finished well testing activities. Kyalla 117 N2-1H ST2 well testing operations are anticipated to extend for three (3) months, with the drilling of the two (2) additional E&A wells only undertaken if the well testing results (production rates) indicate that the Kyalla shale is a viable target.

Drilling of multiple wells on a pad requires the use of specialised surveying tools to ensure the well path is constructed to design and to eliminate the risk of sub-surface collision with the existing wells on location. These survey tools use drill bit Global Positioning System (GPS) tracking to monitor the downhole position and trajectory of the well when drilling. Safety envelopes are established around each existing well to detect when a well has begun to deviate into the proximity of the adjacent well. This reduces the likelihood of a subsurface collision, which represents a significant well integrity and economic risk to the project through loss of multiple assets. The use of GPS surveying tools is a

standard industry control that has been effectively used for multi-well pad drilling within Australia and internationally.

Once the rig is functional, the top-hole section will be drilled for each E&A well to a depth which isolates the shallow aquifers (Anthony Lagoon Formation & Gum Ridge Formation) in this region. The drilling results from the Kyalla 117 N2-1H exploration well have confirmed the undifferentiated cretaceous formation is not water bearing and is therefore not considered an aquifer at this location (i.e. does not contain groundwater).

The top-hole section of each proposed E&A well will be split into two (2) separate sections. The larger top-hole is referred to as the ‘conductor’, which will be installed to isolate the Anthony Lagoon Formation. The smaller lower hole section is referred to as the ‘surface casing’, which will be installed to isolate the Gum Ridge Formation. Each individual section will be cased and cemented (with specifically engineered cement) to seal the aquifer off from the rest of the wellbore to prevent fluid crossflow between formations.

Defining the contact between the Anthony Lagoon Formation and Gum Ridge Formation is critical to ensure the appropriate casing setting points to isolate the two (2) units. Data from the existing Kyalla 117 N2-1H ST2 exploration well and control monitoring bores provides a high confidence that the casing setting point will effectively isolate these two units. Based on the previous drilling results, the conductor section is anticipated to be set in the Anthony Lagoon Formation at a depth of approximately 191 MDRT (measured depth rotary table). The surface casing will then be installed within the cemented conductor casing to a depth of approximately 399MDRT to isolate the Gum Ridge Formation.

During the drilling of the Kyalla 117 N2-1 E&A well, total losses of drilling fluid were observed in both the Anthony Lagoon Formation and Gum Ridge Formation. This scenario was anticipated during the well design, with high permeability conduits, fractures and cavernous zones expected in karstic formations. Loss of circulation material (LCM) is typically used to respond to fluid losses, with additives used to block fluid pathways to re-establish fluid circulation. LCM is often in the form of viscosity enhancers (such as bentonite and polymers), fibrous material (such as coconut coir, nut hulls etc.) or granular material (such as marble chips) with the type of LCM used dependent on the level of losses and formation type. Where drilling fluid losses cannot be stopped, such as in the case of the Kyalla 117 N2-1 E&A well, the drilling fluid systems are reduced back to water to maintain dynamic well control (a continuous supply of water to overcome formation pressures) and to minimise drilling additive losses to the formation. Once the zone of high losses has been drilled through on water, the section is then cased off to regain fluid circulation and allow drilling to continue unimpeded. It is anticipated that LCM and casing off high loss zones will be deployed to manage fluid losses for the additional wells proposed under this EMP.

During cement operations, cement may also be lost to the formation resulting in cement slumping or “patchy” cement sections. In the event that cementing of either the conductor casing or the surface casing for a well is unsuccessful (i.e. the cement does not return to surface or slumping is observed) the following practices may be deployed depending on the casing section:

- For the conductor casing: a top up cement job will be undertaken – this process involves spotting cement from surface in the annulus of the conductor casing and formation
- Surface casing: the use of an External Casing Packer (ECP) and a two-stage cement job will be utilised to provide hydraulic isolation between the casing and formation
- A cement evaluation log is performed to analyse the cement quality in the annulus and determine the appropriate corrective actions

- A Leak-Off Test (LOT) or Formation Integrity Test (FIT) is undertaken to confirm cement integrity.

The cementing operations conducted at Kyalla 117 N2-1, required a 52 barrel (8320L) top up operation for the conductor casing section. Once the External Casing Packer (ECP) was successfully deployed, the cement integrity in the surface casing successfully isolated the aquifers as per design. Cement integrity was verified via a positive FIT to 16.4 ppg was achieved at the surface casing shoe and the cement evaluation log confirmed effective cement isolation between casing and formation.

Once the surface casing is cemented in place, the BOP is installed on top of the casing string. A BOP contains a series of rams and elements that may be closed to prevent a release of pressure and isolate the well at surface. Once installed, the BOP is function and pressure tested to confirm its integrity.

Drilling will then progress down to the target 'kick off' point as part of the intermediate hole section, which is anticipated to be around 2-300m above the target shale formation. When the intermediate hole of each E&A well has reached its target depth, intermediate casing is installed and cemented in place to provide isolation between any potential hydrocarbon-bearing zones and the surface.

The design of the well casing strings of each exploration well is illustrated in Figure 10. Prior to each new hole section of an exploration well being drilled, a Formation Integrity Test (FIT) or Leak-off Test (LOT) is performed to validate the integrity of each casing shoe and provide an operating envelope for drilling the next hole section.

Once the kick-off point has been reached, the build section of each E&A well will be drilled into one of the selected Kyalla shale targets. Once in the targeted shale zone, the well will be drilled horizontally for a distance of between 1,500-2,800m laterally, with each horizontal well separated from each other by approximately 200-400m.

An open hole Diagnostic Fracture Injection Test (DFIT) may be run to further investigate the local rock properties. This test involves injecting small volumes (<10,000L) of water, with salts (NaCl) and biocide (assessed in the drilling chemical risk assessment Appendix C), into the formation to create small fractures, allowing the resulting pressure to fall naturally. The fluid contains no proppant; hence the fracture relaxes and closes naturally when the pressure is released. The pressure decline is monitored on-site and data is analysed to assist reservoir characterisation. This hole section is again cased and cemented in place.

Where a well deviates from the required specification or WAC, a section may need to be plugged and abandoned as per section 3.11. The section of the well may be redrilled to ensure compliance with the Code of Practice and relevant well acceptance criteria.

Once drilling on the Kyalla 117 N2-2H E&A well has been completed, the drill rig will be walked to the Kyalla 117 N2-3H cellar to drill the next well or will be demobilised from site.

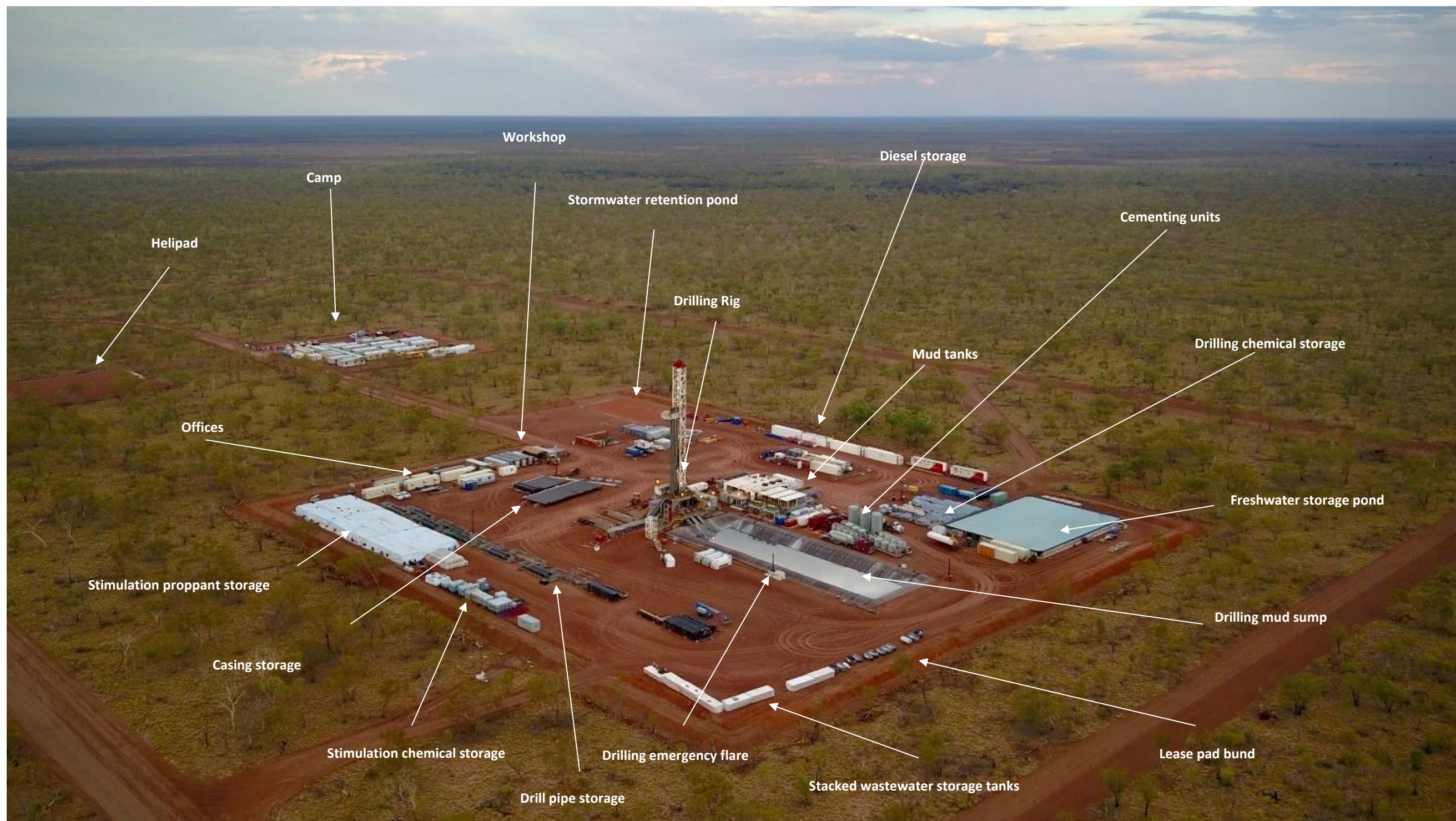


Figure 15: Overview of Kyalla 117 N2 lease pad and infrastructure general arrangement during drilling of the Kyalla 117 N2-1H E&A well (November 2019)

3.4.3.1 Drilling fluids, muds and cuttings

A low toxicity water-based drilling mud is to be used as the base fluid for drilling, which primarily contain salts and polymers. Drilling mud is required to maintain well control, provide formation stability, lubricate and control the temperature of the drill bit and lift cuttings to the surface. The fluid system consists of water with a sodium or potassium-based salt (to prevent formation swelling) and a viscosifying agent such as bentonite. Other low toxicity chemicals such as barite, citric acid, sodium bicarbonate and loss circulation material may also be used. The chemicals used for drilling are consistent with those used for water bore drilling. The details associated with the chemicals used during drilling have been included in the Chemical Risk Assessment attached in Appendix C.

All waste drilling fluids, muds and cuttings will be managed in the existing lined drilling sump on-site. The sump has been designed to support multiple E&A wells. All waste drilling fluids within the sump will be managed and disposed of in accordance with section 3.9.1.

3.5 Hydraulic Fracture Stimulation activities

Upon completion of drilling operations, each of the horizontal E&A wells will undergo Hydraulic Fracture Stimulation (HFS). The hydraulic fracturing process is a series of operations designed to increase the available surface contact area of the shale formation. This enhances the volume of hydrocarbons that migrate into the wellbore and flow to surface.

The process of a hydraulic fracturing completed on each exploration well is conducted in the following sequential stages:

- i. Well integrity verification
- ii. Site set-up
- iii. Stimulation activities

3.5.1 Well integrity validation

Prior to the stimulation of each E&A well, the wellbore will be assessed to ensure that sufficient well integrity is in place to withstand hydraulic fracturing pressures as per the Code of Practice (B.4.7.2 and B.4.13.2) and Section 302A of the Schedule of Onshore Petroleum Exploration and Production Requirements.

The assessment will include the following completed for each exploration well:

- Cement evaluation logs are run to ensure that at a minimum 150mTVD of good quality cement is present from the target reservoir to the nearest aquifer to ensure zonal isolation as per Origin Barriers Standard INT-1000-35-TS-002
- Confirmation of geological barriers and assessment of geological hazards

Mechanical integrity evaluation of the production casing via a pressure test to the Maximum Allowable Operating Pressure (MAOP) of 10,000psi. The pressure test will consist of (a) 10-minute low pressure (300 psi) leak test and (b) 20-minute high (10,000 psi) pressure strength test.

Origin's pressure test acceptance criteria is a 1% pressure drop per five (5) minutes over a stabilised test duration with a decreasing dP/dT trend as per Origin Barriers Standard INT-1000-35-TS-002.

Pressure tests will be undertaken using fresh water which will be re-used.

Well Barrier Integrity Verification Report (WBIV) certified by an independent and reputable validator must be completed and submitted to DITT before and after hydraulic fracturing.

3.5.2 Site set-up

The hydraulic fracturing operation of each E&A well requires various pieces of equipment as illustrated in Figure 16 (previous Kyalla 117 N2-1H drilling set up) and Figure 11.

Equipment utilised for stimulation

- A data van, which is an on-site office to execute stimulation activities
- Water storage – the wastewater tanks will be constructed on-site, capable of managing the total volume of both make-up water and flowback water. Tanks storing flowback will be double lined with leak detection capable of monitoring any leaks between the primary and secondary liner. Specific information on the wastewater tank construction is provided in Section 3.5.3
- Proppant trailer which is a large sand storage and delivery trailer that holds the proppant
- Hydration unit which is used to add stimulation additives and viscosifying fluids
- Blender unit which is used to mix proppant and fluid additives prior to its injection into the well
- High pressure pumps which inject the hydraulic fracturing fluid mixtures from the blender unit down the well via the surface lines and hydraulic fracturing wellhead or coiled tubing unit
- Coiled tubing unit – a large length of coiled steel pipe that can be temporarily installed in the well to perform various downhole operations
- Wireline unit for plug and perforation deployment
- Ancillary support buildings including offices, workshop, cranes, chemical storage area, equipment storage, laydowns and all other activities required to support stimulation activities.

The anticipated lease layout for the hydraulic fracture operation is provided in Appendix B.

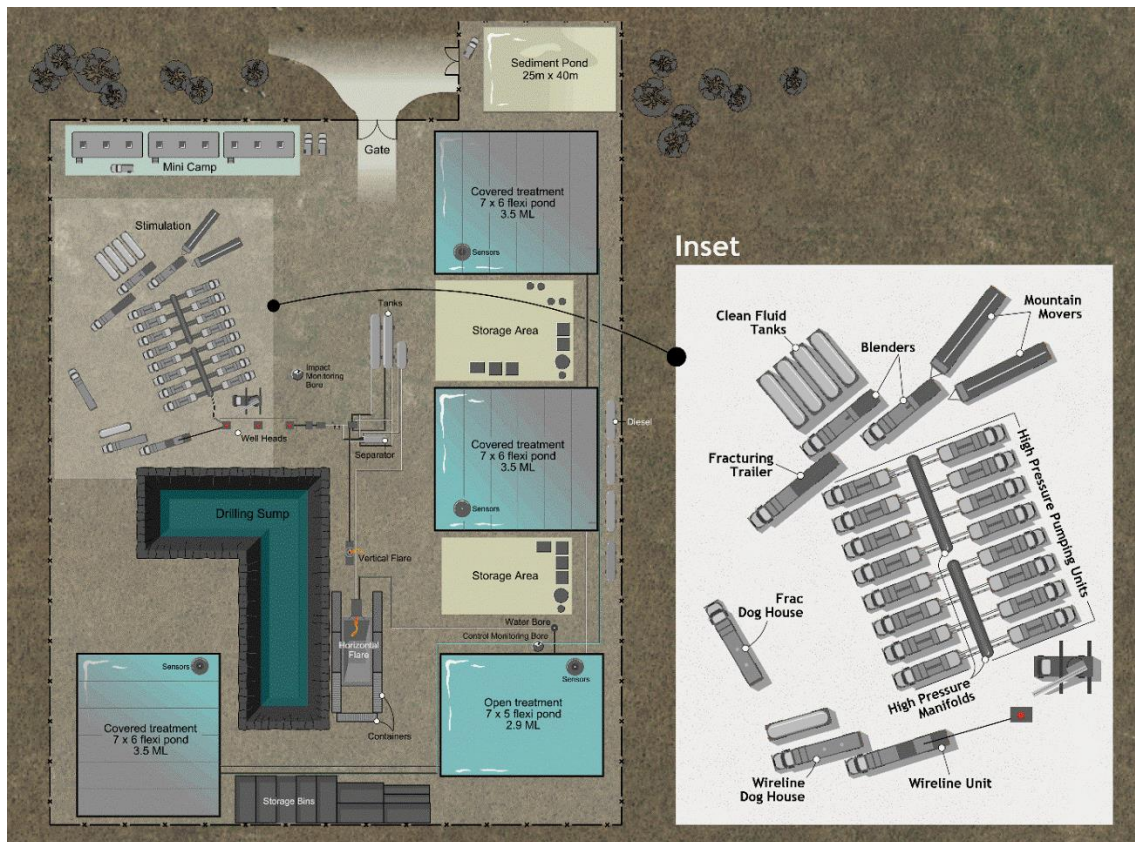


Figure 16: Anticipated Kyalla 117 N2 2H&3H Hydraulic Fracture Stimulation spread used for each E&A well (Note: additional tanks will be installed where the frack spread is located during well test)

3.5.3 Wastewater tank set-up

In accordance with section C.4.2.2 of the Code of Practice, all wastewater must be stored in enclosed tanks unless being treated for disposal or re-use. To comply with this requirement, a series of enclosed wastewater tanks will be constructed on-site to store all encountered flowback wastewater received on-site. Open wastewater treatment tanks will also be constructed to reduce wastewater through evaporation. When wastewater is not being treated, it will be stored in enclosed tanks. Further information on the wastewater management is provided in section 3.9.

Currently, the site has 13.4ML of total tank capacity, with 10.5ML of enclosed storage and 2.9ML of open storage. An additional 3.5ML of enclosed tank storage will be installed progressively to manage flowback as it is produced. This will increase total onsite wastewater storage to 16.9ML. When considering tank freeboard requirements as described in Table 10, this represents available total storage of 14.99ML during the wet season and 16.5ML during the dry season.

The proposed tank set-up consists of the following:

- 4 x 3.5ML enclosed tanks (total 14ML)
- 1 x 2.9ML open treatment tank (0.99ML wet seasons storage and 2.5ML dry season storage)

Table 10 Tank operating capacity and freeboard levels

Tank type	Tank dimensions ⁸	Wet season		Dry season	
		Maximum operating capacity	Freeboard volume	Maximum operating capacity	Freeboard volume
3x 3.5ML enclosed tank	42.6m x 49.0m x 2m	14ML	N/A ⁹	14ML	N/A ⁹
1x 2.9ML Open tank	36.3m x 49.0m x 2m	0.99ML	1.91	2.5ML	0.4ML

On-site wastewater management will be an adaptive process, with enclosed tank and treatment capacity adjusted (added or removed) to meet operational requirements (including meeting mandatory Code of Practice requirements).

Each tank will be engineered to meet both the Code of Practice and site environmental conditions requirements, including:

- Double-lined tank with leak detection in the interstitial space capable of detecting leaks between the primary and secondary liner
- Wastewater tank liners to have an impermeable membrane with coefficient of permeability of less than 10^{-9} m/s permeability, 120N picture resistance and 49N tear resistance
- Tanks are not connected and non-return valves used to prevent uncontrolled discharge from multiple tanks should one fail
- Tanks designed to prevent the risk of build-up of explosive gasses
- Wastewater tanks designed and engineered to Australian Standards (AS3990 Mechanical Equipment – Steel Work, AS 1170.1 Hydrostatic loading, AS1170.2 Wind Rating (cyclonic wind rating)
- Enclosed tanks to have vents and ignition exclusion zones to eliminate the build-up of explosive gasses
- Controls are installed (such as pipe caps and non-return valves) to prevent siphoning of a tank.

Any new wastewater storage tanks will be installed in accordance with the following steps (illustrated in Figure 17):

- Each tank site is flattened to a maximum slope of <0.5% and compacted to above 120kPa- with the lease pad containing a mixture of silt, clay and gravel. Predicted permeability (based on type of material present) exceeds 1×10^{-7} m/s
- Each tank panel is transported to the site in flat packs

⁸ The final shape of each tank is dependent on available location and footprint. The sump and open tanks have an operational wet season and dry season freeboard which cannot be exceeded

⁹ Freeboard not required for enclosed tanks as these tanks have a cover installed.

- Each tank panel is assembled using a simple pin-type set up, with each tank panel lifted into place using a telehandler. No cranes or suspended overhead loads are required
- Each panel is free standing and capable of withstanding 100km/hr winds on their own. They are connected to the adjacent panel using engineered steel pins, which increase the wind rating to above the cyclonic wind load requirements. The structure is engineered to a level that can withstand up to 70% erosion of the panel length, without causing any structural damage. This means the risk of water erosion during rainfall events is low
- Geomembranes are installed under each of the tanks to prevent rock/root penetration
- The first 0.5mm HDPE liner is installed and fixed to the structure. Liners are pre-fabricated, welded and tested off-site, preventing the need for on-site welding
- A moisture and pressure probe is installed between the primary and secondary liner to detect moisture and water pressure
- The second liner is installed and fixed to the structure
- Level sensors are installed within the tanks
- For the enclosed tanks, the covers are installed. The covers have built in vents and rainwater collection system
- Tanks are filled with fresh water and are tested for leaks over a 24-hour period. If moisture and pressure is detected via the leak detection system, the tank is drained to an existing storage tank on-site and leakage point repaired. Leak testing on all tanks will be completed during the Kyalla 117 N2-2H and N2-3H well testing to ensure the tanks are free from leaks.

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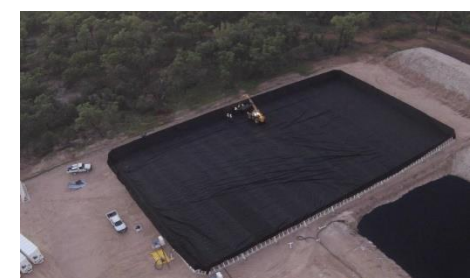
1. Panel Transportation



2. Panel assembly



3. Tank assembly



5. Geomembrane installation



9. Tank commissioning



8. Cover installation



7. secondary liner installation



6. Primary liner installation

Figure 17: Wastewater tank construction steps

3.5.4 Stimulation activities

Hydraulic Fracture Stimulation (HFS) will be undertaken upon completion of the drilling of both E&A wells. Stimulation is generally conducted during daylight hours, with wireline and coiled tubing support activities operating on a 24-hour basis.

HFS involves the injection of a slurry, primarily consisting of water and sand (proppant), plus a small percentage of chemicals at high pressure into the target section of the horizontal wellbore. Typically, 95% or higher of the total volume in stimulation fluids is a combination of fresh water and sand, with the remainder as fluid-conditioning additives. Chemicals used in HFS are designed to optimise stimulation outcomes and are commonly found in food and other household domestic products. The chemical composition of stimulation fluid is discussed further in Section 3.7.

All fluid additives (water and chemicals) and sand are mixed on the surface in the frac spread mixer, which uses a portable containment bund. The mixture and pumping schedule (rates, volume and proppant) are based on modelling which determines the desired fracture attributes. The HFS model is completed prior to the commencement of stimulation activities and is underpinned by a Mechanical Earth Model (MEM). The MEM is generated from data collected during drilling, wireline logging, core analysis and DFIT tests. The stimulation fluid mixture and pumping schedule is continuously updated during and after each stage to ensure optimal outcomes are achieved. An example of the modelled fracture geometry for the Amungee NW-1H well is illustrated in Figure 18.

The stimulation fluid is pressurised by the high-pressure pumping units and directed downhole via a manifold to discrete target intervals along each of the horizontal wellbores (referred to as ‘stages’). It is anticipated that between ten (10) to thirty (30) stages are proposed for each exploration well, with the final number of stages determined based upon the horizontal length of the well and commercial considerations. Each stage being isolated and perforated using a plug and perforation gun assembly deployed via wireline. As the pressure is sustained, the fractures propagate radially from the well, through the target rock. Once optimal fracture propagation has been achieved, the proppant (sand) is pumped down the well and into the open fractures. This process is repeated for each stage. The final number of stages pumped in each well is dependent on the useable length of the horizontal wellbore and in-situ geological conditions. Once all stages are complete, the well is suspended awaiting completion and well testing activities.

It is anticipated that approximately 1.5ML of water and 180-250 tonnes of proppant (sand) will be used for each stage. This equals an approximate volume of between 15-45ML of water and between 2,700-7,500 tonnes of sand per E&A well. Water will be sourced from the Gum Ridge Formation, as described in section 3.8. Proppant will be sourced from locations within Australia (such as South Australia) or imported from international sources.

Wellbore pressures of the E&A well which is being stimulated are monitored during each stimulation to ensure the operations have not compromised the integrity of the production casing or the cement barriers of the well. Pressure monitoring is also completed on each of the casing strings being stimulated and on the adjacent wells to ensure any interference is identified and corrective actions implemented. An example of the monitoring of applied stimulation fluid pressure and annulus pressure monitoring is provided in Figure 19. The risk of a stimulation migrating into an adjacent wellbore is considered low, with conservative well spacing designed to prevent connection. If the stimulation zone of an E&A well were to become connected, the design of each well is sufficient to withstand any likely pressures encountered.

A Maximum Allowable Operating Pressure (MAOP) is an important parameter used to define the safe operating envelope of each E&A well. The Maximum Allowable Pumping Pressure (MAPP) is set below the MAOP to allow for uncertainty and provide an additional safety margin. The anticipated MAPP is 9,200psi and the MAOP is 10,000psi.

Two additional safety measures are set in place to ensure treating pressures do not exceed the MAOP of the system:

1. Each HFS pumping unit has an automated high-pressure shut-off control set at the MAPP or lower, and
2. A pressure relief valve will be installed on the surface treating line to instantaneously bleed-down pressures if the pressure exceeds the MAPP.

A coiled tubing unit is on standby, on location, in the event of contingent wellbore intervention operations, such as a wellbore screen-out. A screen-out occurs when the proppant in the stimulation fluid blocks the perforations or fracture network, creating a sudden and significant restriction to fluid flow, resulting in a premature termination of the stimulation operation.

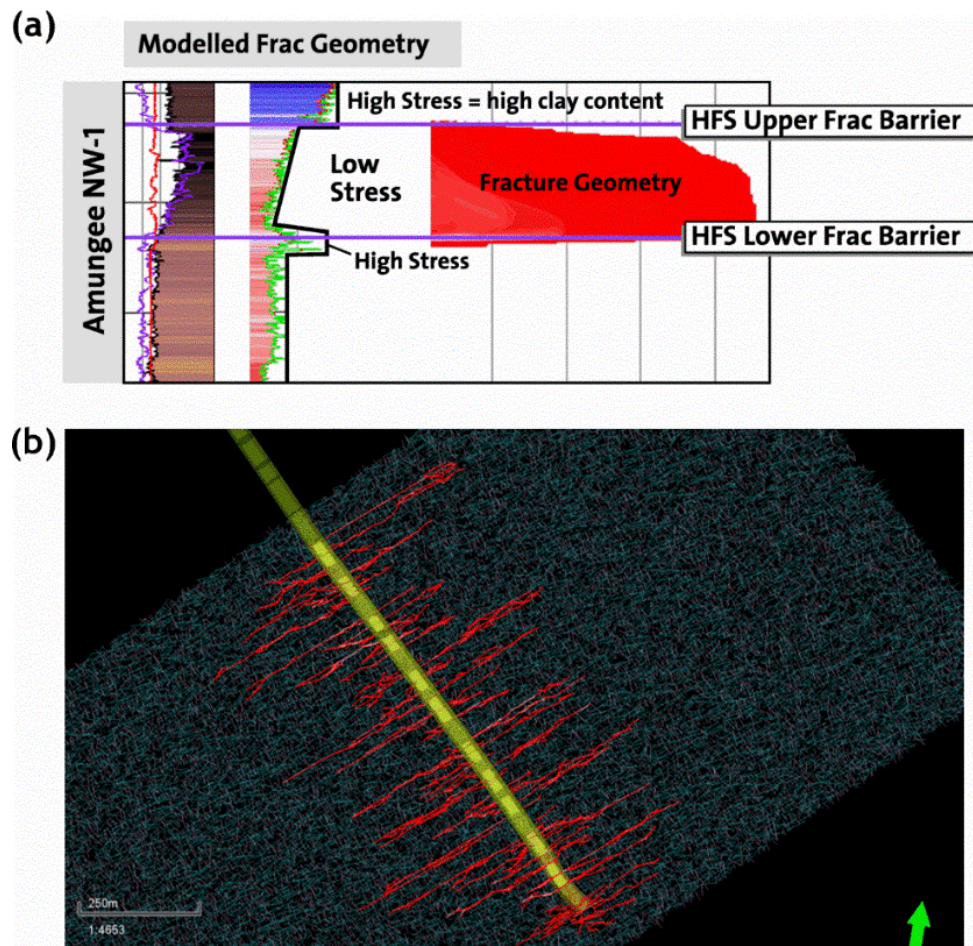


Figure 18: Example of visualised fracture geometry of Amungee NW-1

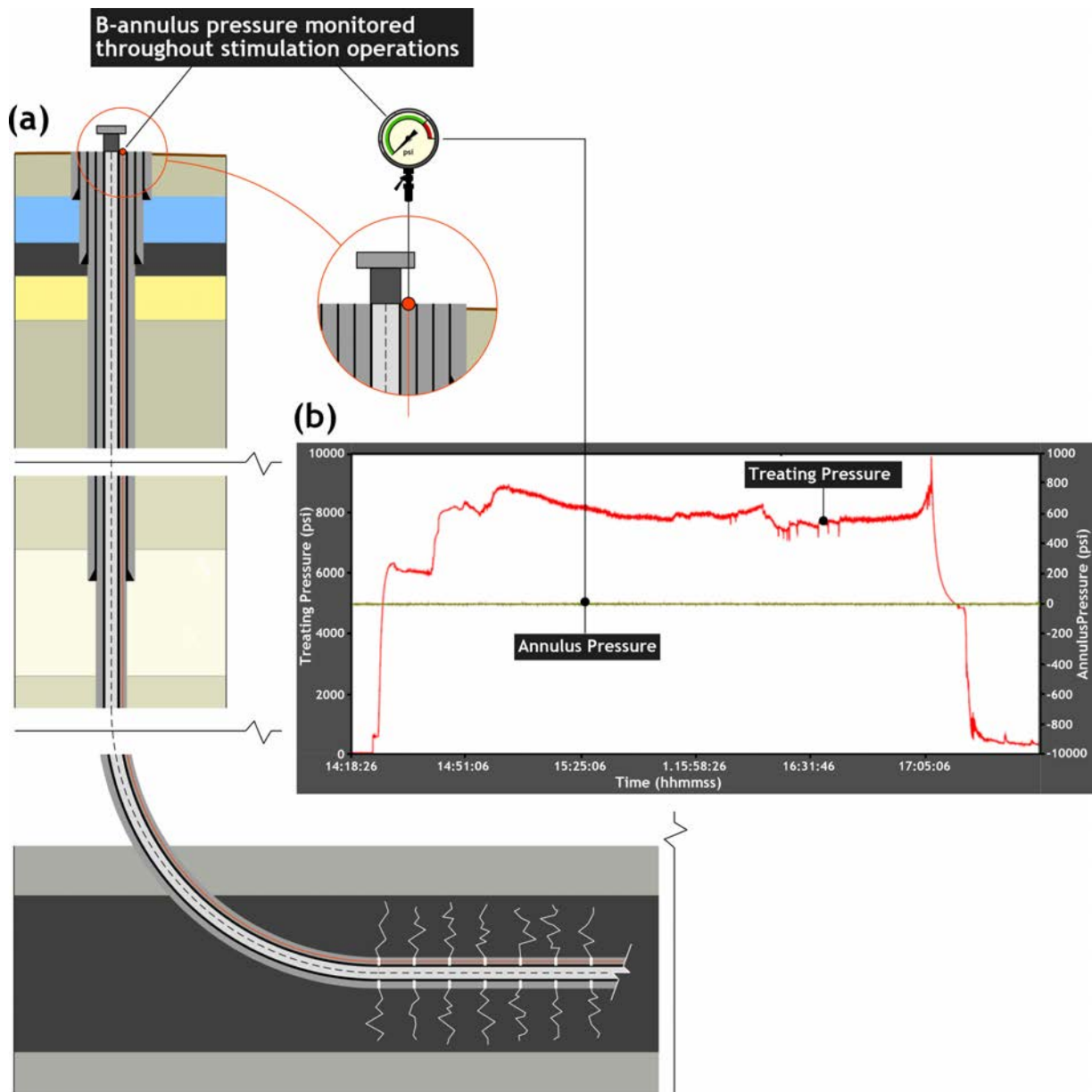


Figure 19: Well and wellhead schematic showing the “B Annulus” monitoring process, and an example from Stage 1 of the observed pressure of the B Annulus (0 psi) while high-pressure HFS operations were underway

3.6 Well completion and test program

Upon finalisation of HFS activities on both wells, each well will be completed and the well testing phase initiated (simultaneously). The Kyalla 117 N2-1H well will also be brought back online, with all three (3) wells tested simultaneously for a maximum three (3) to six (6) months. The well testing program is one of the most critical parts of the program, as information collected during this phase is used to understand the nature, quality, quantity and production performance of the resource.

The well completion and testing program for each exploration well proposed under this EMP consists of:

- Completion activities for each wellbore include:
 - preparing for downhole completion equipment
 - installation of a production packer and production tubing
 - installation of production wellhead
 - underbalance wellbore to initiate production of hydrocarbons
- Well test activities include:
 - flowback of fluids and hydrocarbons
 - measurement and management of hydrocarbons
 - ongoing sampling of flowback and hydrocarbons
 - disposal of gaseous hydrocarbons via flare
 - disposal of liquid hydrocarbons via flare or off-site transportation (including on-site temporary storage)

3.6.1 Completion and well testing activities

The site will consist of the N2-2H and N2-3H wells and several associated, temporary facilities that will be brought on to assist with completion and testing activities. Where possible, Origin will utilise some of the facilities that are already in place from the Kyalla 117 N2-1H well. The N2 site will have the following equipment and infrastructure:

- Completion rig and associated equipment (which installs the production tubing)
- Well testing package, including:
 - Test separator (separates hydrocarbons from flowback fluid)
 - Vertical gas flare, a safe and accepted disposal method of volatile hydrocarbons
 - Horizontal pit flare
 - Surface pipe work and manifolds
 - Emergency Shut Down (ESD) valves
 - Workshops and storerooms
 - Communications and generator shacks
 - Condensate tanks (if required)
 - Bunded diesel and oil storage areas
 - Wastewater (flowback) fluid storage, open-top and covered
 - Water transfer equipment
 - A camp

Each stimulated well will be completed to enable the flow of hydrocarbons and fluids. Completion activities involve the installation of downhole and surface completion equipment, including production packers and tubing and a wellhead.

To initiate the well testing phase, the well will be underbalanced to allow hydrocarbon and fluid production. It is anticipated that the wells will produce both gas (C1-C4 hydrocarbons) and liquids/condensate (C5+). Initially, the flowback will primarily contain HFS fluid and proppant. As the fluid and pressure within the reservoir is reduced, it is anticipated that gas rates will increase. To obtain a comprehensive understanding of the fluid recovery and gas production potential of the target reservoir, well testing may extend between three (3) and six (6) months for each well. The total time required to test each well will depend on several factors including the success of the well and observed depletion curve.

All flowback fluids and hydrocarbons will be directed through a fully contained separator on-site. The separator will separate out the gases, fluids and solids so that they can be measured and managed.

Any liquid hydrocarbons will be separated from the flowback fluid and either combusted in the on-site flare, as discussed in section 3.6.2 and section 3.6.3. or stored within designated condensate storage tanks and transported off-site. The decision to flare versus remove off-site is based upon site access (with limited access in January and February), encountered volumes and economic considerations.

After the well test, the well may be shut-in to complete a pressure build-up test to further characterise the respective reservoirs for a period of up to 12 months. Upon finalisation of the build-up test, the well will be either suspended or plugged and rehabilitated.

An overview of the well testing equipment layout is provided in Figure 20.

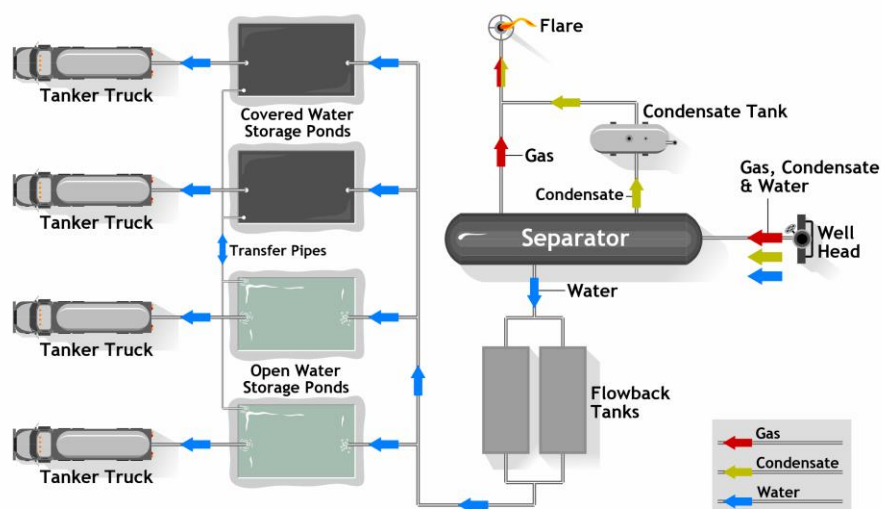


Figure 20: Sample well test schematic

3.6.2 Flaring

During well testing, produced gas and liquids will be separated to split out gas, condensate and flowback fluids. Gas will be sent to an existing vertical flare for combustion and condensate sent to on-site condensate storage tanks (refer section 3.6.3). Condensate may be sent to the existing horizontal flare for combustion or transported off-site for beneficial use or disposal. Flowback fluids will be sent to wastewater storage tanks.

To minimise the potential GHG emissions and potential bushfire risk, the following controls will be utilised:

- The existing flares have been designed and will be operated in compliance with the US EPA 40 CFR § 63.11 control device and work practice requirements to achieve a 98% combustion efficiency
- The vertical flares have been conservatively designed to manage up to 60TJ's of gas and 6,000 barrels (960,000L) of condensate per day. This is an order of magnitude higher than predicted gas and condensate production volumes
- The existing flare design has capacity for the anticipated gas/liquid stream composition (net heating value) and maximum tip velocity ($V^{\max}$) to ensure the optimal flare efficiency
- The flares have been installed with a constant pilot flame and an autoignition system that provides electrical impulses to a spark plug continuously. If the flare was to extinguish, the autoignition system has been designed to reignite the flare within 1.3 seconds
 - The existing flares are located at least 45m from the surrounding vegetation
 - A bushfire management plan implemented outlining the controls and communication requirements (Appendix D).

The vertical flare is an unassisted flare, with the anticipated gas composition likely to achieve the required combustion efficiency without any additional support. Refer to Figure 21 for an overview of the vertical flare.

The existing horizontal flare is located in a 20mx10m coletanche lined pit with a layer of compacted earth (to prevent damage to the liner from radiant heat) (see Figure 22). The horizontal flare is air assisted to increase the air-fuel ratio and subs. This will increase the combustion efficiency of the flare and reduce flare smoking.

Condensate flaring is likely to be undertaken in batches. Based on anticipated production volumes this is likely to be restricted to 0.5 hours to 1 hour per day. To manage radiant heat, a heat shroud (shipping containers) and water curtain will be utilised to dampen the flare flame and reduce heat radiation. The water curtain water usage is anticipated to be between 7,500- 15,000L per day. All water collected during this period will be collected in the flare flume and either re-used or periodically transferred into wastewater storage tanks on-site.



Figure 21: Vertical flare schematic



Figure 22: Horizontal flare set up (Note: the pit has a coletanche liner located ~500mm below the surface)

3.6.3 Condensate tanks

Any produced condensate will be separated and stored in double skinned tanks compliant with Australian Standards 1692 Steel Tanks for flammable and combustible liquids. It is anticipated that up to four (4) x 500 barrel (80,000L) tanks will be utilised, depending on the volume of condensate encountered and factoring in previous well testing of the Kyalla 117 N2-1H well. All tanks will have vents designed to reduce the risk of over pressurisation.

An example of a condensate tanks is provided in Figure 23.



Figure 23: Example of condensate storage tanks (image provided for indicative purposes only)

3.7 Chemical and fuel management

Origin will use a range of chemicals and hydrocarbons to support drilling, stimulation and well testing operations. All chemicals used in Australia must be approved for use by the Federal Government Department of Health and be listed on the Australian Inventory of Chemical Substances (AICS) which is maintained under the National Industrial Chemicals Notification and Assessment Scheme (NICNAS). Origin is also required to disclose all chemicals that are proposed to be used prior to undertaking any drilling and stimulation activities. The CAS number of all chemicals, including proprietary chemicals, is included in a chemical risk assessment which is undertaken by an independent third-party consultant. The final chemical risk assessment report is provided in Appendix C. The proprietary chemical CAS numbers are excluded from the final public submission to protect the intellectual property of chemical manufacturers. This approach ensures that all chemicals can be appropriately assessed, while protecting chemical companies from releasing commercially sensitive information.

3.7.1 Chemical types and quantities

Bulk chemicals and hydrocarbons will be utilised/generated during the drilling, stimulation and well testing activities. These are summarised in Table 11 and include the following chemical types:

- Acids and bases: controls pH and are used to clear perforations of debris prior to stimulation
- Biocides: controls or eliminates bacteria growth in the stimulation fluid to prevent introduction to target formation
- Viscosity regulators: increases or reduces the thickness of a fluid
- Clay control: prevents clays from swelling
- Friction reducers: reduces friction between the stimulation fluid and piping allowing the fluid to be injected further without pressure drop
- Corrosion inhibitors: prevents equipment from rusting
- Chemical inhibitors: such as iron or scale prevention
- Surfactants: reduces surface tension of the hydraulic fracturing fluid
- Bulk diesel: to fuel equipment and generate power

- Drilling muds and weighting agents: used to lubricate the drilling bit, return cuttings to surface, control clay swelling and inhibit formation inflows
- Typical workshop and maintenance chemicals including hydraulic oil, coolant, greases, paints, solvents and engine oils
- Degreasers and domestic cleaning chemicals
- Wastewater (discussed in section 3.9)
- Condensate (discussed in 3.6)
- Camp wastewater (sewage) (discussed in section 3.21)

The maximum chemical storage volume is generally restricted to the materials required for drilling and stimulation of two (2) exploration wells at a time.

Table 11: Anticipated chemical volume and storage used in the drilling and stimulation process

Material name	Typical volume	Maximum volume	Unit	Storage area
Acetic Acid - 60%	3,000	6,000L	L	Stimulation chemical storage area
BE-9 Biocide	17,000	34,000	L	Stimulation chemical storage area
Caustic Soda Liquid	15,000	30,000	L	Stimulation chemical storage area
DCA-11001 Breaker Activator	5,000	10,000	L	Stimulation chemical storage area
DCA-13002 Breaker	300	600	kg	Stimulation chemical storage area
DCA-13003 Breaker	10,000	20,000	L	Stimulation chemical storage area
DCA-16001 Clay Stabiliser	42,000	84,000	L	Stimulation chemical storage area
DCA-17001 Corrosion Inhibitor	1,000	2,000	L	Stimulation chemical storage area
DCA-19001 Crosslinker	600	1,200	kg	Stimulation chemical storage area
DCA-19002 Crosslinker	10,000	20,000	L	Stimulation chemical storage area
DCA-23001 Friction Reducer	5,000	10,000	kg	Stimulation chemical storage area
DCA-23003 Friction Reducer	18,000	36,000	L	Stimulation chemical storage area
DCA-25005 Gelling Agent	35,000	70,000	kg	Stimulation chemical storage area
DCA-30001 Scale Inhibitor	15,000	30,000	L	Stimulation chemical storage area
DCA-32002 Surfactant	15,000	30,000	L	Stimulation chemical storage area
DCA-32014 Surfactant	200	400	L	Stimulation chemical storage area
FE-2 Buffer	200	400	kg	Stimulation chemical storage area
Hydrochloric Acid - 32%	50,000	150,000	L	Stimulation chemical storage area
100 Mesh Sand	91,000	182,000	kg	Stimulation chemical storage area
40/70 Sand	1,650,000	3,300,000	kg	Stimulation chemical storage area
30/50 Sand	610,000	1,220,000	kg	Stimulation chemical storage area

Material name	Typical volume	Maximum volume	Unit	Storage area
Sodium Chloride	15,000	3,000	kg	Completion chemical storage area
ALDACIDE G	500	1,000	L	Completion chemical storage area
OXYGON	100	200	kg	Completion chemical storage area
BARACOR 100	2,000	4,000	L	Completion chemical storage area
CON-DET	50	100	kg	Drilling chemical storage area
SAPP	50	100	kg	Drilling chemical storage area
Bentonite	3,000	6,000	kg	Drilling chemical storage area
Caustic Soda	1,400	2,800	kg	Drilling chemical storage area
EZ MUD DP or EZ MUD Liquid	2000	4,000	kg	Drilling chemical storage area
ALDACIDE G	336	672	kg	Drilling chemical storage area
STOPPIT	1,000	2,000	kg	Drilling chemical storage area
Soda Ash	350	700	kg	Drilling chemical storage area
BARACOR 100	250	500	kg	Drilling chemical storage area
Sodium Chloride (Flossy Salt)	96,000	192,000	kg	Drilling chemical storage area
Barite	500	1,000	kg	Drilling chemical storage area
BARACARB	500	1,000	kg	Drilling chemical storage area
Citric Acid	500	1,000	kg	Drilling chemical storage area
BARADEFOAM HP	500	1,000	kg	Drilling chemical storage area
Sodium Bicarbonate	500	1,000	kg	Drilling chemical storage area
PERFORMATROL	500	1,000	kg	Drilling chemical storage area
SOURSCAV	500	1,000	kg	Drilling chemical storage area
DRIL-N-SLIDE	500	1,000	kg	Drilling chemical storage area
STEELSEAL	500	1,000	kg	Drilling chemical storage area
BARAZAN D or BARAZAN D PLUS	4,150	8,300	kg	Drilling chemical storage area
PAC L	2,300	4,600	kg	Drilling chemical storage area
Potassium Chloride	22,500	45,000	kg	Drilling chemical storage area
GEM CP/GP	500	1,000	kg	Drilling chemical storage area
QUIK-FREE	500	1,000	kg	Drilling chemical storage area
BAROFIBRE, BAROFIBRE Superfine and BAROFIBRE COARSE	500	1,000	kg	Drilling chemical storage area
BaraBlend-657	500	1,000	kg	Drilling chemical storage area
N-DRIL HT PLUS	500	1,000	kg	Drilling chemical storage area

Material name	Typical volume	Maximum volume	Unit	Storage area
DEXTRID LTE	4,600	13,800	kg	Drilling chemical storage area
BARABUF	500	1,000	kg	Drilling chemical storage area
BORE-HIB	500	1,000	kg	Drilling chemical storage area
BDF 933 or BaraLube W-933	864	1,728	kg	Drilling chemical storage area
BAROLIFT	500	1,000	kg	Drilling chemical storage area
OXYGON	500	1,000	kg	Drilling chemical storage area
ENVIRO-THIN	500	1,000	kg	Drilling chemical storage area
Lime	500	1,000	kg	Drilling chemical storage area
BDF 677	4,770	9,540	kg	Drilling chemical storage area
BDF 988	3,390	6,780	kg	Drilling chemical storage area
Waste Drilling Fluids	2,500	2,500	m3	Drilling mud sump
Completion fluids	1.4	1.4	ML	Drilling mud sump/on-site tank
Condensate	160	320	KL	Condensate storage area
Diesel	250	500	KL	Diesel storage tanks
Hydraulic oil	1,000	3,000	L	Workshop
Engine oil	1,000	3,000	L	Workshop
Degreasers	100	300	L	Workshop
Flowback	<10	13.8	ML	Flowback tanks

3.7.2 Chemical risk assessment

A chemical risk assessment was completed to evaluate the potential human health and environmental health effects of all compounds to be used during drilling and stimulation. The chemical risk assessment is provided in Appendix C.

The assessment methodology is based upon the following guidance documents:

- Northern Territory Department of Environment, Parks and Water Security (DEPWS) – Draft Guideline for the Preparation of an EMP under the *NT Petroleum (Environment) Regulations, 2019* (herein referred to as NT 2019)
- Department of the Environment and Energy, Exposure Draft – Chemical Risk Assessment Guidance Manual: for chemicals associated with coal seam gas extraction, 2017 (herein referred to as DOE 2017)
- National Industrial Chemicals Notification and Assessment Scheme (NICNAS), National Assessment of Chemicals Associated with Coal Seam Gas Extraction in Australia, 2017 (herein referred to as NICNAS 2017)
- enHealth “Environmental Health Risk Assessment, Guidelines for Assessing Human Health Risks from Environmental Hazards” 2012

- National Environment Protection (Assessment of Site Contamination) Measure 1999 (ASC NEPM); Schedule B4, Site-specific health risk assessment methodology 2013.

The chemical risk assessment comprised the following tasks:

- Hazard assessment: An evaluation of the environmental and human health hazards of the chemical additives in the hydraulic fracturing fluid, based on their environmental persistence, bioaccumulation and aquatic toxicity properties.
- Exposure assessment: The exposure assessment comprises an evaluation of surface and sub-surface exposure pathways and reviews the effectiveness of the proposed controls in preventing a complete pathway.
- Screening and validation processes via Tier 1 and Tier 2 assessments to determine chemicals known to be of low concern and identify chemicals for further risk assessment:
 - Tier 1: Using published information about each chemical proposed to be used in the hydraulic fracturing activity.
 - Tier 2: A quantitative evaluation of the risks using toxicity values and quantitative estimates of chemical intake to provide an estimate of potential human health and environmental risk associated with the hydraulic fracturing activities, based on the identification of complete exposure pathways and hazard identification.

3.7.2.1 Results of risk assessment

The results of the chemical hazard and exposure analysis are provided in Appendix C.

A Tier 1 assessment was undertaken on all chemicals except for light petroleum distillate (CAS# 64742-47-8). Certain chemicals (14 from Slick Water, 17 from Hybrid and 15 from High Velocity Friction Reduced) require standard flowback water and wastewater disposal controls to ensure the risk of management is low. These controls are consistent with the requirements outlined in the Code of Practice and summarised in Section 6.5 of this plan. It must be noted that none of these chemicals were identified to be persistent and bioaccumulative.

An assessment of the potential valid environmental and human health exposure pathways is summarised in Table 12. The exposure pathways assessment considered the:

- properties of the chemicals
- site setting and physical separation distances between receptors (environmental and human) and the activity as outlined in Section 3.1
- lack of protected flora and fauna and high conservation value areas in the vicinity of the activity as outlined in Section 4.2
- description of the activity and summary of controls as provided in Section 3 and Section 6.5.

The exposure pathway assessment identified only one partially complete exposure pathway; the on-site release of particulates and vapour during chemical mixing and flowback evaporation. The limited number of valid pathways is consistent with the limited size and duration of the proposed activities.

A Tier 2 assessment was conducted on hydrotreated light petroleum distillate, which was classified as a bioaccumulative and toxic substance. As per NICNAS 2017 and DOE 2017 guidance, the Margin of Exposure (MOE) approach was used to assess the health risk to workers. For each occupational activity scenario (i.e. transport and storage, mixing/blending of hydraulic fracturing chemicals, evaporation of flowback and cleaning and maintenance), an MOE was derived by comparing the point



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of departure (e.g. No Observed Adverse Effects Level [NOAEL]) for long-term health effects from the critical toxicological study to the estimated total human internal dose from all routes of exposure.

Based on the calculated MOEs, the chemical is of low concern for workers (refer to individual toxicity profile for further detail).

A summary of the Tier 2 risk assessment is provided in Appendix C.

Table 12: Stimulation chemical exposure pathways

Pathway	Controls	Regulatory controls/guidelines	Effectiveness of controls	Scientific certainty	Pathway assessment
Off-lease release via spill – water	As per the Spill Management Plan (Appendix I) 1. All chemical storage and handling areas to have appropriate secondary containment. 2. Lease pad are banded to contain any major spill of flowback chemicals (capacity of 9.6ML). 3. Offset distances from sensitive receptors (groundwater extraction bores, homesteads, culturally sensitive areas and communities). 4. Routine inspections (daily inspections during the wet season and weekly during the dry season) are completed to ensure any leaks or spills from chemical and waste storage are prevented or promptly identified.	Petroleum Code of Practice Part A – Surface Activities A.3.1 Site selection and planning A.3.2 Well pad site selection requirements 3.8 Containment of Contaminants C.7.2 Spill Management Plan American Petroleum Institute Standards API RP Recommended Practice 100-2 Managing Environmental Aspects Associated with Exploration and Production Operations Including Hydraulic Fracturing Section 13.2: Storage and Management of Fluids and Materials for Hydraulic Fracturing Australian Standards (AS) AS/NZS 4452: The storage and handling of toxic substances AS1940: The storage and handling of flammable and combustible liquids AS 3780:2008: The storage and handling of corrosive substances AS/NZS 3833:1998: The storage and handling of mixed classes of dangerous goods	High – The use of secondary containment and bunding reduces the probability of an off-lease release via a spill down to ‘remote’.	High – The certainty around the use of secondary containment and bunding to prevent spills is well recognised within international spill containment standards and legislation.	Incomplete – Controls in place unlikely to result in any off-site releases.
On-lease release via spill – water	1. All chemical storage and handling areas to have appropriate secondary containment. 2. Routine inspections (daily during drilling weekly post drilling) are completed to ensure any leaks or spills are prevented, promptly identified and rectified. 3. Spill kits and clean up equipment available on-site.	Petroleum Code of Practice Part A – Surface Activities 3.8 Containment of Contaminants C.7.2 Spill Management Plan American Petroleum Institute Standards API RP Recommended Practice 100-2 Managing Environmental Aspects Associated with Exploration and production Operations Including Hydraulic Fracturing Section 13.2: Storage and Management of Fluids and Materials for Hydraulic Fracturing Australian Standards (AS) AS/NZS 4452: The storage and handling of toxic substances	High – The use of secondary containment and bunding reduces the probability of releases.	High – The certainty around the use of secondary containment and bunding to prevent spills is well recognised within international spill containment standards and legislation.	Incomplete – Controls in place unlikely to result in any exposure.

Pathway	Controls	Regulatory controls/guidelines	Effectiveness of controls	Scientific certainty	Pathway assessment
		AS1940: The storage and handling of flammable and combustible liquids AS 3780:2008: The storage and handling of corrosive substances AS/NZS 3833:1998: The storage and handling of mixed classes of dangerous goods			
Off-lease release via particulate during mixing and flowback evaporation – air	1. All chemical mixing on-site to comply with the Workplace Health and Safety guidelines for handling of chemicals. 2. Chemical transfer and mixing procedures deployed to avoid the generation of dust. 3. Chemical mixing location away from lease boundary, with a separation distance of 50m and within a portable containment bund. 4. Wind speed and direction sensors deployed with automatic cut-offs to prevent off-site drift from evaporation units.	Petroleum Code of Practice Part A – Surface Activities Containment of Contaminants American Petroleum Institute Standards API RP Recommended Practice 100-2 Managing Environmental Aspects Associated with Exploration and production Operations Including Hydraulic Fracturing Section 13.2: Storage and Management of Fluids and Materials for Hydraulic Fracturing Managing risks of hazardous chemicals in the workplace Code of Practices 2013 Section 4— Controlling risk Australian Standards (AS) AS/NZS 4452: The storage and handling of toxic substances AS1940: The storage and handling of flammable and combustible liquids AS 3780:2008: The storage and handling of corrosive substances AS/NZS 3833:1998: The storage and handling of mixed classes of dangerous goods	High – Legislation controlling the handling of chemicals is mature and standardised across Australia to limit exposure to employees and surrounding receptors.	High – The certainty around the handling of chemicals is mature and standardised across Australia to limit exposure to employees and surrounding receptors.	Incomplete – The deployment of standard chemical handling procedures to minimise dust, combined with separation distance from the lease boundary, is likely to limit off-site releases.
On-lease release via particulate – air	1. All chemical mixing on-site to comply with the NOHSC guidelines for handling of chemicals. 2. Chemical transfer and mixing procedures deployed to avoid the generation of dust. 3. Chemical mixing location away from lease boundary, with a separation distance of at least 50m and within a portable containment bund.	Petroleum Code of Practice Part A – Surface Activities Containment of Contaminants American Petroleum Institute Standards API RP Recommended Practice 100-2 Managing Environmental Aspects Associated with Exploration and production Operations Including Hydraulic Fracturing Section 13.2: Storage and Management of fluids and Materials for Hydraulic Fracturing	High – Legislation controlling the handling of chemicals is mature and standardised across Australia to limit exposure to employees and surrounding receptors.	High – The certainty around the handling of chemicals is mature and standardised across Australia to limit exposure to employees and surrounding receptors.	Partially complete – On-site release of particulate chemicals during handling is potentially complete with human error.

Pathway	Controls	Regulatory controls/guidelines	Effectiveness of controls	Scientific certainty	Pathway assessment
		Managing risks of hazardous chemicals in the workplace Code of Practices 2013 Section 4 – Controlling risk Australian Standards (AS) AS/NZS 4452: The storage and handling of toxic substances AS1940: The storage and handling of flammable and combustible liquids AS 3780:2008: The storage and handling of corrosive substances AS/NZS 3833:1998: The storage and handling of mixed classes of dangerous goods			
Off-site release via transport accident	1. All chemicals and waste products to be transported by licenced contractors in accordance with the <i>NT Dangerous Goods (Roads and Rail) Regulations</i> and <i>NT Waste Management and Pollution Control Act 1998</i> . 2. Legislation, regulations and national standards set out the requirements for the safe transport of chemicals, including for packaging, driver training, safety equipment and vehicle standards. These measures reduce the risk of a spill occurring, or of not being detected and cleaned up if it does occur. 3. Origin has undertaken 100,000s of chemical transport movements without any major accidents causing environmental harm.	Petroleum Code of Practice Part A – Surface Activities 3.8 Containment of Contaminants C.7.2 Spill Management Plan Transport of Dangerous Goods by Road and rail (National Uniform Legislation) Regulations 2011	High – Legislation controlling the transportation of chemicals and wastes is mature and standardised across Australia.	High – The certainty around the transportation of chemicals and wastes is mature and well understood across Australia. Origin has undertaken 100,000's of chemical transport activities without major incident.	Incomplete – The probability of exposure via a transport accident is limited via the mature legislative framework in place.
Subsurface release of chemicals to aquifer	1. Code of Practice requiring multiple strings of casing and cement designed to protect aquifer. 2. Integrity validation of casing and cement barriers prior to completing stimulation. 3. Pressure monitoring during stimulation of both the formation and the B well annulus. 4. Physical separation distance of 1,400m between aquifer and the target formation prevents any migration of stimulation fluid to aquifer units. 5. 16km separation distance between exploration well and closest pastoralist extraction bores.	Petroleum Code of Practice Part B – Well Operations B.4.2 Aquifer protection B.4.3 Well design and well barriers B.4.6 Casing and tubing B.4.10 Drilling fluids B.4.13 Hydraulic stimulation and flowback operations B.4.7 Primary cementing B.4.17 Groundwater monitoring B.5 BTEX Limit	High – The legislation and guidance notes relating to aquifer protection and well integrity are mature, with extensive industry experience.	High – High certainty around the effectiveness of controls around the protection of aquifers using industry standard practice.	Incomplete – The probability of contamination of an aquifer from release of stimulation fluid during stimulation is remote and therefore incomplete.



Pathway	Controls	Regulatory controls/guidelines	Effectiveness of controls	Scientific certainty	Pathway assessment
Surface release of chemicals to aquifer	1. Secondary containment to be used to manage all chemicals and wastes handled on-site. 2. Code of Practice requires double-lined tanks with in-built leak detection. 3. Spill Management Plan and Wastewater Management Plan to be implemented. 4. Routine inspections to identify leaks (daily during drilling weekly post drilling). 5. 70m vertical separation between surface and underlying aquifer. 6. Closest groundwater extraction bore is 16km away.	Part A – Surface Activities 3.8 Containment of Contaminants C.7.2 Spill Management Plan American Petroleum Institute Standards API RP Recommended Practice 100-2 Managing Environmental Aspects Associated with Exploration and production Operations Including Hydraulic Fracturing Section 13.2: Storage and Management of Fluids and Materials for Hydraulic Fracturing	High – The controls managing the storage of chemicals and wastes are mature with secondary containment measures limiting potential pathways to receptors.	High – The certainty around the effectiveness of secondary containment in preventing groundwater contamination is mature.	Incomplete – The probability of contamination of an aquifer from release of stimulation fluid is remote and therefore incomplete.

3.8 Water supply and use

The extraction of water for all activities associated with stimulation is approved under the Water Extraction Licence (WEL) number GRF10285. This approval allows for an extraction of up to 175ML/year from the Gum Ridge Formation to cover all its proposed exploration until April 2022. The WEL will be renewed periodically (i.e. beyond the 2022 licence period), to ensure sufficient water is available to support operations.

It is estimated that between 50-110ML of water will be extracted from the Gum Ridge Formation to support the Kyalla 117 N2-2H and Kyalla 117 N2-3H drilling, stimulation and well testing E&A program. A water balance for the activity is provided in Table 15. The breakdown of groundwater take for the drilling, stimulation and well testing campaign consists of the following breakdown per activity:

- 5ML per exploration well for drilling (total 10ML)
- 15- 45ML per well for stimulation and well testing activities (total 30-90 ML)
- 5ML camp activities
- 5ML dust suppression and general activities

Water sourced for drilling and stimulation operations will be extracted from the Gum Ridge control bore (RN 41132), which was installed prior to the drilling of the N2-1H well.

All groundwater take is metered with continuous flow meters and reported to DEPWS as per the WEL. Water take records will be kept and updated weekly during operations, to ensure the water take volumes are not exceeded. The predicted take versus WEL licence limit is provided in Table 13. This breakdown includes actual and proposed water take data from other exploration activities approved or proposed outside of this EMP.

Groundwater will be used to supply potable water, with on-site water treatment used to provide water in accordance with the Australian Drinking Water Guidelines.

The cumulative impact associated with current and future groundwater takes were addressed in the Water Extraction Licence (WEL) GRF 10285 statement of reason. This WEL covered the anticipated (conservatively high) future water take for civil construction, drilling, stimulation and well activities over the next three (3) years. A copy of the WEL is provided in Appendix E. The WEL statement of reason is available from DEPWS Water Resources at <http://www.ntlis.nt.gov.au/walaps-portal/report/current/gwel>.

Table 13: Cumulative groundwater take versus WEL reporting period

Site	Activity	Water extraction licence use period				
		August 2019- November 2019* Actual take	20 November 2019-20 April 2020* Actual take	May 2020- April 2021 Actual and predicted take	May 2021- April 2022	May 2022- April 2023
Kyalla 117 N2 -2&3H	Camp (ML)	0	0	0	2.5	2.5
Kyalla 117 N2 -2H&3H	Drilling (ML)	0	0	0	10	0

Site	Activity	Water extraction licence use period				
		August 2019- November 2019* Actual take	20 November 2019-20 April 2020* Actual take	May 2020- April 2021 Actual and predicted take	May 2021- April 2022	May 2022- April 2023
Kyalla 117 N2-2H&3H	Stimulation and well testing (ML)	0	0	0	90	0
Kyalla 117 N2-2H&3H	Dust suppression (ML)	0	0	0	2	2
Total take under this EMP					110	
Other approved activities under WEL 2019-2022						
Kyalla 117 N2	Water bores (ML)	0	0.5	0	0	
Kyalla 117 N2	Civils (ML)	14	5	0	0	
Kyalla 117 N2	Camp (ML)	2	3	1	1	
Kyalla 117 N2-1H	Drilling (ML)	3	3	0	0	
Kyalla 117 N2-1H	Stimulation and well testing (ML)	0	0	17	0	
Velkerri 76 S2	Water bores (ML)	0.5	0	0	0.5	
Velkerri 76 S2	Camp (ML)	0	0	0	1	4
Velkerri 76 S2	Civils (ML)	2	6	0	24	
Velkerri 76 S2	Drilling (ML)	0	0	0	0	5
Velkerri 76 S2-1H	Stimulation and well testing (ML)	0	0	0	0	26
Total cumulative take all exploration activities (ML)		21.5	17.5	18	131	39.5
Water Extraction Licence Limit		95	80	175	175	175

*WEL period modified during licence amendment

3.9 Wastewater management

A project-wide Wastewater Management Plan (WWMP) has been developed to manage wastewater generated under this EMP. The WWMP has been developed in accordance with the Code of Practice and covers the following wastewater streams:

- Drilling fluids, muds and cuttings
- Stimulation fluids
- Completion and kill fluids
- Produced fluids.

The WWMP covers the following information on the management of wastewater during Origin's exploration activities:

- Storage, handling and disposal requirements for wastewater, including the requirement for flowback tanks
- Spill management and response requirements
- Prohibited reinjection or surface disposal of wastewater.

The following section provides an overview of the wastewater management strategy, with further information provided in the Wastewater Management Plan attached in Appendix F.

3.9.1 Drilling fluids, muds, cuttings and cement returns

The following section provides an overview of the management summary associated with waste drilling fluids, muds, cuttings and cement returns.

3.9.1.1 Sump design

All drilling fluids, including cuttings, muds and cement returns, will be directed to the drilling sump. The drilling sump, as illustrated previously in Figure 2, is designed to accommodate the drilling of multiple wells with an overall capacity of 3,000m³. Waste drilling fluids may also be transferred and stored on-site in wastewater tanks to ensure sufficient capacity is always in place to accommodate the freeboard requirements.

An overview of the drilling sump design is provided in Appendix B. The sump surface has been rolled and compacted, with a Coletanche liner installed. Coletanche is a composite liner consisting of five (5) different layers:

1. A highly resistant anti-root film able to withstand puncturing by vegetation or rough substrates
2. Glass fleece which ensures dimensional stability
3. A non-woven geotextile reinforced structure which is highly resistant to tearing and puncturing
4. An elastomeric bitumen binder ensures that the geotextile is waterproof and resistant to ageing
5. A coating of sand ensures that workers can move on the surface in all weather conditions in order to carry out maintenance work. It also provides a rough surface which allows coverage of the membrane by soil.

The Coletanche liner product data sheet is provided in Appendix B. Coletanche was selected based upon the following:

- Easily installed and shaped to fit sump geometry
- High resistance to tearing/puncturing and to hydrostatic pressures
- Low water permeability, with a 6×10^{-14} m/s permeability
- Can withstand high temperature fluctuations

3.9.1.2 Volume and quality

It is anticipated that approximately 1500m³ (750m³ per E&A well) of waste drilling solids (cuttings, muds and cement returns) and approximately 2 ML (0.75- 1ML per E&A well) of drilling and completion fluids will be generated. This estimate is based on engineering calculations and observed drilling waste volumes recorded during the Kyalla 117 N2-1H E&A well. Drilling fluids and muds are saline, with sodium and potassium-based salts used as a weighting agent and formation inhibitor. Other compounds, such as barite (Barium Sulphate) and polymer-based compounds are also utilised during drilling process.

Drill cuttings waste will largely reflect the quality of the rock overburden and target shale formations. Testing of the cuttings from the Kyalla 117 N20-1 E&A were as expected and contain the following:

- elevated levels of certain metals, including barium (230mg/kg- 6560 mg/kg), copper (9mg/kg - 106mg/kg) and Zinc (15mg/kg – 84mg/kg).
- extremely low levels of Benzene, Toluene, Ethylbenzene and Xylenes (BTEX), with a maximum of 6.5mg/kg
- Elevated hydrocarbons, with Total Petroleum Hydrocarbon (TPH) C10- C36 (100mg/kg – 4,140mg/kg)
- No detectable Polycyclic Aromatic Hydrocarbons (PAH's)

Drilling fluids and solids (cuttings, muds and cements returns) may be removed periodically from the sump between wells, or as required to maintain the safe operating level of the sump. Drilling fluids and solids may be transferred to lined tank/ pit (in accordance with section C.4.1.2 of the Code of Practice), disposed of in accordance with section 3.9.1.3 of this EMP.

3.9.1.3 Drilling muds, cuttings and cement returns disposal

It is anticipated that drilling material may either be disposed of during operations (i.e. between the drilling each E&A well to accommodate storage volume requirements) or upon completion of drilling/well testing operations (with the potential for onsite storage of material in accordance with section C.4.1.2 of the Code of Practice).

Prior to the disposal of drilling waste material, a suitably qualified third-party will test the dried material and determine whether the material is suitable to be disposed of on the lease pad (or within the approved disturbance area) using a 'mix, bury and cover' approach (as per C.4.1.2 of the Code of Practice). 'Mix, bury and cover' involves the mixing of dried drilling waste material with the soil located within the drilling sump batters to reduce the concentration of any potential contaminants to an acceptable level. The material is then track-rolled and approximately 300mm of clean material placed over the top. An additional 150mm of topsoil is added to the sump upon remediation of the entire lease site. DEPWS will be consulted if on-site disposal is proposed.

If the material is unsuitable for on-site disposal (such as the moisture content is too high or the material is incompatible with surrounding soils or the analysis of the material indicates it is inappropriate for onsite disposal (as per C.4.1.2 of the Code of Practice)), the material may be left in-situ across the wet season to allow for the material to dry during the subsequent dry season or be transported off-site. If on-site disposal is not feasible, all solid material (~2,600m³ which includes 1500m³ of waste from the 2 proposed E&A wells (2 wells @750m³/well) and the existing Kyalla 117 N2-1H actual volume of 1100m³) will be transported off-site to a licenced facility. Off-site disposal will be undertaken in accordance with the *NT Waste Management and Pollution Control Act 1998*.

All fluids collected in the sumps will either be evaporated in the sump or transferred to wastewater tanks for storage and evaporation. The use of evaporation is the main mechanism used to reduce the volume down to as low as possible. The residual concentrated liquid waste stream will be disposed of off-site at a licenced facility in accordance with the NT *Waste Management and Pollution Control Act 1998*.

The sumps will be operated with sufficient freeboard available to accommodate the total rainfall anticipated based on a 1:1000-year Average Recurrence Interval (ARI) for the duration the sump is in operation. As per the calculations within the WWMP (Appendix F), this equates to a 1.3m wet season freeboard and a 0.3m of dry season freeboard. Any rainwater that has come into contact with contaminants in the sump will be collected and disposed of in accordance with the WWMP.

3.9.1.4 Monitoring

Wastewater volumes within the mud sumps will be monitored daily during operations. Once drilling has finished, sump levels will be monitored weekly during the dry season and daily during the wet season. The wastewater balance and storage curves will be updated weekly to ensure sufficient freeboard in compliance with the Code of Practice.

Drilling mud and cuttings will be sampled prior to disposal and characterised in accordance with requirements set out in section 3.24.

3.9.2 Flowback

Production from the Kyalla formation is anticipated to be similar to the Velkerri formation, with learnings anticipated to be available from the existing approved Kyalla 117 N2-1H E&A well testing to underpin ongoing wastewater management strategies. The anticipated flowback will be composed of formation reservoir hydrocarbons only, with an absence of movable indigenous water from the reservoir. The absence of water is due to a combination of the extremely low reservoir permeabilities and clay adsorption effects.

3.9.2.1 Volume

Origin anticipates that a potential load fluid recovery of 30% of injected stimulation fluid over a 6 month well testing duration based upon previous Amungee NW-1 and indicative Kyalla 117 N2-1 results. Origin estimates a flowback wastewater production volume range from 4.5ML to 13.5ML per E&A well, with a mid-case up to 9ML considered a realistic estimate for the purpose of wastewater balance estimates.

The majority of the recovered flowback fluid is likely to be returned within the first two (2) months of operations, with 20% (6ML) of the injected fluid for each E&A well recovered in the first three (3) months.

The predicted maximum volume of flowback stored onsite at any given time is estimated to be 13.7ML, which includes flowback from the Kyalla 117 N2-2H&3 E&A wells and the existing approved Kyalla 17 N2-1 E&A well.

An overview of the site wastewater balance is provided in section 3.9.3.

3.9.2.2 Quality

The Kyalla 117 N2-1 H E&A well is currently in the early stages of well test, with preliminary data available on the flowback water quality. A summary of the flowback monitoring results is provided in Table 14 and is likely to be similar to that encountered during well testing under this EMP.

Geogenic chemicals requiring careful management, with salt the main contaminate of concern (predominantly sodium chloride). The flowback is likely to be elevated in some metals (primarily

barium) and hydrocarbons. BTEX, phenolic compounds and polycyclic aromatic hydrocarbons (PAHs) are either not anticipated, or likely to be present at low concentrations.

Table 14: flowback quality based on Kyalla 117 N2-1 flowback results

Parameter	Flow back levels
BTEX compounds	Total BTEX levels in the flowback ranged between 63 and 190 µg/L
Total nitrogen (as N)	Maximum value of 180mg/l observed within flowback
Salinity (TDS)	Saline with total dissolved solids level from 120,000- 290,000mg/L
pH	Slightly acidic with a median value of 6.54
Major ions	flowback predominantly Na and Cl dominated, with elevated levels of calcium and magnesium
Dissolved metals	All detected dissolved metal concentrations within the flowback were low, with the exception of Barium (1029mg/L), Gallium (290mg/l) and Strontium (279mg/l)
Polycyclic Aromatic Hydrocarbons	All values in the flowback below laboratory Limit of Reporting (LOR),
Petroleum Hydrocarbons	All fractions of TPH are anticipated to be elevated, with Total Petroleum Hydrocarbon levels likely to range from 25mg/l – 150 mg/l)
Phenolic Compounds	Low level of phenolic compounds detected in flowback with phenol and phenol compounds <3ug/
Radionuclides	Maximum Gross Alpha Activity and Gross Beta Activity of 36.2Bq/L and 97Bq/L encountered in the flowback, the anticipated source is likely to be Radium-226

3.9.2.3 Flowback storage

On-site wastewater management will be an adaptive process, with enclosed tank and treatment capacity adjusted (added or removed) to meet operational requirements (including meeting mandatory Code of Practice requirements).

The site will have 16.9ML of available wastewater storage available to support the proposed activities. This includes 14ML of enclosed tank capacity and 2.9ML of open treatment capacity. The available enclosed tank capacity of 14ML exceeds the total predicted flowback wastewater volume of 13.7ML. Trucking of wastewater may also be undertaken periodically to provide additional storage capacity onsite for weather events and unexpected volumes of water.

A picture of the enclosed tanks currently installed on the Kyalla 117 N2 site is provided Figure 24.



Figure 24: Covered water storage tank located on the existing Kyalla 117 N2 site

3.9.2.4 Wastewater operating strategy

The operating plan for the working evaporation tanks is provided in the WWMP (Appendix F). The wastewater treatment tanks will be operated in accordance with the following philosophy:

- Evaporation tanks must not be the primary storage tank, with the enclosed tanks being the primary storage tank.
- Enough covered storage must always be present on-site to manage all wastewater stored on-site.
- Mechanical enhanced evaporators will be utilised within the evaporation tanks to maximise evaporation rates.
- All wastewater within open working evaporation tanks will be transferred to enclosed storage at least eight (8) hours before the onset of a significant rainfall event.
- All treatment tanks and sumps operated with enough freeboard to manage the entire rainfall from of an entire 1:1000 ARI wet or dry season (i.e. the entire seasons rainfall and not just one single event), as specified in the WWMP, this equates to a minimum 1.3M of freeboard for the wet season and 300mm for the dry season.
- Wastewater may be trucked off-site periodically as a method to manage on-site wastewater volumes.
- Where sufficient enclosed tank capacity is unavailable, all E&A wells will be shut in to ensure compliance with the Code of Practice wastewater management guidelines and prevent overtopping of the tanks. Wastewater levels must be reduced to below the enclosed tank capacity before recommencing operations.

Mechanical enhanced evaporators will be utilised in each wastewater treatment tank to enhance natural evaporation. It is anticipated that up to three (3) evaporator units will be deployed on each

tank, with a combined water treatment rate of up to 550L/minute. Based upon the results from the existing Kyalla 117 N2-1 well, evaporation rates above 100 barrels (16000L) per day have been observed, which aligns with the estimate evaporation rates used in the wastewater balance.

The evaporator units have an estimated diesel consumption of 13L/hour will be required while the aits are in operation. To mitigate the drift of wastewater outside of the tank, the units will have an automated wind speed and direction cut-off mechanism to stop operations during periods of moderate wind (11-16 knots as defined by the BOM (refer to: <http://www.bom.gov.au/marine/knowledge-centre/reference/wind.shtml>)). The exact wind speed cut-off will be determined during the installation of the units and tested with fresh water. This proposed approach was used successfully during the flowback operations at the Amungee NW-1H well and Kyalla N2-1H well.

Where a significant rainfall event is predicted (defined as a 300mm rainfall event predicted over four (4) days as per the WWMP), the total volume of flowback stored on-site will be transferred to the covered storage tanks eight (8) hours prior to the onset of the event. The Bureau of Meteorology's four (4) day total rain forecast (<http://www.bom.gov.au/jsp/watl/rainfall/pme.jsp>) will be reviewed daily to identify periods of significant rainfall. This forecast provides an eight (8) day look ahead, which will be able to identify periods of significant rainfall several days before its onset.

Origin will have up to six (6) x 6-inch transfer pumps on-site capable of transferring up to 23ML/day each. The on-site pumping capacity is significantly more (up to three (3) times more) than the total worst-case volume of wastewater that will be stored on-site. Commencement time to begin transferring the flowback fluid will be selected to ensure that it is completed at least eight (8) hours prior to the predicted commencement of the significant rainfall event.

In the event of a catastrophic failure of a tank, all wastewater will be contained within the bunded site. The earthen bund around the Kyalla 117 N2 site has the capacity to manage approximately 9.6ML of wastewater (minimum 300mm bund around the entire site) to accommodate the entire volume of up to two (2) tanks if they were to fail simultaneously (highly improbable). Where a tank fails, water will be pumped from the bund into the available waste storage tanks on-site. In such a case, the exploration well would be shut in and the regulator notified as per the SPMP. A site assessment and rehabilitation strategy would be developed in alignment with Schedule A of the *National Environmental Protection (Assessment of Site Contamination) Measure*.

3.9.2.5 Monitoring

Monitoring of wastewater levels within tanks will be undertaken at least daily during drilling and well testing, with wastewater pond storage curves compiled and updated weekly to track wastewater volumes on-site. Each wastewater tank will be equipped with level sensors to monitor the fluid volumes in real time. Alarms are set below the freeboard level (referred to as the maximum operating water level) to trigger a management response if exceeded. Automated cut-off sensors will also be deployed to ensure wastewater tank levels do not exceed the safe operating level and 1:1000 ARI freeboard requirements during operations. Where freeboard requirements are exceeded, well operations will cease in accordance with the response criteria outlined in the WWMP and logged as a recordable incident.

Monitoring of flowback and gas samples will be undertaken in accordance with Section 3.24. It is also anticipated that independent external testing will also be undertaken by CSIRO and the Australian Government's Geological and Bioregional Assessment (GBA) program. Further information on the GBA program can be found at: <https://www.bioregionalassessments.gov.au/assessments/geological-and-bioregional-assessment-program/beetaloo-gba-region>

3.9.2.6 Flowback disposal

When the tanks are decommissioned, the associated residual solids, brines, sludges and liners are removed, transported by road and disposed of at a licensed waste disposal facility. It is anticipated that associated residual solids, brines, sludges and liners will be sent interstate to the Westrex waste facility in Jackson, Queensland as the default location. Options for alternative authorised facilities are under review and if they become available during the disposal of flowback materials they may be used. All interstate transfers of controlled wastes will require an interstate/ territory consignment authority to authorise the movement of waste between administrative boundaries.

It is anticipated that the operational strategy will reduce residual flowback volumes from approximately 24ML (includes a 6ML contribution from the existing approved Kyalla 117 N2-1H), down to approximately 2.6ML by the end of 2022. Trucking is anticipated to commence over a two (2) week period in October/November 2022, with 40 return B-quad truck movements required to transport all predicted wastewater from the site. Using the Westrex facility as the default disposal option, all truck movements would be directed to Queensland via the Stuart and Barkly highways. It should be noted that the above timelines are indicative and is subject to change.

3.9.3 Site water balance

A water balance has been prepared summarising the anticipated volumes of water to be used and volumes of wastewater that is expected to be generated, stored and disposed of off-site. This balance includes existing wastewater generated from the Kyalla 117 N2-1H exploration well and all subsequent future activities associated with the drilling, stimulation and well testing of Kyalla 117 N2-2H and Kyalla 117 N2-3H. Observed average monthly rainfall and evaporation rates for the region are used to calculate the rainfall inputs and evaporation outputs from open tanks.

The water balance includes the make-up water and wastewater generated from the main processes of drilling, stimulation, well testing, dust suppression and camp activity.

An overview of on-site water management is provided in Figure 25 and in Table 15.

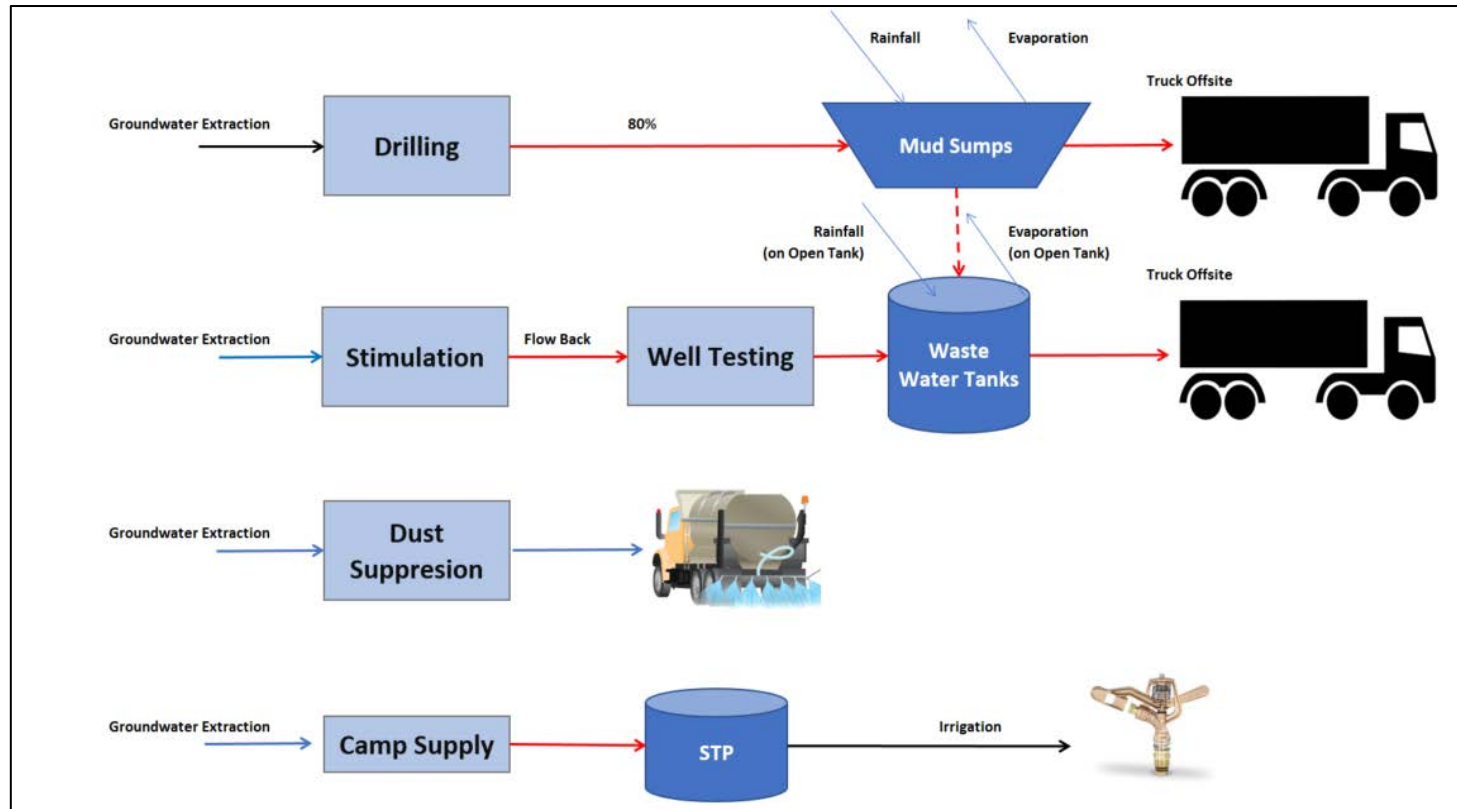


Figure 25: Site water management illustration

Table 15: Site process water balance by activity of Kyalla 117 N2-1H, 2H &3H E&A wells

Summary			2020																2021																2022															
	Month	Total	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec																				
Groundwater water used per month																																																		
Drilling	ML	5.0	0	0	0	0	0	0	0	1.25	1.25	1.25	1.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0																			
Stimulation	ML	75.0	15	0	0	0	0	0	0	0	0	0	0	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0																			
Drilling and stimulation Sub Total	ML	80.0	15	0	0	0	0	0	0	1.25	1.25	1.25	1.25	60.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0																			
Camp	ML	4.1	0.32	0.12	0.03	0.03	0.03	0.00	0.00	0.60	0.62	0.60	0.62	0.03	0.03	0.65	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.00	0.00																			
Dust suppression	ML	4.0	0.15	0.16	0.15	0.16	0.16	0.14	0.16	0.15	0.16	0.15	0.16	0.16	0.15	0.16	0.15	0.16	0.16	0.14	0.16	0.15	0.16	0.15	0.16	0.16	0.15	0.16	0.16	0.15	0.16	0.00	0.00																	
Total	ML	88.1	15.47	0.28	0.18	0.19	0.19	0.14	0.16	2.00	2.03	2.00	2.03	60.19	0.18	0.81	0.18	0.19	0.19	0.17	0.19	0.18	0.18	0.18	0.19	0.19	0.18	0.19	0.18	0.19	0.00	0.00																		
Wastewater generated per month																																																		
Drilling	ML	1.5	0	0	0	0	0	0	0.00	0.38	0.38	0.38	0.38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0																		
Stimulation	ML	23.9	0.00	1.49	1.49	1.49	1.49	0	0	0	0	0	0	4.86	4.86	4.86	0.90	0.90	0.90	0.36	0.36	0	0	0	0	0	0	0	0	0	0	0																		
Wastewater stored onsite per month (Cumulative total includes evaporation/ rainfall additions/losses)																																																		
Drilling wastewater mud Sumps (free only)	ML																																																	
			1.00	1.00	1.00	1.00	0.87	0.89	0.95	0.92	1.00	0.98	1.00	1.00	0.46	0.21	0.00	0.00	0.00	0.03	0.09	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00																		
Drilling wastewater tank	ML		2.00	1.37	0.68	0.06	0.00	0.00	0.00	0.00	0.12	0.00	0.16	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00																		
Total drilling wastewater onsite	ML		3.00	2.37	1.68	1.06	0.87	0.89	0.95	0.92	1.12	0.98	1.16	1.04	0.46	0.21	0.00	0.00	0.00	0.03	0.09	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00																		
Flowback Wastewater onsite	ML		0.00	1.73	2.79	3.65	4.68	4.32	3.81	3.10	2.47	1.77	1.25	5.43	9.40	13.19	13.01	13.26	13.72	13.72	13.59	12.13	10.63	9.23	7.83	6.23	4.53	2.62	0.00	0.00	0.00	0.00																		
Wastewater trucking	ML		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.62	0.00																		
Total Wastewater onsite	ML		3.00	4.10	4.46	4.71	5.55	5.21	4.77	4.02	3.59	2.75	2.42	6.48	9.86	13.40	13.01	13.26	13.72	13.75	13.68	12.18	10.63	9.23	7.83	6.23	4.53	2.62	0.00	0.00	0.00																			

3.9.4 Fauna and bird access

The use of open top working evaporation tanks could, if consumed, represent a risk to fauna (including birds). Literature reviewed on wastewater mortality of birds indicate that the Hyper salinity of the Beetaloo flowback water is likely to be the main factor that reduces the potential exposure to birds and fauna. The wastewater is hypersaline, with total dissolved solids (TDS) > 200,000mg/L. It is well documented that birds, insects and mammals are unable to drink hypersaline water greater than 46,000 mg/L TDS (Bartholomew and Cade 1963; Ohmart and Smith, 1970; ANZECC, 1992; Griffiths et al, 2009). The TDS of the wastewater is likely to reduce the palatability of the wastewater, thus reducing the potential exposure of fauna, including birds to wastewater. This has been documented within the gold industry, where studies have identified links between the hyper salinity of wastewater to reduced bird mortality associated with cyanide ecotoxicity (Adams et al. 2013, Adams et al. 2008, Griffiths et al. 2009a and Griffiths et al. 2009b).

The wastewater is also abiotic, with no aquatic macroinvertebrate food source present. This lack of aquatic food source is understood to be a protective mechanism by reducing wildlife foraging in hypersaline environments (Griffiths et al. 2009a). Other food sources, such as insects attracted to activity lighting is likely to attract insectivorous bats and some birds, which then feed on the insects in the airspace above the flow back tanks. However, as stated above, it is considered extremely unlikely that insectivorous bats and birds will drink from hypersaline wastewater (Smith et al. 2007; Adams et al. 2008; Griffiths et al. 2009a). Furthermore, it is unlikely that flying insects will drink from the flowback water, given the expected salinity, which reduces the potential for any food-chain transfer effects between the insects and insectivorous birds and bats.

Monitoring of flowback storages and surrounding areas will be implemented to document the interaction of fauna with wastewater and identify any mortalities within the wastewater storages and the area surrounding the area immediately within the lease pad (within 50m). These programs include:

- Remote motion cameras to detect fauna movements – the program is designed to demonstrate the risk to fauna associated with wastewater storage is low. The program is currently in progress and uses eight (8) remote cameras surrounding the perimeter of the lease and wastewater tanks to detect fauna passage onto the site stimulation and wastewater storage areas. It is anticipated that the program will extend for approximately 12 months, with the program extended if ongoing fauna mortality is evident. The program has been designed in consultation with DEPWS and in alignment with a guide for the use of remote cameras for wildlife survey in northern Australia (Gillespie et al. 2015). Preliminary data collected during drilling has confirmed limited fauna interaction with wastewater stored onsite.
- Fauna (including bird) interactions and mortalities will be recorded as per the following:
 - Ad hoc bird and fauna observations to be taken around wastewater storages
 - Daily checks for fauna mortality
 - Weekly checks for fauna mortalities immediately surrounding the lease pad (within 50m)
 - Fauna remains present during tank emptying and decommissioning.

Where ongoing bird or fauna mortalities are identified, additional controls shall be implemented in consultation with DEPWS. These may include the use of bird deterrents and netting to prevent wastewater interaction. Ongoing bird or fauna mortality is defined as >7 per week for two (2) consecutive weeks or any mortality of a threatened fauna species.

3.9.5 Stormwater

The Kyalla 117 N2-1 site has existing stormwater management infrastructure which will be utilised to manage stormwater for the proposed additional E&A wells. Stormwater is typically characterised by low electrical conductivity (<100us/cm) and will contain sediment sourced from the cleared lease pad surface. The following describes how stormwater is managed on the site:

- The lease pad has been designed to divert stormwater around the lease pad to prevent contamination.
- Stormwater falling on the lease site is segregated from drilling and stimulation chemical storage and handling areas to minimise contamination. Segregation is largely through bunding of chemical and waste storage areas which minimises contaminated stormwater spilling to the surrounding area.
- Stormwater collected in bunds will be visibly inspected for contamination post rainfall events and discharged to the lease surface if uncontaminated. If signs of contamination are present, stormwater will be removed from the bunds and either recycled within the drilling and stimulation process or stored in a wastewater tank and removed from site in accordance with the Code of Practice.
- A sediment basin is utilised to capture all stormwater falling on the lease pad.
- During drilling and stimulation activities where the risk of off-site release of contaminants is low (due to the low volume of drilling and stimulation fluids retained on-site during these activities), a 'first flush' system will be implemented where the first 20mm of run-off is retained. This run-off is most likely to contain any contaminants from the site. The additional rainfall above 20mm will be diverted off-site via a dedicated spill point.
- When flowback is being stored on-site, all stormwater will be retained with the water backing up into the lease rather than flowing off-site. This is to ensure the system can retain any flowback tank failure event.
- Stormwater collected in the sediment basin during drilling, stimulation and well testing will be tested prior to release/re-use in accordance with Section 3.24
- Clean stormwater that meets the quality outlined in Table 16 will be discharged off-site or re-used for dust suppression.
- Where the water is visibly turbid, a sediment sock will be used to remove sediment from the release.
- All stormwater above the specified limit will be captured and either recycled within the drilling and stimulation process or treated as wastewater disposed of in accordance with Section 3.9.2.6
- Once all work on the site has ceased and all contaminant sources have been removed from the lease pad, the stormwater system will be:
 - (Where the well is to be suspended and well pad kept in place) turned into a passive system with the primary purpose of reducing sediment loads. The first flush (20mm) of stormwater run-off will be retained and allowed to naturally evaporate. The remaining stormwater will be directed off-site.
 - (Where the well and lease pad is to be rehabilitated) the retention system is to be removed and rehabilitated in accordance with Section 3.25

Table 16: Stormwater release and re-use limits

Monitoring parameter	Release limit	Limit basis
Off-site release and dust suppression		
Electrical conductivity	1300µs/cm	Irrigation Salinity values used due to the absence of adjacent watercourses, with the protection of soils the most relevant environmental Value (EV). The Guideline was based on the irrigation water salinity ratings for moderately sensitive crops. sources from Table 9.2.5 of the ANZEC Guidelines (2000) Volume 3, Chapter 9, Primary industries, Sodium adsorption ratio (SAR) of stormwater is anticipated to be low, well below <20 . Receiving soils are sandy loam (as described in section 4.1.3), with SAR in irrigation water > 20 permissible which will not increase the sodicity of soils (Table 9.2.6 ANZEC Guidelines (2000) Volume 3, Chapter 9, Primary industries.
pH	6.5-9.5	Limit based upon the background surface water quality data ¹⁰ and Table 8.2.8 of the ANZECC Guidelines 2000 volume 2 Aquatic ecosystems- rationale and background information.

3.10 Ongoing monitoring and well integrity management

Following construction, a well enters its operational phase (Figure 26) and typically, Origin's Operations team would take accountability of the well at this point. The Operations team have a separate, complimentary standard to manage integrity, known as the Well Integrity Management Plan (WIMP). The WIMP defines monitoring, maintenance and integrity testing requirements and frequencies and well integrity assurance activities, this ultimately forms a part of the Well Operation Management Plan (WOMP). The WIMP and WOMP are both designed to satisfy the Code of Practice to ensure the integrity of a well throughout its life.

¹⁰ HLA 2005 report summarising the Beetaloo Basin Surface water quality monitoring completed for Sweetpea Petroleum

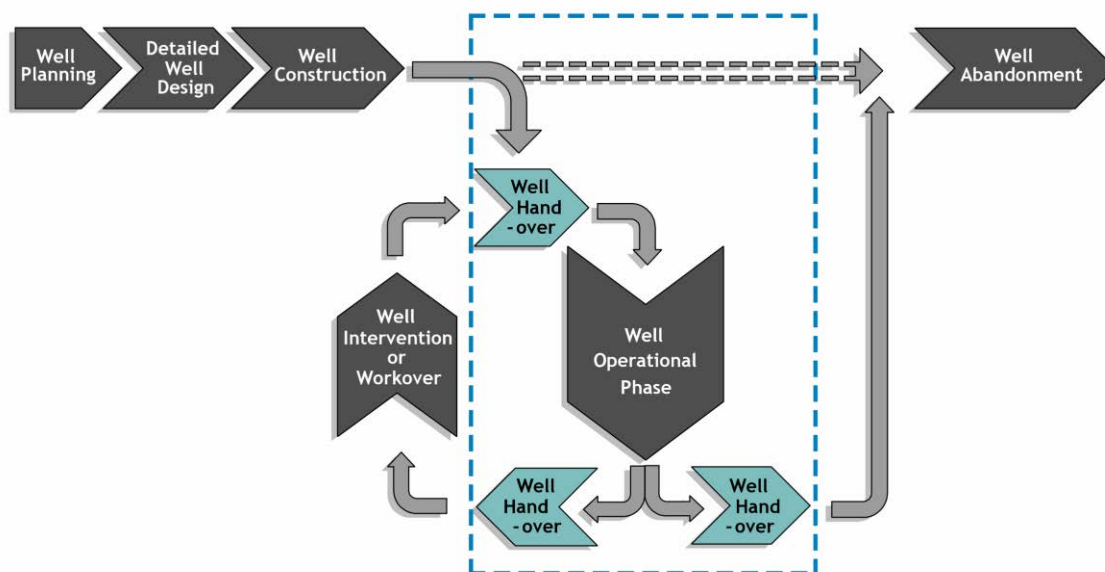


Figure 26: Well lifecycle with operational phase highlighted where well integrity monitoring is a key activity

Information from all Origin wells is gathered and stored in a database and made available to key technical staff via a software tool – Well Integrity Management System (WIMS). WIMS contains information such as wellhead and production valve maintenance results, annular and tubing pressures, well operating windows, key well information and historical well integrity data and maintenance. WIMS is used in the identification and assurance of the integrity of each individual well and also outlines the well integrity status for each well.

Well barriers are tested and pressures monitored regularly to ensure their performance over the lifecycle of the well. Remediation of well integrity anomalies could include well integrity barrier replacements, i.e. valves, tubing, and/or barrier remediation, such as casing patches and cement squeezes to ensure pressure isolation. If remediation does not prove to be a feasible option, plugging and decommissioning operations will be considered to ensure well integrity.

3.11 Well suspension and decommissioning

Once all drilling and testing has been completed, each E&A well will either be suspended or plugged and decommissioned. The fundamental difference between the two options being that suspended wells can be re-entered later for further down-hole activities. If a well is decommissioned, cement plugs will be installed as permanent barriers to flow prior to cutting off the wellhead. The cement plugs will be set and tested as per Origin Standards and Section B.4.15.2 of the Code of Practice. In some circumstances, such as a loss of the bottom hole assembly or hole stability issues, the entire well or a specific section of a well may need to be plugged and abandoned with a new well drilled or the well side-tracked around the affected area. Such an activity is undertaken to ensure the operational integrity of the well and ongoing compliance with the Code of Practice.

If the well is suspended, the barriers are, at a minimum, cemented casing and a wellhead. While the well is suspended, pressures on the well will be continuously monitored as per Origin's Well Integrity Management System (WIMS) to confirm well integrity is intact.

3.12 Well Operation Management Plan (WOMP)

The WOMP provides a key overview of how Origin plans to design, drill, stimulate, test and decommission the Kyalla 117 N2 exploration well in a manner that ensures all risk to the environment are reduced to As Low As Reasonably Practicable (ALARP). The WOMP for each well is required to be submitted to and approved by the Minister for Industry, tourism and Trade before drilling can commence. A summary for how Origin proposes to address the relevant requirements of the Code of Practice and WOMP are provided in Appendix G.

3.13 Geohazards and seismicity

Major faults are avoided as they can represent hazards to both drilling and stimulation operations. Risks associated with geohazards are assessed and managed via the following steps:

- **Locating E&A wells:** Origin has more than 9,500km of 2D data available which is used to screen for large scale, regional faults or structures prior to the finalisation of any exploration well location. The data for Origin's broader Beetaloo exploration area 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.
- **Geohazard assessment post drilling:** Prior to completing stimulation, geological data is analysed to determine the presence of minor and major faults which may pose a hazard to stimulation activities. Where faulting is encountered during the drilling of the horizontal section of the well, a risk assessment is undertaken to determine whether stimulation activities can occur safely. In some instances, location of stimulation stages along the wellbore may need to be moved/removed, to isolate the feature encountered.
- **Real-time monitoring of pressure during stimulation:** Pressure data provides a tool to prevent fault activation and fluid/pressure communication out of the target interval. If anomalous pressure behaviour is observed, stimulation operations can be ceased immediately. This prevents any substantial volume of fluid or proppant from being pumped into an open geological structure.

Preliminary drilling results from the Kyalla 117 N2-1H E&A well has confirmed the absence of major structural features or faults. This confirms that the site is stable, with the risk of induced seismicity consistent with the current assessment level.

Monitoring of seismic events will be undertaken using the Geoscience Australia's Waramanga seismic array located approximately 300km of the proposed Kyalla 117 N2 well pad. It is likely that any material seismic events will be detected via this array if they occur.

An additional traffic light system is currently being developed by the NT in response to the NT Inquiry recommendation. This system is likely to be in place, prior to any full-scale development occurs.

A well plan summary is provided to DITT outlining any known geohazards, structural features or faults prior to stimulation.

3.14 Greenhouse gas emissions

Total greenhouse gas (GHG) emissions generated during exploration activities are summarised in Table 17.

Emissions from the activities covered under this EMP are estimated to be between approximately 24,525CO₂^e (three (3) month well test base case) and 60,796tCO₂^e (6-month worst-case well test). Both these estimates assume material gas is encountered at consistent rates for each E&A well. The total greenhouse gas emissions are small when compared to the total 2018 greenhouse gas emissions for the NT (16,000,000 tCO₂^e) and for Australia (536,500,000 tonnes) (Department of Industry, Science, Energy and Resources, 2020). Emission proposed under this EMP represent 0.15 to 0.38% of NT 2018 GHG emissions and 0.0046% - 0.011% of Australia's total emissions.

Over 90% of the anticipated emissions are associated with flaring. Flaring of produced hydrocarbons is required under exploration tenure to evaluate the commercial viability of a resource.

Greenhouse gas emissions generation will be mitigated through adoption of the Code of Practice and implementation of a Methane Emission Management Plan (MEMP Appendix H). Mandatory requirements include:

- Restrictions on venting (D.5.9)
- Use of a Reduced Emissions Completion (REC) (D.5.9)
- Condensate to be beneficially sold where permissible (D.5.1.2)
- Six monthly routine leak detection and repair program to detect, repair and report leaks to be implemented (D.5.3)
- Pressure and gas testing all in service equipment to ensure any leaks are identified and fixed prior to commissioning (D.5.9)
- Flanges, valves and fittings are all API compliant and gas tight (D.5.9)
- Equipment is appropriately sized and regularly maintained to minimise diesel wastage. (D.5.9)

RECs involve the capture and combustion of hydrocarbons in a flare; a standard practice that has been utilised by Origin for all exploration activities. The combustion of gases produced will reduce the emissions generated by flaring by 94% when compared to venting.

In addition to monitoring emissions from drilling, stimulation and well testing activities, baseline assessments have been completed by CSIRO in the vicinity of the lease pad as per the Code of Practice.

Table 17: Greenhouse gas (GHG) summary for the proposed activities

Activity	Anticipated volume	Total 3-month well testing per well (base-case) tCO ₂ e^	Total 6-month well testing per well (worst-case) tCO ₂ e^	Estimate methodology and assumptions
Diesel combustion - transport	118KL of diesel per well	640	640	Diesel estimated using forecasted usage estimates multiplied by NGERs emission factor from Table 2.4.2B Emission and energy content factors- fuels for transport energy purposes - NGERs 2017-18 Technical

Activity	Anticipated volume	Total 3-month well testing per well (base-case) tCO ₂ e [^]	Total 6-month well testing per well (worst-case) tCO ₂ e [^]	Estimate methodology and assumptions
				guidelines for the estimation of greenhouse gas emissions by facilities in Australia: Energy Content Factor (GJ/kill) 38.6 CO₂ Factor 69.9 kgCO₂-e/ GJ of diesel CH₄ Factor 0.1 kgO₂-e/ GJ of diesel N₂O Factor 0.5 kgCO₂-e/ GJ of diesel
Diesel combustion - horizontal and vertical drilling	500KL of diesel per well	2,721	2,721	Diesel estimated using forecasted drilling estimates multiplied by NGERs emission factor from Table 2.4.2A Emission and energy content factors- liquid fuels and certain petroleum-based products for stationary purposes- NGERs 2017-18 Technical guidelines for the estimation of greenhouse gas emissions by facilities in Australia: Energy Content Factor (GJ/kill) 38.6 CO₂ Factor 69.9 kgCO₂-e/ GJ of diesel CH₄ Factor 0.1 kgO₂-e/ GJ of diesel N₂O Factor 0.2 kgCO₂-e/ GJ of diesel
Diesel combustion- camps	500L per day	367	497	Diesel estimate using forecasted camp usage @500L/day assuming 9 months (270 days) of camp use for the 3 month well test scenario and 12 month camp use for a 6 month well test scenario. Diesel usage multiplied by NGERs emission factor from Table 2.4.2A Emission and energy content factors- liquid fuels and certain petroleum-based products for stationary purposes- NGERs 2017-18 Technical guidelines for the estimation of greenhouse gas emissions by facilities in Australia: Energy Content Factor (GJ/kL) 38.6 CO₂ Factor 69.9 kgCO₂-e/ GJ of diesel CH₄ Factor 0.1 kgO₂-e/ GJ of diesel N₂O Factor 0.2 kgCO₂-e/ GJ of diesel

Activity	Anticipated volume	Total 3-month well testing per well (base-case) tCO ₂ e^	Total 6-month well testing per well (worst-case) tCO ₂ e^	Estimate methodology and assumptions
Fugitive methane emissions – drill cuttings	0.188 tonnes of methane per well	9.43	9.43	Available Kyalla gas saturation combined with anticipated shale cutting volume multiplied by NGERS Global Warming Potential (GWP) of 25tCO ₂ e/tCH ₄
Fugitive emissions – completion (venting)	51.8tonnes of methane per completion	2,590	2,590	2 completion days anticipated per well. Table 5-23 Compendium of Greenhouse Gas Emissions Methodologies for the Oil and Gas Industry; American Petroleum Institute (API), 2009 NGERS completion factor of 25.9 tonnes of methane per day multiple by NGERS Global Warming Potential (GWP) of 25tCO ₂ e/tCH ₄
Fugitive emission-wastewater storage	9ML of flowback per well	144	175.5	Assumed flowback recovery of 30% with 80% of recovered flowback within the first 3 months. Assume 100% of recovered flowback returned within 6 months. Emissions multiplied by Table 5-10 produced salt water tank methane flashing emission factors- Compendium of Greenhouse Gas Emissions Methodologies for the Oil and Gas Industry; American Petroleum Institute (API), 2009 emission factor of 0.39tCH ₄ /ML multiplied by NGERS Global Warming Potential (GWP) of 25tCO ₂ e/tCH ₄ . Assumes 50% of injected flowback is returned to the surface.
Well testing-flared natural gas emissions	1.5Tj per day of natural gas per E&A well (26.34 tonnes per day)	16,948	50,845	Flared estimate using forecasted success case production rates multiplied by section 3.44 Method 1- oil and gas exploration NGERS 2017-18 Technical guidelines for the estimation of greenhouse gas emissions by facilities in Australia: CO ₂ Factor 2.8 tCO ₂ -e/ t unprocessed gas CH ₄ Factor 0.8 tCO ₂ -e/ t unprocessed gas N ₂ O Factor 0.03 tCO ₂ -e/ t unprocessed gas
Well testing-flared condensate	15 barrels of condensate per EA well per day (1.7	984	2,951	Flared estimate using forecasted success case production rates multiplied by section 3.52 Method 1- crude oil production (flared) emissions NGERS 2017-18 Technical

Activity	Anticipated volume	Total 3-month well testing per well (base-case) tCO ₂ e [^]	Total 6-month well testing per well (worst-case) tCO ₂ e [^]	Estimate methodology and assumptions
and entrained gas emissions	tonnes per day)			guidelines for the estimation of greenhouse gas emissions by facilities in Australia: CO ₂ Factor 3.2 tCO ₂ -e/ t condensate CH ₄ Factor 0.008 tCO ₂ -e/ t condensate N ₂ O Factor 0.07 tCO ₂ -e/ t condensate
Well testing-stationary sources (diesel combustion)	500Lper day	122	367	Diesel estimate using historic well testing data of 500L/day under a 90 day and 270 well test scenario for generator and pumps estimates multiplied by NGERs emission factor from Table 2.4.2A Emission and energy content factors- liquid fuels and certain petroleum-based products for stationary purposes- NGERs 2017-18 Technical guidelines for the estimation of greenhouse gas emissions by facilities in Australia Transport emissions cover under transport component: Energy Content Factor (GJ/kL) 38.6 CO ₂ Factor 69.9 kgCO ₂ -e/ GJ of diesel CH ₄ Factor 0.1 kgO ₂ -e/ GJ of diesel N ₂ O Factor 0.2 kgCO ₂ -e/ GJ of diesel
Total		24,525	60,795	

[^] Based on Global Warming Potential (GWP) of 25tCO₂^e/tCH₄ (Clean Energy Regulator 2016)

* https://www.api.org/~media/files/ehs/climate-change/2009_ghg_compendium.ashx

3.14.1 GHG cumulative emissions

The total emissions for Origin's current approved and proposed activities are anticipated to be between 70,902 and 183,777tCO₂^e spread over the next 2-3 years (Table 20). The potential emissions of Origin's activities represent between 0.44% and 1.14% of the total NT GHG emissions for 2018 or 0.013% to 0.034% of Australia's total emission.

When considering the broader emissions from the Beetaloo Sub-basin oil and gas explorers (Table 19) the anticipated total (not annualised) emissions are between 222,865 to 335,740 tCO₂e. This represents between 1.4% and 2.1% of the total NT GHG emissions for 2018 or 0.04% to 0.034% of Australia's total 2018 GHG emissions. It should be noted that this cumulative estimate is extremely conservative as it:

- assumes all E&A wells are drilled and other associated activities are completed
- assumes E&A wells stimulated are successful and trigger well testing
- covers activities spread over multiple years

In comparison to the emission estimates from the other NT sectors (Figure 27), the foreseeable emissions from the onshore oil and gas industry in the Beetaloo sub-basin is substantially lower than that of Stationary Energy (7,015,000tCO₂e), land use, land use change and forestry (5,507,000 tCO₂e) and agriculture (3,192,000 tCO₂e) (Department of Industry, Science, Energy and Resources, 2020).

On a regional, national and activity perspective, the emissions from the industry are not considered significant.

Table 18: Greenhouse gas emission estimates from the Beetaloo Sub-Basin – all Origin approved activities

Activity	Approximate tCO ₂ e base-case (3 month well test)	Approximate tCO ₂ e worst-case (6 month well test)
Origin Energy Kyalla 117 N2-2H&3 drilling, stimulation and well testing	24,525	60,795
Origin Energy Kyalla 117 N2-1H drilling, stimulation and well testing activities	22,630 ¹¹	52,156 ¹²
Origin Energy Kyalla 117 N2 Groundwater Monitoring EMP	2,183	2,183
Origin Energy Kyalla 117 N2 Civil Construction EMP	717	717
Origin Energy Velkerri 76 S2-1 production drilling, stimulation and well testing	18,815	65,894
Origin Energy Velkerri 76 S2 civil construction activities	626	626
Origin Energy Velkerri 76 S2 groundwater monitoring bore	1,406	1,406
2019-2023 Activity total potential GHG (success case)	70,902	183,777

¹¹ Under this scenario, Kyalla 117 N2-1H would be tested for a total of 6 months, as the well will have been brought online and tested with the additional two E&A wells for an additional period of 3 months.

¹² Under this scenario, Kyalla 117 N2-1H would be tested for a total of 9 months, as the well will have been brought online and tested with the additional two E&A wells for a period of 6 months.

Table 19: Beetaloo sub-basin onshore petroleum industry emission total estimates for 2019-2023

Activity	Approximate tCO ₂ e base-case (3month well test)	Approximate tCO ₂ e worst-case (6 month well test)
Origin Energy proposed E&A activities	70,902	183,777
Santos Environment Management Plan: McArthur Basin 2019-2020 Hydraulic Fracturing Program [^]	145,325	145,325
Imperial Oil and GAS EP187 2D SEISMIC WORK PROGRAM Environment Management Plan [^]	6,638	6,638
2019-2023 Activity total potential GHG (success case)	222,865	335,740

[^]unable to determine duration and period of emissions

Figure 18: Northern Territory, annual emissions by sector, 2005 and 2018

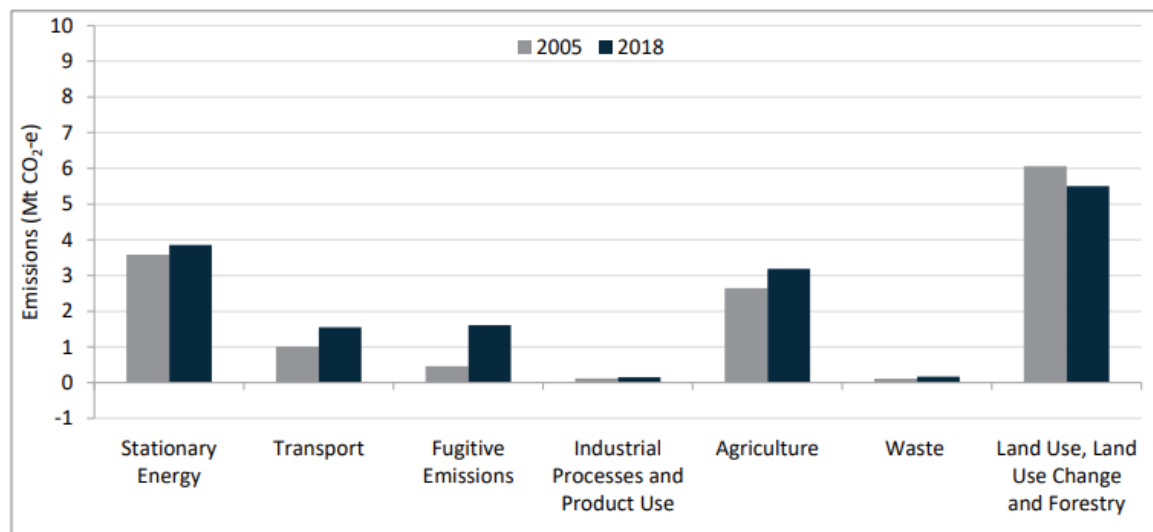


Figure 27: Exert from State and Territory Greenhouse Gas Inventory 2020 showing Northern Territory tonnes of CO₂ equivalent by sector

3.14.2 Origin's ongoing emission projection

Based on Origin's current approved tenure commitments, it is anticipated that annual greenhouse gas emissions will be below 100,000 tCO₂e/year for the next three (3) years. This is below the NGER safeguard mechanism, which is triggered when an emitter produces above 100,000 tCO₂e/year during a financial year.

A breakdown of the annual distribution of greenhouse gas emissions between 2018 (actuals) to 2023 (forecast) is provided in Table 20. These emissions are primarily associated with flaring, which is required during the exploration and appraisal phase. The highest annual predicted greenhouse gas

emission intensity represents (approximately) 0.57% of the NT total 2018 emissions and 0.017% of Australia's total GHG emissions.

Although a full-scale shale development is beyond the scope of this EMP, if a shale development were to occur in the future (post E&A phase), the emissions intensity per well is likely to be significantly lower than during exploration. All development wells will be flowed inline, negating the need to undertake flaring activities at the wellhead. The selection of infrastructure, equipment and operational practices will be specifically focused on eliminating emissions. Based upon the life cycle assessment analysis of a similar (but different) unconventional gas development in Australia completed by the Gas Industry Social and Environmental Research Alliance (GISERA) (Heinz 2019), the current net climate benefits of using natural gas in replacing coal for electricity generation is up to 50% less emissions (Heinz 2019). It is anticipated that a future shale gas development will utilise world's best practice emission reduction technology, such as field electrification, flare minimisation strategies, use of renewable energy sources and potentially carbon capture and sequestration (CCS) technology. This would further reduce the emission intensity of a future gas developments and highlights the role of natural gas as a transition or 'firming' fuel to support the roll out of large-scale renewables in the future. This is reflected by Origin's ongoing commitment to invest in both renewable energy sources and firming fuels such as natural gas.

Table 20: Cumulative Origin 2019-2021 greenhouse gas emissions by period for approved, proposed and potential future exploration activities

Activity	2018	2019	2020	2021	2022	2023
Approved						
Kyalla 117 N2 water bores	1,092	1,092	0	0	0	0
Kyalla 117 N2 civil construction	0	717	0	0	0	0
Kyalla 117 N2-1 drilling, stimulation and well testing ¹³	0	2,290	10,709	29,566	0	0
Velkerri 76 S2 water bores	0	470	157	0	0	0
Velkerri 76 S2 civil construction	0	1,055	0	352	0	0
Velkerri 76 S2-1 drilling, stimulation and well testing	0	0	0	0	18,815 ¹⁴	0
Proposed (this EMP)						
Kyalla 117 N2-2&3 drilling, stimulation and well testing ¹⁵	0	0	0	60,795	0	0

¹³ Assumes a total of 9 months of well test

¹⁴ A 3 month well test is anticipated

¹⁵ Assumes a 6 month well test

Potential (likely future scenario)						
Potential (not approved) 4 total E&A wells per year with associated water bores, civil construction and drilling, stimulation and 3 months well testing (this assumes ongoing E&A success).	0	0	0	0	40,838.29 ¹⁶	54,451
Total annual emissions	1,092	5,623	10,866	90,713	59,653	54,451

3.15 Naturally Occurring Radioactive Material

A detailed assessment of Naturally Occurring Radioactive Material (NORM) was undertaken during the Amungee NW-1H well drilling and testing in 2016. The assessment collected data on the drill cuttings, gas and flowback water, with the results considered applicable to the Kyalla 117 N2-2H and 3H EA program.

The observed radionuclide level within flowback and gas samples observed from Amungee NW-1H are at the lower end of those observed in the USA shale developments (Kibble et al. 2013).

The analysis concluded the following:

- Drill cuttings:** X-Ray Fluorescence (XRF) data was collected at regular intervals (average 5m), providing an estimate of up to 48 elements (including uranium, thorium and potassium) present in the formations being drilled. This data was analysed by a third-party contractor. Analysis determined that the Uranium and Thorium (primary sources for mineral contained NORM) content of the geological formations drilled was well within the ranges of normal geological rocks. In addition, a study commissioned by Origin Energy in 2016 with the company 'Radiation Professionals' analysed drill cuttings samples from four (4) wells drilled by Origin Energy (Kalala S-1, Amungee NW-1, Amungee NW-1H, Beetaloo W-1). Results concluded that none of the samples provided exceeded limits provided in the '*Radiation Protection Regulations, 2012 (NT) Regulations 7*' or the '*National Directory for Radiation Protection, Part B, section 3.2*'. Given the distribution of the wells across the tenure and the geological continuity of the Roper Group formations, the risk of NORMs is considered low. The assessment of NORMs potential will be able to be accurately assessed and screened using a combination of well site wireline natural gamma and post drilling XRF analysis on cuttings samples to detected analogous samples with high radioactive producing elements such as Uranium and Thorium. If levels approaching the *Radiation Protection Regulations* are detected, a more thorough evaluation will be conducted. Furthermore, NORMs assessments of drilling muds are required under the Petroleum Code of Practice and will be completed as per Section 3.9.1.
- Flowback:** NORMs samples of flowback were collected weekly during the well testing of Amungee NW-1H. An assessment of the results indicated that for the flowback to breach the regulatory limit of 1 mSv/year, a person would have to consume greater than 80 litres of flowback fluid. Given fluid is strictly managed in accordance with the Code of Practice and correlating Wastewater Management Plan, this scenario is considered highly unlikely.
- Gas:** Results for the raw gas analysis from Amungee NW 1 indicated that at the observed radon level of 225 Bq/m³. An exposure above 1mSv/m³ from raw natural gas is considered

¹⁶ Three (3) potential additional E&A wells tested for 3 months each is anticipated

remote, as a person would need to be continuously exposed to raw gas on a long-term basis (years). This exposure scenario is not deemed a credible pathway, as there are stringent requirements within the Code of Practice which prohibit unnecessary venting and requires operators to conduct ongoing leak detection and repair program. Furthermore, the observed levels of radon are:

- well below the maximum radon level limit for natural gas of 600Bq/m³. These limits are imposed by the Australian Energy Market Operation (AEMO) and outlined in the *Australian Standard AS4564 Specification for general purpose natural gas (AEMO 2017)* to protect the safety of the end domestic user of gas.
- an order of magnitude lower than many shale radon level in the US; including the Marcellus (Cassman et al. 2016) which has been deemed safe to use for domestic purposes.
- consistent with the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) recommendation that radon levels should not exceed 200 Bq/m³ in households and 1000Bq/m³ in workplaces (ARPANSA 2019). The exposure of a pastoralist to unventilated gas is considered remote, based on the separation distance between the well and the inherent controls that limit venting. The potential exposure to workers is also considered a low risk, based upon the radon levels being within the ARPANSA workplace guidelines and Code of Practice controls.

Risk controls have been implemented to manage the risk of exposure to personnel, including eliminating raw gas exposure and preventing access to drilling material and wastewater. The risk of exposure from NORMs generated during shale exploration activities is considered low. Testing of the drilling cuttings, gas and flowback water will be undertaken during this campaign, as described in Section 3.24.

Further information on the NORMs level encountered was provided to the Inquiry as part of Origin's submission (<https://frackinginquiry.nt.gov.au/?a=424843>).

3.16 Spill management

The use of secondary containment to prevent spills during drilling and stimulation activities is a regulatory requirement embedded in national and state chemical handling legislation and guidelines. These requirements have been further covered in the Code of Practice.

A Spill Management Plan has been developed covering Origin's proposed exploration activities. This SPMP is provided in Appendix I.

An example of bunding used for drilling and stimulation activities is provided in Figure 28.



Figure 28: Example of spill mats used to contain stimulation additives and under a pressure pumping unit

3.17 Wet season operations

Stimulation and well testing operations may occur over the wet season. Where wet season operations are undertaken the following risk controls will be implemented:

- All chemicals, fuels, equipment, tanks and materials required for ongoing operations will be stored on-site prior to the onset of the wet season
- All equipment required to respond to emergency situations will be on-site; this include earth moving equipment, vacuum trucks, wireline rigs, cementing equipment etc. and equipment and material to deal with well control issues, spills and other emergency events
- All chemicals storage areas will be bunded, with covers used (where safe and appropriate) to prevent rain ingress and bund overflows
- Enclosed tanks will be utilised as the primary measure to store wastewater with enough enclosed tank capacity to store all wastewater on-site
- Enclosed wastewater storage volume will be sufficient to manage all wastewater stored on-site
- Open working evaporation tanks and mud sumps will have enough freeboard to manage an entire 1:1000 ARI wet season event (not just one (1) rainfall event but an entire seasons rainfall total)
- Helicopters will be used to transport people and supplies into and out of the site when access is restricted

- 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 of Practice)
- Lease pad is bunded, which will prevent all off-site release of chemicals and stormwater
- All stormwater will be retained on-site via the sediment retention pond prior to release
- Overland flow will be diverted around lease pads

3.18 Helicopter operations

If access to the site is prevented during operations, helicopters will be utilised to move people and supplies into and out of the site. Helicopter activities are an existing, approved activity on the Kyalla N2 site. Helicopter activities ensures the site can be manned during all activities, regardless of the season.

The use of helicopters in the NT for transportation is a standard activity and ensures that personnel and material can be moved to and from the site during periods of wet weather or in emergencies.

All helicopter movements will be managed under an aviation journey management plan. This plan addresses the risk associated with vehicle selection, maintenance, flight routes and flight procedures.

Audits are completed prior to the engagement of a helicopter service provider and at least annually. This ensures all aircraft are being appropriately maintained and operated to reduce the risk of accident.

3.19 Waste management

Waste management methods for the proposed exploration program are summarised in Table 21. Waste is managed in accordance with the internationally accepted guide for prioritising waste management practices, with the objective of achieving optimal environmental outcomes. Waste will be managed in accordance with the following hierarchy principals:

1. **Avoid:** eliminate the generation of wastes through design modification
2. **Reduce:** reduce unnecessary resource use or substitute a less resource intensive product or service
3. **Re-use:** reuse a waste without further processing
4. **Recycle:** recover resources from a waste
5. **Treatment:** treat the waste to reduce the hazard of the waste prior to disposal
6. **Disposal:** dispose of waste if there is no viable alternative

Waste transfer certificates will be retained and provided to DEPWS upon completion of the project.

Drilling, stimulation and well testing wastewater is managed in accordance with Section 3.12

Table 21: Waste and disposal methods

Activity	Disposal method
Sewage, grey and stormwater	Treatment: Grey water and sewage treated and disposed of on-site in an approved, portable treatment system accordance with

Activity	Disposal method
	Department of Health Code of Practice for small on-site sewage and sullage treatment systems and disposal for reuse of sewage effluent. Sewage treated will be surface irrigated to a dedicated, fenced area. The area will be left vegetated, with no clearing required. Sludge removed from site and disposed of at an appropriately licenced facility. Uncontaminated stormwater will be tested (refer Sections 3.12 and 3.16) and either released off-site or re-used for dust suppression.
Food waste, paper and plastic	Disposal: Collected in dedicated waste bins for back-loading to an approved landfill.
Glass and cans	Recycled: Collected in separate waste bins for recycling at an off-site facility.
Chemical bags and cardboard packaging materials	Recycled: Compacted and collected at rig site for transport to a licenced recycling centre.
Scrap metals	Recycled: Collected in designated skip for recycling at an approved location.
Used chemical and fuel drums	Recycled: Collected in designated skip for recycling at an approved location.
Chemical wastes	Re-use/Disposal: Collected in approved containers for disposal at approved landfill or returned to supplier or recycled.
Timber pallets (skids)	Recycled: Recycled at an approved facility.
Vehicle tyres	Disposal: Disposed of at an approved landfill.
Oily rags, oil-contaminated material, filters and any hydrocarbon material	Recycled/Disposal: Oil from machinery or encountered during drilling. Collected in suitable containers for disposal at approved landfill or recycled at an approved recycling facility.
Flowback	Treatment and Disposal: Managed in accordance with Section 3.8.2. Highly saline wastewater collected in a series of open and closed tanks. Evaporated on-site using mechanical evaporators and then disposed of off-site at a licenced facility interstate.
Exploration well drill cuttings, muds and fluids	Treatment and Disposal: Managed in accordance with Section 3.9.1. Saline fluids and solids stored within a lined sump. Fluids segregated from muds and cuttings. Solids dried out, with liquids evaporated. Solids tested and disposed of on-site or off-site depending on hazard. Fluids transported off-site to a licenced facility interstate.
Extraction bore drilling cutting and muds (cuttings mixed with drilling fluids)	Disposal: Freshwater cuttings and drilling muds with low hazard. Disposed of on-site in accordance with the <i>Minimum Construction Requirements for Waters Bores in Australia</i> for water bore drilling practices.

Activity	Disposal method
Spill contaminated soils and water	Disposal: All contaminated material (solids and liquids) will be disposed of off-site at a licenced facility.
Stormwater	Discharged/Recycled/Disposal: All stormwater will be collected on-site in a designated sediment retention system as described in Section 3.9.4. Stormwater will be tested and either released off-site or recovered and either recycled within the drilling process or disposed of at a licenced wastewater treatment facility in accordance with the <i>NT Waste Management and Pollution Control Act 1998</i> .
Waste sand	Re-use/Disposal: Waste and returned sand from stimulation activities will be re-used or disposed of in the drilling sumps with the residual cuttings and muds.

3.20 Weed management

Exploration activities are undertaken in accordance with Origin's Beetaloo Weed Management Plan (NT-2050-PLN-019 Appendix J). This plan has been developed in accordance with the *Weed Management Planning Guide: Onshore Shale Gas Developments Project*.

Weed surveys have confirmed the proposed area of activity has an extremely low presence of weeds. Efforts will therefore focus on both eliminating the potential introduction of weeds into the region and preventing the spread of existing weeds.

From a cumulative impact perspective, the risks of increasing weed pressure in the area is reduced through the mandated use of weed hygiene inspections/certification for all equipment and vehicles and routine weed monitoring and maintenance. Any weeds that are introduced into the activity areas will be promptly identified and managed, reducing the potential additional stress to the region.

3.21 Camps

Two (2) camps will be utilised for E&A activities. The existing main camp located onsite is designed to house up to 65 people. The camp will support two (2) crews that will work 12-hour shifts, plus the camp staff, supervisory staff and service company personnel on an as-required basis. The main camp includes:

- accommodation
- ablutions and septic(s) waste treatment and irrigation
- recreation room
- kitchen and mess
- freezer unit
- site office
- generator and diesel storage
- water tank.

- water treatment facility (reverse osmosis plant).

The approved drilling mini-camp will be set up on the exploration well lease during activities. The mini-camp will house up to eight (8) people and will support the 24-hour drilling activities.

Each camp has its own sewage treatment plant and wastewater treatment plant with a wastewater works design approval issued by the NT Department of Health. Treated water is dispersed via drainage away from the camp to the designated irrigation area. The designated irrigation areas are located adjacent to the camp pad and exploration lease pad. These areas are approximately 50x50m and are within the broader lease area fence, which will exclude livestock access.

The existing camp infrastructure is temporary and portable and powered by diesel generators. The potable water supply for the camps is sourced from groundwater bores established for drilling activities and treated to the appropriate drinking water standards (2011 NHMRC Australian Drinking Water Guidelines). A temporary reverse osmosis water treatment plant is utilised, which produces approximately 10KL of potable water per day. Approximately 2,000L of RO reject is likely to be produced per day, which will have an Electrical Conductivity of approximately 1,500-2,000 $\mu\text{S}/\text{cm}^3$. This water will be re-used or blended (diluted) with raw water at a 4 to 1 ratio and used for dust suppression.

All camp Kitchens have been registered under the NT Food Act 2004 and comply with all food hygiene requirements.

The domestic solid waste generated by camp activities will be removed by a waste contractor in accordance with the NT WMPCA.

3.22 Traffic

The periods of highest traffic generated from exploration and appraisal activities will generally occur over a short duration and are generally associated with the mobilisation and demobilisation of equipment. The drilling rig is currently located at the Kyalla 117 N2 site, meaning the maximum anticipated traffic flow is associated with the demobilisation of the rig after the completion of the Kyalla 117 N2-2H&3H E&A wells. The peak maximum anticipated traffic flow increase associated with the activity is conservatively estimated at approximately 44 vehicles per day during the demobilisation of equipment from site.

To assess the potential impact on pastoralist and tourism amenity and experience, a Traffic Impact Assessment (TIA) is discussed below. This assessment includes heavy equipment mobilisation to and from site and is a suitable conservative scenario to assess the potential associated traffic impacts.

The TIA involved the following steps:

- Identification of project traffic movements including approach and departure direction
- Existing traffic levels and road Level of Service
- Assessment of total traffic levels and potential impacts
- Determine required impact-mitigating treatments.

The results of the TIA are discussed below.

Identification of project traffic movements

The access to Kyalla 117 N2 site is via the Stuart Highway, approximately 23km south of the town of Dunmarra as illustrated in Figure 1 . The Highway has a 130km/h posted speed limit in the vicinity of

the project and is generally a two-lane, two-way road with a sealed width of 7 metres and unsealed or grassed shoulders varying between 2.5 and 5 metres in width.

The peak maximum anticipated traffic flow increase associated with the activity will be approximately 44 vehicles per day, during rig and heavy equipment demobilisation from site.

The duration of the activity will extend over an 18-month period, with the peak movements restricted to a two-week period during the final rig demobilisation. Average daily traffic additions during the operational phase (drilling, stimulation and well testing) of the period are likely to be 10-15 movements per day for the first three-six months, reducing to three-four movements for the remainder of the period.

Existing traffic levels, road capacity and Level of Service

Existing traffic figures were obtained from the *DIPL Annual Traffic Report 2017* showing Average Annual Daily Traffic (AADT) figures for the Stuart Highway roughly 30km south of the proposed access location. This station is approximately 65km north of the access point to the Kyalla 117 access track and it can be assumed that the traffic figures at the site will be similar.

The total daily traffic flows from the 2017 annual survey data are in the order of 551 vehicles; effectively split evenly between north and south bound (refer Figure 29). Traffic rates during the dry season are likely to be substantially higher than the average figures, with peak dry season traffic observed to be up to 50% higher than the average volumes (GHD 2013). Therefore, a revised figure of 827 vehicles per day is considered a representative worst-case traffic volume.

AUSTROADS guidelines (Austroads 2017) were used to determine the typical capacity that would be expected by traffic on the Stuart Highway to maintain a free-flow Level of Service (LOS). The Stuart Highway in the project location is a two-lane, two-way road. The capacity of roads is based on the maximum rate at which persons or vehicles can reasonably be expected to traverse a point or uniform section of lane or roadway during a given time period. The Level of Service relates to the operating conditions encountered by traffic as defined in the AUSTROADS guidelines (Austroads 2017). This data was then used to determine the capacity of the Stuart Highway to maintain a Category A (free flowing) LOS for the site. A conservative 700-1,000 vehicle/hr/lane figure was used to determine the vehicle movement capacity of the Stuart Highway.

In an urban situation it can be assumed that the peak hour volumes will be about 10% of the daily traffic volumes. However, the remoteness of this site means that a peak hour is not realistic and has not been considered. Due to the low anticipated volumes that are likely to be spread over the duration of the day, this is considered appropriate.

Rural Coverage Count Stations				Year: 2017									
Table: 4.1 AADT For Coverage Stations - 10 Year Period				Region: Tennant Creek									
Road Name / Location	ADT Station	Direction	Units	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Carpentaria Highway 5km East of Tablelands Highway	RTVDC033	Inbound	Veh	30		37		55		51		42	
		Outbound	Veh	33		44		42		46		42	
		Both	Veh	63		81		97		97		84	
Nathan River Road 2km North of Ryans Bend Road	RTVDC034	Inbound	Veh	5		5		7		9		4	
		Outbound	Veh	6		7		4		7		5	
		Both	Veh	11		12		11		16		9	
Newcastle Waters Road 2km West of Stuart Highway	RTVDC037	Inbound	Veh		34	39	34		41		40		39
		Outbound	Veh		45	38	38		50		50		51
		Both	Veh		79	67	72		91		90		90
Old Bing Bong Road 5km North of Borroloola	RTVDC035	Inbound	Veh	76		42		60		73		59	
		Outbound	Veh	83		51		46		75		49	
		Both	Veh	159		93		106		148		108	
Ranken Road 5km East of Brunette Downs	RTVDC028	Inbound	Veh		1		3		1		1		2
		Outbound	Veh		1		4		2		2		3
		Both	Veh		2		7		3		3		5
Stuart Highway 20km North of Elliott SITE NOT SURVEYED IN 2008 and 2009	RTVDC020	Inbound	Veh			225	211	210	225	222	229	223	280
		Outbound	Veh			221	195	197	205	213	213	222	271
		Both	Veh			446	406	407	430	435	442	445	551

Figure 29: Traffic flows on the Stuart Highway approx. 30km south of the proposed site access point

Assessment of total traffic levels and reduction to road capacity and Level of Service

The total anticipated peak traffic volume for the project has been determined at 871 vehicles per day. This consists of an additional peak project vehicle movement level of 44 vehicles per day in addition to the existing peak dry season traffic volumes of 827 vehicles per day.

The total volume of traffic is considerably lower than the capacity of the Stuart Highway, with any reduction in LOS from the volume of project traffic considered extremely unlikely.

Traffic LOS may also be impacted through changes in traffic compositions, with the volume of trucks affecting the road capacity greater than light vehicles. To assess the changes in traffic composition, vehicle category data obtained from the *DIPL Annual Traffic Report 2017* were assessed against expected total project traffic figures. These figures were increased by 50% to represent peak dry season traffic volumes. The assessment is provided in Table 22.

Table 22: Traffic impact summary – existing versus proposed additional

Vehicle category	Existing vehicles per day (vpd) and %	Proposed additional vehicles per day (vpd)	Total vehicles per day (vpd) during activity and %
Short (light vehicles)	603 vpd (72.9%)	12 vpd	615 (70.6%)
Medium (heavy vehicles or short towing)	76 vpd (9.2%)	0 vpd	76 (8.7%)
Long (heavy vehicles)	53 vpd (6.4%)	5 vpd	58 (6.7%)
Medium combination (heavy vehicles)	27 vpd (3.3%)	0 vpd	27 (3.1%)

Large combination (heavy vehicles)	68 vpd (8.2%)	27 vpd	95 (10.9%)
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The results in Table 22 demonstrate that there are minimal changes in traffic composition associated with the project, with an additional 2.7% of large combination vehicles (the vehicle class considered the highest potential risk to local road users) when compared to the total volume composition. This percentage is unlikely to significantly impact upon the road's capacity and LOS.

3.22.1 Traffic risk management strategies

The management of risks of injury to staff, contractors and the community is a key focus of every Origin activity. To reduce the risks associated transport, all vehicle movements undertaken as a part of Origin activities must comply with the Origin Land Transport Directive. Mandatory controls include:

- Avoiding vehicle movements where possible (such as the use of buses and aircraft)
- Requirement for all vehicles to be fitted with an in-vehicle monitoring systems (IVMS) to monitor speed limits, seat belt usage, harsh breaking and acceleration, and fatigue
- Driving at night to be avoided
- Defensive driver training for all employees and contractors performing work
- Zero alcohol and drug policy – with all staff breath tested when on-site and random drug tests completed
- Fatigue management policy – with mandatory breaks required for every two (2) hour and maximum ten (10) hour in a single 24-hour period working hours (unless the driver of a fatigue regulated heavy vehicle, where the driver must then comply with the applicable law for fatigue management where the vehicle is operated)
- Chain of responsibility training for all logistics/supply chain roles to ensure they understand their obligations to ensure the safety of their transport activities under the Heavy Vehicle National Law
- Journey management plan requirements for all remote journeys, with all journeys lodged with Origin's National Response Contact Centre.
- Requirements to comply with the National Transport Code Load Restraint Guide
- Contractor and employee driver performance tracking and reporting, with all breaches investigated, formally documented and disciplinary actions taken

In addition to the above requirements, Origin has also implemented the following additional controls:

- Current use of the access track Stuart Highway intersection is approved by DIPL with traffic management in place where required. Ongoing engagement with DIPL is underway covering all future exploration activities
- Large loads to have their own journey management plan outlining proposed controls, including fatigue management, route selection, load constraint, speed restrictions, pilot requirements etc.
- Communication with pastoralists when heavy/multiple transports are likely to occur

- Peak transport period to be restricted to the demobilisation of the rig, with the majority of mobilisations occurring via internal access tracks from the existing approved Velkerri 76 S2 site
- The use of camps reduces vehicle movements between the site and local communities

Other potential risks and controls associated with traffic are discussed further in section 6.6.

3.23 Cumulative impact summary

This section provides a summary of the cumulative impacts associated with the proposed activity in accordance with Section 3b of the *NT Petroleum (Environment) Regulations 2016*. These include cumulative impacts associated with groundwater extraction, flora and fauna, greenhouse gas generation, traffic and social impacts. The assessment of cumulative impacts is summarised in Table 23.

Table 23: Summary of cumulative impacts addressed within the EMP

Aspect	Summary	EMP section
Water	Groundwater extraction cumulative impacts assessed under the Water Extraction Licence GRF 10285. This includes water use for Origin's future exploration program, adjacent petroleum operators and surrounding users. No material impacts on surrounding users expected.	Section 3.8
Flora and fauna	No additional clearing is proposed under this EMP. No active clearing permits present within the Hayfield property or surrounding area (within 50km according to NRMMaps). Impacts associated with weed introduction are managed through the weed management plan. All other petroleum operators and pastoralists required to have a weed management plan.	Section 3.20
Greenhouse gases	Cumulative emissions from all of Origin's 2019/20/21 activities has been provided. Emission levels are mainly attributed to flaring. In a development scenario, gas production is likely to have 50% less emissions than coal, thus playing an important role as a transition or firming fuel to support large scale renewable energy supply.	Section 3.14
Traffic	Impacts of traffic are anticipated to be minor, with no reduction in level of service of the Stuart Highway. Maximum peak traffic level assessment considers cumulative user traffic load, with project movements anticipated to be 44 movements per day during demobilisation.	Section 3.22
Social	Risk associated with increased competition for labour from exploration activities, including	Appendix K and Section 4.6

Aspect	Summary	EMP section
	other petroleum operators is low and well within the capacity of existing service providers. Ongoing engagement with local and regional businesses is underway, providing information and updates on the status of any future projects. Increased industrialisation of landscape resulting in a loss of amenity and tourism value considered low due to limited extent of petroleum activities, including from other petroleum or mining operators.	

3.24 Monitoring

A series of monitoring programs has been developed under this EMP to:

- monitor and detect changes in environmental values associated with Origin's activities
- characterise waste streams to understand the nature of the waste and determine the disposal requirements
- characterise the quality of the produced hydrocarbons
- report on rehabilitation progress.

An overview of each of the monitoring programs is provided in Table 24.

3.24.1 Groundwater monitoring

Baseline monitoring data has been collected from the control monitoring bores in accordance with condition B.4.17.2(b) of the code of Practice. 6 months of baseline data was commissioned prior to the commencement of Kyalla 117 N2-1H stimulation activities, with monitoring data provided to DEPWS quarterly. Monitoring data can be accessed via the DEPWS website located at: <https://denr.nt.gov.au/onshore-gas/onshore-gas-in-the-northern-territory/industry-compliance-and-reporting/groundwater-monitoring-results>

A summary of the key baseline groundwater quality monitoring results from the Anthony Lagoon and Gum Ridge formation are provided in Table 25. This table summarises the primary indicators of electrical conductivity, pH, sodium, chloride, BTEX, barium and strontium, which are used to identify potential changes in groundwater quality associated with exploration activities (in addition to groundwater level). Investigation thresholds are also provided in Table 25, calculated as the 75th percentile of all results. Where an investigation threshold is exceeded, an investigation as described in section 3.24.3 is to be implemented.

An summary of the groundwater monitoring programs is provided in Table 24.

Table 24: Monitoring program summary

Monitoring program	Purpose	Monitoring points	Parameters	Frequency	Investigation thresholds	Reference document
Flowback Monitoring	Characterise flowback quality Field chemistry	Post separator before entering into flowback tank	Field Chemistry: pH, Dissolved Oxygen, temperature and electrical conductivity	Field Chemistry: Daily during the first four-weeks and weekly thereafter Analytical Suite: Weekly for the first 12-weeks of flowback and monthly thereafter	N/A	Code of Practice C.5.4
	Characterise stimulation fluid – laboratory analysis	Exploration well pre-injection	Field Chemistry: pH, Dissolved Oxygen, temperature and electrical conductivity Analytical suite: Appendix L including NORMS	Each fluid system used during injection (one of each in total)	N/A	Code of Practice C.5.4 and C.5.3
Drill cuttings, fluid and muds characterisation	Characterise the quality of drill cuttings, fluids and muds to determine disposal options	Drilling sump – as determined by a suitably qualified third-party	Table 10 of the Petroleum Code of Practice (NORMS), Particle size distribution, bulk density	Prior to disposal	N/A	Code of Practice C.5.2

Monitoring program	Purpose	Monitoring points	Parameters	Frequency	Investigation thresholds	Reference document
Gas composition and isotopes	Characterise produced gas	Post-separator	Gas composition (Nitrogen, Oxygen, Carbon Dioxide, C1-C10+, H ₂ S) Isotopes (C ¹³ (CO ₂ and CH ₄) and H ² (CH ₄ , C ₂ H ₆ +). Radon and radioactivity.	Monthly – internal characterisation program	N/A	N/A
Groundwater monitoring	Detect changes in groundwater as a result of drilling and stimulation activities	Control and impact monitoring bores (RN040896, RN041132, RN041133, RN041136)	Level	Quarterly measurements with real-time (continuous) level logging before, during and one-month after stimulation	+/-1m water level change observed at the impact monitoring bore	Code of Practice B.4.17
			Temperature, electrical conductivity, pH	Quarterly commencing six-months prior (baseline) and three-months after stimulation and then annually for 3-years	Refer Table 25	
			Appendix L	Quarterly commencing six months prior (baseline) and three-	BTEX and Dissolved Methane - outside of the control bore and baseline	

Monitoring program	Purpose	Monitoring points	Parameters	Frequency	Investigation thresholds	Reference document
				months after stimulation	interquartile (75 th percentile) range	
	Pastoralist bore monitoring	Pastoralist bores within 10km of an exploration well	Level	Baseline collected three-months prior to stimulation and 12-months after stimulation	1m sustained water level decline against baseline	N/A
			Temperature, electrical conductivity, pH	Baseline collected three-months prior to stimulation and 12-months after stimulation	+/- 20% compared to pre-stimulation reading	N/A
			Appendix L	Baseline collected three-months prior to stimulation and 12-months after stimulation	BTEX and Dissolved Methane – outside of baseline interquartile range	N/A
Groundwater take	Groundwater volume	Each groundwater extraction bore	Litres	Continuous flow meter	Total extraction <110ML	<i>NT Water Act</i>
Stormwater	Manage stormwater collected during activities	Sediment basin release point	Field EC and pH	Prior to release and at least every 12-hours during continuous discharges	Off-site release and dust suppression limits: - pH 6-9 - EC 1300µs/cm	N/A

Monitoring program	Purpose	Monitoring points	Parameters	Frequency	Investigation thresholds	Reference document
Erosion and sediment control	To detect the presence of erosion and sedimentation from infrastructure	Inspection of all disturbed areas, including lease pads, access tracks, gravel pits, laydown yards, camp pads etc.	Visual inspection of astructure and erosion sediment controls	Visual inspections pre- and post-wet season	Visible erosion or failure of erosion and sediment control	Origin's Approved Erosion and Sediment Control Plan (NT-2050-15-MP-0019)
Fauna-photographic	Collect data on fauna presence	Six (6) locations surrounding the lease pad	Photographic records	During stimulation and well testing (~12-months)	N/A	A guide for the use of remote cameras for wildlife survey in northern Australia
	Collect data on fauna interactions with wastewater	Wastewater tank and sump inspections	Inspection records	Daily during operations	>7 per week for two (2) consecutive weeks or >1 threatened fauna species	Field Guide to NT Fauna
Weeds	Identify weeds potentially introduced or spread by Origin's activities	Inspection of all disturbed areas, including lease pads, access tracks, gravel pits, laydown yards, camp pads etc.	Visual inspection	Visual inspections pre- and post-wet season	1. Positive confirmation of the detection of a weed of national significance species within Origin's disturbance footprint	Origin's Weed Management Plan NT-2050-15-MP-0016.

Monitoring program	Purpose	Monitoring points	Parameters	Frequency	Investigation thresholds	Reference document
					2. An increase in existing weed density and spatial extent	
Methane emission monitoring program	To identify and remediate gas leaks	Each exploration well	Methane (PPM)	6 monthly	>500PPM	Methane Emissions Management Plan (Appendix H)
Post rehabilitation	Monitor ongoing rehabilitation success	Inspection of all rehabilitated areas, including lease pads, access tracks, gravel pits and camp pads	Visual inspections of: - Stem count - Vegetation cover % - Species diversity % - Erosion	Annually	Decline in rehabilitation criteria value compared to previous year results	Section 3.25

Table 25 Control monitoring bore data summary

			RN040896 Anthony Lagoon Formation				RN041132 Gum Ridge Formation			
			Min	Max	Average	Investigation 75 percentile	Min	Max	Average	Investigation 75 percentile
Parameter	Unit	EQL								
Electrical Conductivity (Field)	µS/cm		1,142	1,746	1,469	1,553	1,245	1,634	1,463	1,573
pH (Field)	pH_Units		6.9	7.4	7.1	7.2	6.7	7.1	6.9	6.9
Sum of BTEX	µg/L	1	<1	<1	<1	<1	<1	<1	<1	<1
Chloride	mg/L	1	163	192	173	176	151	174	163	166
Sodium (filtered)	mg/L	1	92	111	104.6	108	94	107	99	102
Barium (total)	mg/L	0.001	0.057	0.13	0.07	0.082	0.058	0.07	0.06	0.063
Strontium (total)	mg/L	0.001	0.624	0.92	0.67	0.676	0.74	0.82	0.78	0.81

3.24.2 Water sampling methodology

Water samples will be collected in accordance with Table 26. All samples will be collected by appropriately qualified personnel, with all meters calibrated in accordance with the manufacturer's instructions before use. Samples will be collected in laboratory-supplied sampling containers and placed in chilled eskies and transported under Chain of Custody (COC) procedures. Analysis will be performed by laboratories with National Association of Testing Authorities (NATA) accredited analysis methodology. Each sample will have a unique identifier that is cross-referenced to the monitoring location and time of sampling.

Table 26: Monitoring program methodologies

	Methodology
Drilling sump characterisation	<i>National Environment Protection (Assessment of Site Contamination) Measure</i> <i>AS4482.1:2005. Guide to the investigation and sampling of sites with potentially contaminated soil</i>
Flowback monitoring	<i>Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000 (ANZECC Guidelines).</i> <i>AS/NZ5667.1: 1998. Water Quality Sampling Part 1: Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples</i>
Groundwater monitoring	<i>AS/NZ5667.11: 1998. Water Quality Sampling Part 11: Guidance on Sampling of Groundwaters</i> <i>AS/NZ5667.1: 1998. Water Quality Sampling Part 1: Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples</i> - Origin Groundwater purging and sampling procedure CDN/ID8212543 - Geoscience Australia 2009: Groundwater Sampling and Analysis

3.24.3 Investigation and response framework

Where an exceedance of a monitoring program investigation trigger is observed from one of the monitoring programs outlined in Table 24, an investigation and response will be implemented as summarised in Figure 30.

The investigation and response process will be divided into the following components:

- Verification – is the result real?
- Evaluation – is the result related to petroleum activities?
- Remediation or management – what is the potential impact?
- Ongoing monitoring

The initial step in the process is *verification* of the measurement. This process begins with a check on integrity of the measurement, including a review of the protocol used to collect the measurement, calibration of equipment and the integrity of the monitoring infrastructure itself (such as the integrity of a monitoring bore). If the original data point is found to be correct, then a risk-based (appropriate to the scale and nature of the exceedances) investigation of the results is conducted and an evaluation phase is initiated.

The *evaluation* phase will have two (2) major goals; to identify the origin or source of the trigger exceedance and characterise the potential effects on environmental factors in order to reduce or eliminate negative consequences. This phase of investigation is conducted in a manner consistent with the type of threshold exceedance observed. Simple exceedances of water quality triggers during stormwater releases for example, may require simple investigations into the procedures and processes contributing to the event. Groundwater threshold exceedances may require more detailed assessment, whereby a comprehensive set of information is accessed and utilised, including a review of operational activities, the influence of other regional activities (e.g. mining or pastoral activities), changes in climatic conditions etc. Detailed investigation may include the identification of knowledge and/or data gaps and collection of additional data to fill these gaps and bring the issue into proper context.

If the *evaluation* phase of the investigation identifies the issue as being natural or not associated with petroleum activities, then the result is documented and monitoring continues. This may lead to the revision of a trigger or threshold. However, if the results indicate an influence of a petroleum activity, an assessment of risks is undertaken to assess the potential impact on environmental factors. This will involve a more in-depth evaluation or characterisation of the affected area and potential source. Regulatory notification may be required in accordance with section 7.7.

If the *evaluation* phase of the investigation indicates the influence of a petroleum activity, then mitigation measures may need to be implemented to prevent ongoing impacts to an environmental factor. These mitigation measures will be appropriate to the nature of the incident and will be based upon a risk assessment and technical feasibility assessments. Such mitigation measures may include:

- Stopping the activity and/or
- Modifying the activity to directly address the source of harm (i.e. additional procedures, training, ceasing or redesigning an activity) and/or
- Implementation of mitigation measures to reduce the potential effects (i.e. make good agreements, direct removal and treatment of contaminants etc.)

Upon implementation of mitigation measures, further *evaluation* through increased monitoring is undertaken to determine the success of the mitigation measures. If a positive result is observed, and trends begin to stabilise or reverse, then the result is documented and a return to regular monitoring occurs. If not, then the continued operation of the identified activity or activities causing the effected may need to be reviewed and adjusted in consultation with the regulator and other affected parties.

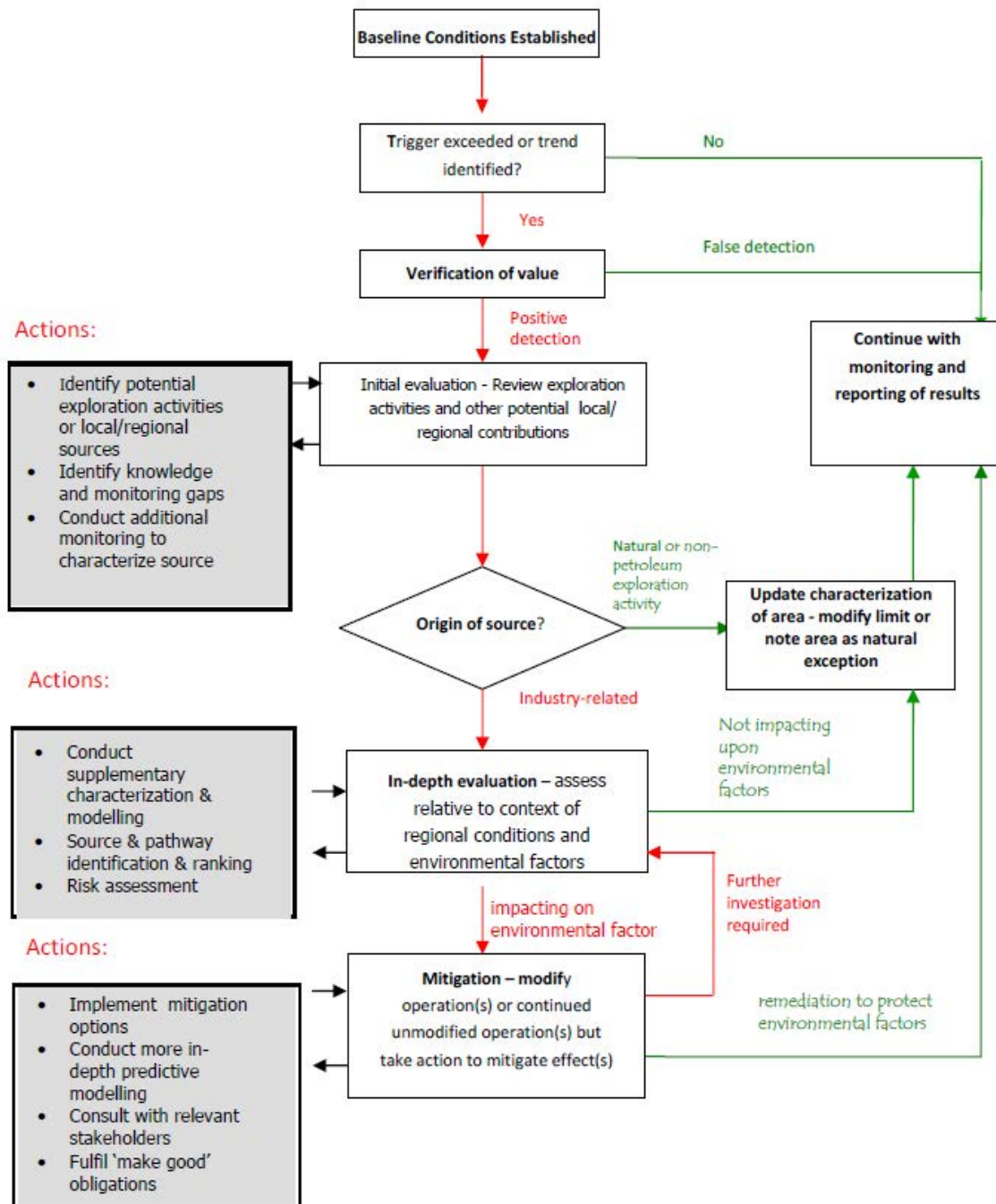


Figure 30: Investigation and response process

3.25 Rehabilitation plan

The proposed drilling and stimulation leases will form part of Origin's ongoing exploration program. Once a determination has been made to decommission an asset, each E&A well will be plugged and decommissioned, with the site rehabilitated in accordance with the Code of Practice. All tanks, surface infrastructure and wastes will be removed from site and disposed of in accordance with the *NT Waste Management and Pollution Control Act 1998*.

All remaining assets with a residual beneficial use (such as water bores, laydown yards, gates, fences, fresh water tanks etc.) will be offered for transfer to the pastoralist, subject to DEPWS approval and compliance with the Code of Practice. Prior to considering the transfer of ownership, Origin will:

- undertake an assessment of the current status of the asset and whether it can be beneficially used by the local pastoralist. Where a beneficial use is anticipated, identify works required to be undertaken to ready the asset for transfer (i.e. any repairs, site remediation, equipment removal etc.)
- obtain written agreement from the pastoralist to take ownership of the asset and document any stipulated liabilities.

Where an asset cannot be beneficially utilised, the site will be rehabilitated to the pre-existing condition using assisted natural regeneration. This will include:

- Removal of all surface facilities
- Removal of all weeds and contaminated materials/wastes
- Re-spreading of stockpiled topsoil
- Backfilling of all open sumps
- Reshaping the site to as close to natural form as possible
- Ripping or scarifying any compacted surface
- Spreading of stockpiled vegetation to aid in surface water flow control
- Spreading seed of suitable local native species which has been determined through analogue sites representative surrounding vegetation communities
- Any native seed supply and rehabilitation services will be sourced using Indigenous suppliers (where available).
- Yearly monitoring of the rehabilitation success requirements to assess the rehabilitation status of a site and determine where additional remedial works are required.

The rehabilitation plan is provided in Appendix M.

4 Description of the existing environment

4.1 Physical environment

4.1.1 Climate

The climate of the permit areas is arid to semi-arid, with rainfall decreasing in frequency and quantity from north to south. The climate is monsoon influenced, with a distinctive wet and dry season experienced through the year.

Rainfall in the north of the permit area is recorded at 681mm at Daly Waters. The southern portion of the permit area records an average annual rainfall of 536mm at Newcastle Waters and 602mm at Elliott. Approximately 90% of the rainfall occurs during the wet season between the months of December and March.

The area is characterised by a net precipitation deficit of between -1,800 to -2,150mm per year.

4.1.1.1 1:1000 wet season annual re-occurrence interval calculations

Monthly rainfall totals were analysed from the Scientific Information for Land Owners (SILO) data to interpolate rainfall data from 1900 to the present day. Consistent with industry accepted methodology associated with practices (such as dam risk assessments which calculates the wet season based on your geographical location) a 3-month time period was determined applicable.

The highest 3-month rainfall period during the wet and dry seasons was predicted for every year from 1900 till 2018. These values were then used to fit a Log Pearson III distribution to the data to allow us to extrapolate to the 1,000 year, 3-month duration wet season (Figure 31) and 3-month dry season (Figure 32). This method is consistent with the *Australian Rainfall & Runoff* methodologies. The median 1 in 1,000-year 3-month wet season is 1,289mm and 3-month dry season is 300mm. These figures do not include any evaporation and are therefore considered extremely conservative.

Based on the assessment, a 1,300mm wet season and 300mm dry season freeboard will be applied to all open sumps and tanks.

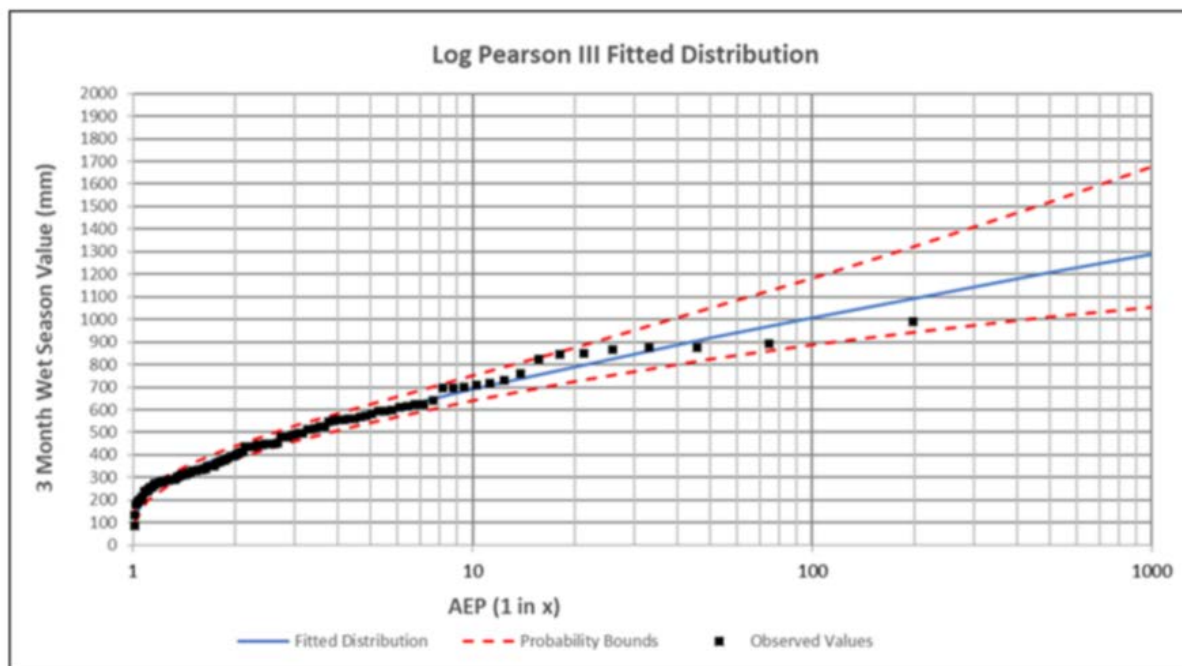


Figure 31: Log Pearson determination of 1:1000 wet season ARI

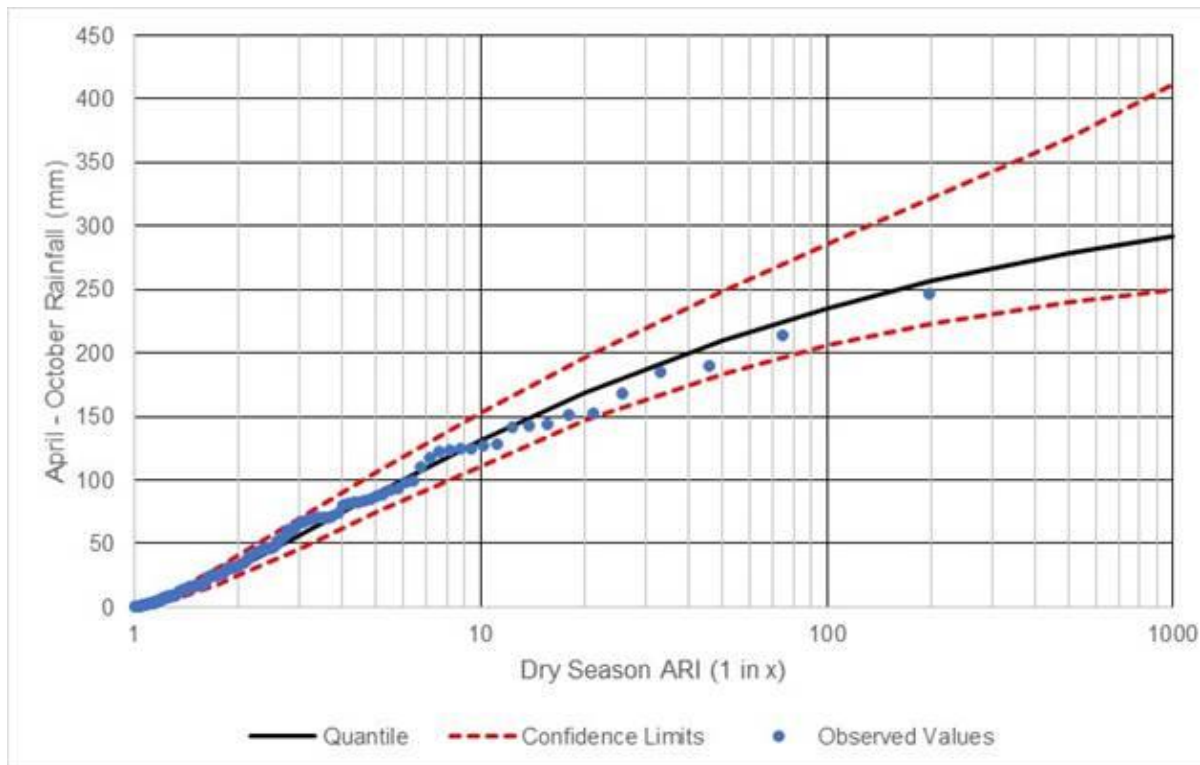


Figure 32: Log Pearson determination of 1:1000 dry season ARI

4.1.2 Geology

The Beetaloo Sub-Basin comprises a thick sequence of mudstone and sandstone formations (Roper Group) that were deposited approximately 1,500-1,300 million years ago (Ma) (Table 28). The Roper Group is estimated to reach 5,000m in thickness in the centre of the sub-basin and estimated to be thinner outside the formally defined Beetaloo Sub-Basin. The Roper Group is overlain unconformably by the yet to be formally defined Neoproterozoic Group. Unconformably overlying the Neoproterozoic group is the Georgina Basin (Cambrian) sedimentary package, which includes widespread extrusive flood basalts and a thick limestone sequence that forms the Cambrian Limestone Aquifer (CLA), a significant water supply aquifer. The Georgina Basin is capped unconformably by a thin section of Cretaceous mudstone and sandstone (Albian aged ~100-113 Ma) and recent alluvial and laterite deposits.

The Kyalla Formation, dominated by grey and black siltstone and shale, is separated from the Velkerri Formation by the Moroak Sandstone. The Kyalla and Velkerri formations share some similar basic lithological characteristics, although the current Kyalla Formation exploration targets are not as enriched in organic carbon as those within the Velkerri Formation. Organic richness within the Kyalla Formation is generally confined to three (3) discrete intervals (informally named by Origin as the lower, middle and upper SRR), with the deepest of these (lower Kyalla SRR) being the primary target of the 2019 Kyalla 117 N2-1H exploration well. The thick overlying mudstone and siltstones of the Kyalla Formation provide an effective geological barrier to any HFS in the organic rich lower Kyalla SRR target. The effectiveness of geological barriers to fracture height growth can be assessed with geomechanical data from core analysis, wireline log data and modelling.

4.1.3 Soils

The Stuart Plateau bioregion covers an area of 103,857 km² and comprises undulating plains on sandstones, with mostly neutral sandy red and yellow earth soils (ANRA, 2008).

The soil types located within the plateau range from the very strongly leached lateritic soils of the Tertiary land surface to the calcareous desert soils and desert loams in the southern drier areas.

The lateritic plains, located within EP98 and the northern part of EP117, are classed as very strongly leached soils of the Tertiary land surface. The three (3) main soil types located within the permit area, include:

1. **Tertiary Lateritic Red Earths:** which occur on the gently undulating topography. The soil profile can be described as:
 - **A-Horizon** Grey-brown sandy loam
 - **B-Horizon** Reddish-brown sandy clay loam
 - **C-Horizon** Red-brown to red light clay, overlying heavy ferruginous gravel and massive laterite
2. **Tertiary Lateritic Red Sands:** which occur on gently undulating to undulating topography of the Tertiary Lateritic Plain, formed from sandstones and complex parent materials of the deep sandy soils. The soil profile can be described as:
 - **A-Horizon** Grey-brown to brown sand
 - **B-Horizon** Brown sand
 - **C-Horizon** Red-brown to yellow-brown sand overlying pisolitic ferruginous gravel and massive laterite. Altered colouring of highly siliceous parent sandstone is only evident in the mottled and pallid zones
3. **Tertiary Lateritic Podzolic Soils:** formed on the gently undulating topography over a variety of rocks. These soils are located in the northern section of the Barkly Basin. The soil profile can be described as:
 - **A-Horizon** Grey sand
 - **B-Horizon** Yellowish-grey sand
 - **C-Horizon** Yellow-grey sandy loam with ferruginous gravel overlying massive laterite, mottled and pallid zones

Other areas of Black Soil Plains are located within the Barkly Tablelands, including EP76, the southern part of EP117 and a small section of EP98.

Geotechnical investigations of the Kyalla 117 N2 site have confirmed the underlying geology consist of red silty sand with some gravel pieces. The surface soils collected during the field survey indicated the soils were slightly acidic (pH range of 5.0 to 6.2) across the permit area. A dispersion test was also undertaken on the samples which indicated that the soils were non-dispersive and maintained their shape when submerged in water.

Table 27 presents the erosion risk rating based on average monthly rainfall using the rating system provided in the *IECA (2008) Table 4.4.2 for Daly Waters*. All construction activities are anticipated to be undertaken on the existing lease pad which has a stormwater sediment basin. No additional clearing or major civil construction activities are planned for the wet season. The overall risk of erosion is considered very low.

Table 27: Erosion risk rating based on average monthly rainfall at Daly Waters

Item	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall (mm)	165.4	165.4	120.1	23.6	5.0	5.6	1.5	1.7	4.9	22.5	59.4	110
Erosion Risk*	H	H	H	VL	VL	VL	VL	VL	VL	VL	M	H

* **E** = Extreme (>225 mm); **H** = High (100+ to 225 mm); **M** = Moderate (45+ to 100 mm); **L** = Low (30+ to 45 mm); **VL** = Very Low (0 to 30 mm)

4.1.4 Seismicity

Large earthquakes are relatively rare in Australia with an earthquake exceeding magnitude 7 on the Richter scale occurring somewhere in Australia every 100 years (SRC 2017). Earthquakes are comparably rare in the NT, aside from limited areas around Tenant Creek and west of Alice Springs (refer Figure 33) where several earthquakes with a magnitude of 6.2-6.4 occurred in a 12-hour period. Thousands of aftershocks have occurred since and whilst the rate has decreased, it has not yet returned to its pre-1987 level (McCue 2013).

In the Beetaloo, there have been no earthquakes over magnitude 3 measured since records began. The area is not prone to seismic activity and there is no evidence of recent earthquake activity as most faults and the major subsurface structure are confined to Cambrian or older strata.

The issue of induced seismicity from HFS activities has gained increasing exposure due to some high magnitude events in Oklahoma. However, the United States Geological Survey has stated very clearly that HFS is not causing most of the induced earthquakes and has pointed out that wastewater disposal via reinjection is the primary cause of recent earthquakes in the Central USA (USGS 2017b). Davies et al. (2013) illustrates that induced seismicity directly attributed to HFS operations is of such low occurrence that the documented cases are statistical anomalies rather than commonly occurring phenomena.

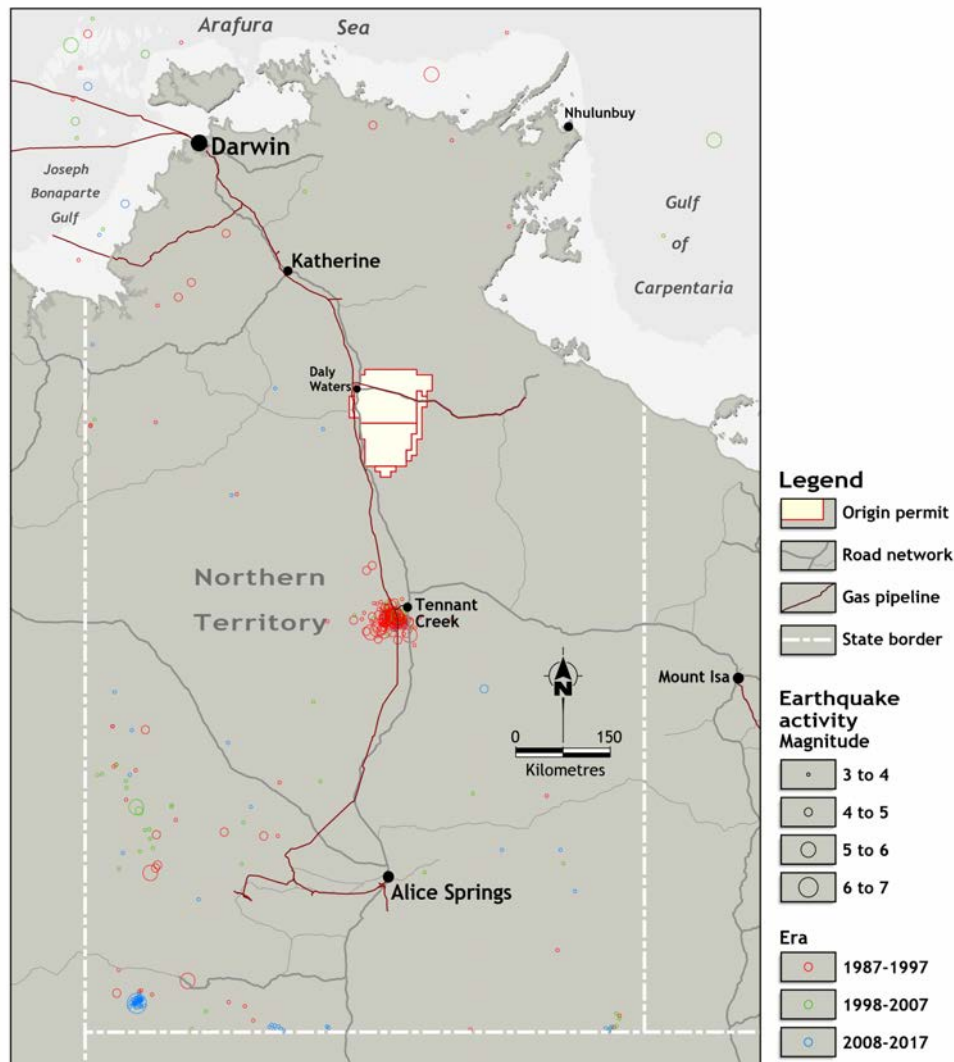


Figure 33: Earthquakes greater than magnitude 3 from 1987 to 2017 across the NT showing an absence of seismic activity in the Beetaloo area

4.1.5 Hydrology

The Kyalla 117 N2 lease sites all fall within the Wiso River Basin. The Wiso River Basin covers the southern half of EP98 (south of the Carpentaria Highway) and the majority of EP76 and EP117 and is internally drained by Newcastle Creek and a number of small ephemeral creeks. Newcastle Creek is approximately 60km to the south of the lease pad and ultimately flows into Lake Woods, which is located south of Newcastle Waters Station. Lake Woods covers an area of inundation of approximately 50,000ha in normal rainfall years, extending to 80,000ha in exceptionally wet years, after which it can retain water for several years (HLA, 2005). Lake Woods is described as a major quasi-permanent surface water body in the region, although some semi-permanent and many ephemeral waterholes are located across the permit area (HLA, 2006b).

There are no major creeks in the proposed area that are likely to be potentially impacted by the proposed activities. A number of small ephemeral streams (Stream Order 1 and 2) are located along the existing access tracks., with the closest being 12km from the Kyalla 117 N2 site (refer Figure 7

and figure 3 of the Land Condition Assessment report (AECOM 2018). The minor streams are overland flow paths that only flow for a short period during the wet season. During heavy wet seasons, large areas of the internal drainage systems are flooded, with the proposed area likely to remain dry as it is higher than the surrounding areas.

During the wet season, it is likely the broader region could experience widespread periodic surface flooding, to a depth of 30cm, which has previously been identified by debris being collected on fence lines (HLA, 2005).

4.1.6 Hydrogeology

Within the project boundary, groundwater use is primarily from the Cambrian Limestone Aquifer (CLA) with minor, localised use from other formations where shallower groundwater is intersected or where the CLA is not saturated. This includes:

- Overlying Cretaceous sediments where it is saturated in the central-south of the Beetaloo Sub-Basin
- The Antrim Plateau Volcanics in the north-west
- The Bukalara Sandstone in the north-east.

Table 28 summarises the encountered stratigraphy confirmed during the Kyalla 117 N2 exploration well drilling.

Across parts of the Beetaloo Sub-Basin, undifferentiated Cretaceous deposits form the uppermost aquifer are targeted for stock use. Notably, a basal sandstone unit immediately overlying the CLA produces yields of up to 5L/s. Shallow, perched groundwater has also been recorded in the laterised zone within the permit area with groundwater levels recorded between 1 and 6mbgl. These systems are dynamic with periodic saturation resulting from recharge during the wet season with no documented groundwater use. The CLA, comprising the Gum Ridge Formation and the Anthony Lagoon Formation, is an extensive regional aquifer system that forms the principal water resource in the Beetaloo Sub-Basin. In the vicinity of the Kyalla 117 N2 site, both aquifer units have a standing water level of approximately 114m below top of casing. The limestone in the CLA is commonly fractured and cavernous; regionally bore yields of up to 100L/s have been recorded from this aquifer. Such high yielding sections were encountered when drilling the Kyalla 117 N2-1 E&A well through the Anthony Lagoon and Gum Ridge Formation, with total losses of drilling fluid circulation at specific intervals. This is further discussed in section 3.4.3.

Approximately 80% of groundwater bores drilled in the basin screen the CLA and the aquifer supplies water for the pastoral industry and local communities including Elliot, Daly Waters, Larrimah and Newcastle Waters. The CLA contains a significant but largely undeveloped groundwater resource with the sustainable yield from the Georgina Basin estimated to be in the order of 100,000ML/year (NALWTF, 2009). Existing groundwater use in the Beetaloo Sub-Basin is estimated at 6,000ML/year, primarily used for agricultural production (Foulton and Knapton 2015).

The Antrim Plateau Volcanics conformably underlies the CLA in the north and central part of the Beetaloo Sub-Basin. Across much of the Basin it consists of sequences of massive basalt flows with negligible primary porosity. In the north-west of the Basin, where the formation is shallow and fractured, it forms a marginal aquifer, however, reported use is primarily from a sandstone sequence at the contact with the Gum Ridge Formation. There is no reported use within the three (3) petroleum exploration permits held by Origin.

The Bukalara Sandstone forms a fractured and weathered aquifer where it outcrops beyond the north-east margin of the Beetaloo Sub-Basin. The formation consists of quartz sandstone with shale interbeds and probable enhanced permeability in these areas due to jointing within the sandstone. No

use is reported from the formation away from the north-east margin of the Beetaloo Sub-Basin where it is at considerable depth. This unit, if present, will be protected through intermediate casing and cement.

The regional groundwater flow direction in the CLA is north-west toward Mataranka, where the aquifer discharges into the Roper River and supports significant groundwater dependent ecosystems (aquatic, riparian and floodplain) including the Roper River at Elsey National Park and Red Lily/57 Mile Waterhole. These discharge features occur around 100km north-west of the Beetaloo Sub-Basin. Dry season flow in the Roper River has been gauged at 95,000-126,000ML/yr and provides an estimate of the magnitude groundwater discharge from the CLA. Large decadal changes in the discharge to the Roper River suggest that most recharge input occurs close to the discharge zone (i.e. beyond the Beetaloo Sub-Basin region). Groundwater recharge mechanisms to the CLA are poorly characterised but are likely to be dominated by infiltration through sinkholes and preferential recharge through soil cavities. A Geological and Bioregional Assessment project led by CSIRO is currently collecting additional information on this recharge mechanism.

Limited information exists on the hydrogeological characteristics of the deeper Roper Group and undefined Neoproterozoic group sequence is available as it occurs at depth within the Beetaloo Sub-Basin. This unit lies below the Georgina Basin which contains the CLA and other important aquifers. The deeper sandstone dominated formations may behave as aquifers, however, drilling results suggest these formations have limited potential as groundwater resources due to their depth, low permeability and high salinity. Groundwater in the Roper Group and undefined Neoproterozoic group is highly saline and contrasts with the shallower, utilised aquifers of the Georgina Basin sediments in which groundwater is generally table 35

of drinking water quality. A schematic of the Kyalla 117 N2 E&A wells within the underlying geological formations is provided in Figure 12.

Table 28: Summary hydrostratigraphy at the Kyalla 117 N2 site

Province	Period/Age	Formation		Aquifer status	Encountered Depths (top and bottom) (m)	Regional Yield (L/s)	Avg regional EC (ms/cm)
CARPENTARIA BASIN	CRETACEOUS ALBIAN (100-113Ma)	Undifferentiated		Regional aquifer-Undersaturated at location	0m-70m	0.3-4	1,800
GEORGINA BASIN	CAMBRIAN	Cambrian Limestone Aquifer (CLA)	Anthony Lagoon Formation	Regional aquifer	70 -191.4m	1-10	1,600
			Gum Ridge Formation	Regional aquifer	191.4-399.5m	0.3- >20	1,400
		Antrim Plateau Volcanics		Regional aquitard	399.5-499m	0.3-5	900

Province	Period/Age	Formation	Aquifer status	Encountered Depths (top and bottom) (m)	Regional Yield (L/s)	Avg regional EC (ms/cm)
		Bukalara Sandstone	Regional aquifer	499-506.7m	0.3-5	1,000
Undefined – Under NTGS Review	NEOPROTEROZOIC	Hayfield Formation	Regional saline aquifer	506.7-891.33m	ID	32,000
		Jamison Sandstone	Local saline unit	891.33-988.97m	ID	138,000
BEETALOO SUB-BASIN (ROPER GROUP)	MESOPROTEROZOIC 1,300-1,500 Ma	Kyalla Formation	Regional aquitard	988.97-1851.75m	ID	ID
		Moroak Sandstone	Local saline unit	1851.75- not determined	0.5-5	131,000
		Velkerri Formation	Regional aquitard	700-900	-	-
		Bessie Creek Sandstone	Local aquifer (not regionally connected)	450	0.5-5	-

ID - insufficient data

4.2 Biological environment

A Land Condition Assessment (LCA) was completed in August 2018 to gather baseline information on the current biological environment within the proposed activity area. This was included in the previous Kyalla 117 N2 Civil Construction EMP NT-2050-15-MP 026 and summarised in the following section.

A summary of the LCA is provided in the [Beetaloo Basin Kyalla, Civil Construction EP117 N2 EMP](#), approved 6 June 2019, Appendix C.

4.2.1 Bioregions

Two bioregions occur within the Origin permit areas:

- Stuart Plateau bioregion
- Mitchell Grass Downs bioregion

The Kyalla 117 N2-1 site is located within the Stuart Plateau Bioregion which comprises undulating plains on sandstone, with predominantly neutral sandy red and yellow earth soils. Dominant vegetation associations included extensive areas of Lancewood (*Acacia shirleyi*), Bullwaddy

(*Macropteranthes kekwickii*) vegetation and associated fauna, including the Spectacled Hare-Wallaby (*Lagorchestes conspicillatus*). Land condition in the bioregion is moderate to good but is threatened by impacts from weeds, feral animals, pastoralism and changed fire regimes.

4.2.2 Vegetation communities

Vegetation communities within the permit areas have been ground-truthed during baseline assessments in 2004, 2006 (HLA, 2006; 2006c), 2010, 2014, 2016 (AECOM, 2011; 2014; 2016) and more recently in August 2018. The August 2018 survey focused on the full extent of areas to be impacted by Origin's proposed exploration activities.

The infrastructure location has been evaluated through detailed habitat assessments which included identification of vegetation community, dominant flora species at each strata, habitat condition, disturbance factors (fire, weeds, erosion, feral fauna species), and fauna attributes (e.g. tree hollows, logs, grass cover, mistletoe abundance). The area of the proposed activity is largely characterised as *Corymbia* low woodland/*Terminalia* (mixed) sparse shrubland/*Chrysopogon* (mixed) low tussock grassland. The access track to the lease pad is characterised with the same vegetation unit, with patches of Bullwaddy and Lancewood. The vegetation communities are considered regionally extensive and not subjected to extensive clearing. A summary of the survey of the Kyalla 117 N2-1 site is shown in Table 29, with the surrounding vegetation community illustrated in Figure 34. Figure 34: Vegetation communities surrounding the proposed Kyalla 117 N2 site.

Table 29: Kyalla 117 N2 summary of existing environment

Site ID	Kyalla 117 N2	Habitat survey photos of the Kyalla 117 N2 site pre-clearance, indicative of the vegetation / habitat of the surrounding environment	
Location	-16°50' 29.01, 133°39' 0.16		
Landform and soil	Plains and rises associated with deeply weathered profiles (laterite) including sand sheets and other depositional products, sandy and earth soils		
Habitat type	<i>Corymbia</i> low woodland		
Vegetation community	<i>Corymbia</i> low woodland/ <i>Terminalia</i> (mixed) sparse shrubland/ <i>Chrysopogon</i> (mixed) low tussock grassland This vegetation community is considered regionally extensive and not subjected to extensive clearing		
Dominant flora species	Canopy dominated by <i>Corymbia dichromophloia</i> , <i>Eucalyptus setosa</i> . Shrub layer including <i>Acacia ancistrocarpa</i> , <i>Alphitonia pomaderroides</i> , <i>Brachychiton paradoxus</i> . Ground layer species include <i>Triodia bitextura</i>		
Habitat condition	No core habitat for threatened fauna identified. Good condition with evidence of recent grazing. Vegetation appeared to have been heavily burnt in recent years. No evidence of hollow bearing trees and logs. Habitat contained moderate to high refuge opportunities in the form of dense leaf litter, tussock grass cover, and woody debris. Good continuous cover adjoining adjacent woodland habitat and regionally extensive. No evidence of weeds or feral animals.		

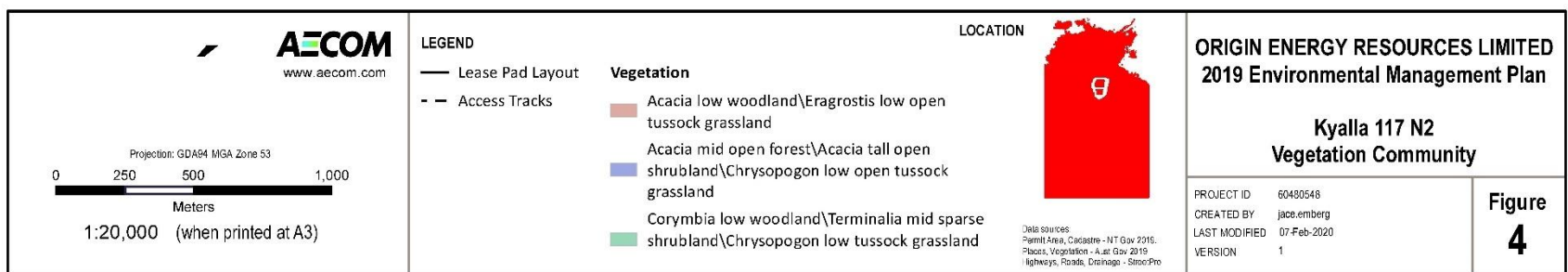


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Potential listed threatened species	Grey Falcon, Northern Shrike-tit, Plains Death Adder, Gouldian Finch	Hydrogeology Groundwater resources and use is primarily from the Cambrian Limestone Aquifers (the Anthony Lagoon Formation and Gum Ridge Formation) with the shallower undifferentiated Cretaceous or perched alluvium systems being unsaturated.
Weeds	No <i>Weeds of National Significance</i> present	



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Figure 34: Vegetation communities surrounding the proposed Kyalla 117 N2 site

4.2.3 Flora

A total of 805 plant species have been recorded within the wider region, and during the August 2018 survey, 28 dominant flora species were identified. As the survey was conducted during the late dry season, grasses and other annual species were difficult or impossible to identify due to the lack of inflorescence or because they had already died-back.

No Commonwealth or NT threatened plant species were identified as occurring by the Protected Matters Searches or NRM Infonet search. One species, the prostrate, herbaceous vine *Ipomoea argillicola*, is listed as Near Threatened under Section 29 of the *Territory Parks and Wildlife Conservation Act 2000 (TPWC Act)* and could potentially occur in the project sites, although has not been reported in previous and current surveys. The NT flora database shows that this species has been recorded from the Bullwaddy Conservation Reserve and at locations surrounding the area in previous searches (AECOM, 2015).

The region supports fragmented stands of Bullwaddy, which is listed under the TPWC Act as 'Least Concern', which refers to species that are either widespread or common and cannot be categorised as Critically Endangered, Endangered, Vulnerable, Near Threatened or Data Deficient. However, Bullwaddy is significant in terms of the habitat it provides for a range of native species. The extent of Bullwaddy in the permit area is far more extensive than that indicated by the NT Herbarium records.

4.2.4 Weeds

Regional Weed Management Plans (RWMP) have been developed for areas of the NT, with the Barkly and the Katherine RWMP overlapping Origin's Beetaloo exploration tenure.

The weed species of high risk of introduction or spread through Origin's activities are listed in Table 30. These high-risk weeds have been determined through consideration of the following criteria:

- Weed species that has been confirmed in the area within the relevant RWMP or through field surveys
- Weed species listed in a RWMP that are in close proximity to Origin tenure
- Weed species that is at risk of introduction through the use of machinery sourced from other regions in the NT or from other states

Weed baseline surveys were completed by AECOM in August 2018 covering all access tracks and lease pad areas. These surveys were completed with the DEPWS Weed Officer. A summary of the weed surveys is provided in the Land Condition Assessment (AECOM 2018)

Routine (6-monthly) weed monitoring has commenced on the access tracks, gravel pits and lease pads. No weeds were identified along the existing access track, except for *Calotropis procera* (Rubber Bush) which was identified prior to construction at the access track intersection with the Stuart highway. Rubber bush has been previously identified along/in close proximity to the Beetaloo W1 exploration well access track, which is approximately 30km south of the proposed areas.

The absence of weeds identified during surveys suggests good habitat condition in the areas of the proposed activity. Primary controls for this program have been focused on preventing the introduction of weeds and managing any weeds promoted through site disturbance. Routine pre and post-wet season inspections are ongoing and will confirm the success of control measures implemented to date as a part of E&A activities.

Additional information on the full list of weeds and control measures for the development are provided in the Beetaloo Weed Management Plan (Appendix J).

Table 30: High priority weeds to be managed or prevented within the permit area

Scientific name	Common name	Status	Priority reason
<i>Acacia nilotica</i>	Prickly Acacia	Class A, WoNS	Mapped in the exploration lease within the Katherine RWMP
<i>Andropogon gayanus</i>	Gamba Grass	Class A, WoNS	Mapped in the exploration lease within the Katherine RWMP
<i>Calotropis procera</i>	Rubber Bush	Class B and C	Mapped in the exploration lease within the Barkly RWMP
<i>Hyptis suaveolens</i>	Hyptis	Class B and C	Confirmed within exploration lease during previous weed Origin surveys
<i>Jatropha gossypifolia</i>	Bellyache Bush	Class A, WoNS	Mapped in the exploration lease within the Katherine RWMP
<i>Parkinsonia aculeata</i>	Parkinsonia	Class B and C, WONS	Confirmed within exploration lease during previous weed Origin surveys and Mapped in the exploration lease within the Katherine RWMP
<i>Prosopis pallida</i>	Mesquite	Class A and C, WONS	Mapped in the area surrounding exploration lease within the Katherine and Barkly RWMP
<i>Themeda quadrivalvis</i>	Grader Grass	Class B and C, WoNS	Mapped in the area surrounding exploration lease within the Katherine RWMP. High potential introduction through sourcing of equipment from Katherine area
<i>Xanthium occidentale</i>	Noogoora Burr	Class B and C	Weed Management Branch – Mapping data DLRM databases (DLRM <i>et al</i> 2018)
<i>Parthenium hysterophorus</i>	Parthenium	Class A and Class C, WoNS	Potential introduction through equipment sourced from QLD

4.2.5 Fauna

Previous surveys and database searches indicate that the exploration area is an important area for a diverse array of fauna. The NT Fauna database provides records for the following fauna species (excluding migratory birds): 32 species of mammal, 198 species of birds, 96 species of reptiles and 19 species of frogs. Surveys undertaken elsewhere within the region have recorded:

- 78 bird, 33 reptile, 11 mammal and 6 frog species in the Bullwaddy Conservation Reserve (PWCNT, 2005)

- 148 bird, 47 reptile, 21 mammal and 6 frog species in the Junction Stock Reserve and nearby Newcastle Waters (Fleming et al., 1983)
- 157 bird species within the project area as determined by a search of the Birds Australia bird atlas database (Birds Australia, 2010)

The Eucalypt/Corymbia woodland at the Kyalla 117 N2-1 site will provide habitat for a range of species. The areas have high native grass cover and include numerous species suitable for granivorous birds (seed eaters). Dense leaf litter and numerous logs provide suitable refuge and foraging sites for fauna such as reptiles. Many of the sites have a high density of hollow-bearing trees that provide important habitat for many fauna species. Although most of the species found in this vegetation type are widespread in the tropical savannas of the Northern Territory, some such as the threatened Crested Shrike-tit (*Falcunculus frontatus whitei*) are rare and known to utilise this habitat (DAWE, 2014, Ward, 2008).

In the broader area, Savanna grasslands and open woodland provide suitable habitat for species such as Emu (*Dromaius novaehollandiae*) and Australian Bush Turkey (*Ardeotis australis*). Drainage lines and seasonally inundated grasslands may also provide habitat for migratory species during the wet season and are breeding areas for frogs. The proposed activity will have limited disturbances in these areas.

The location of the infrastructure has been selected to minimise the clearing on areas of high value habitat (such as large hollow-bearing trees) to reduce any impact to native wildlife within the permit area. Due to the regional extensiveness of the vegetation communities and limited scale of disturbance, impacts to fauna have been assessed as unlikely.

4.2.5.1 Fauna monitoring results

Data on fauna interactions with E&A activities during the Kyalla 117 N2-1H exploration well drilling have been collected. Data on fauna sightings is collected through routine (daily) inspections and the fixed fauna cameras located around the perimeter of the lease. Since drilling began in October 2019, 23 different species have been observed, including 18 birds, four (4) mammal and one (1) reptile species. Of these observed species, budgerigars, agile wallaby, northern freetail bat and welcome swallow are the most encountered fauna when on-site. No endangered or listed threatened fauna species have been observed interacting with wastewater onsite.

During operations, the welcome swallow appears to be attracted to the freshwater tanks and guy wires of the rig. The northern freetail bat appear to be hunting insects that are attracted to the drilling rig lights at night.

Two (2) bird mortalities of unknown species (due to decomposition) were recorded within the drilling wastewater tank at the Kyalla 117 N2 site between August 2019 and September 2020. Another two (2) individual birds, the Australian hobby and welcome swallow, were found on the rig floor in a disorientated state. These two (2) individuals were removed, allowed to rest and later released. The Australian hobby may have become disorientated when it was chasing prey near the rig. Conversely, the welcome swallow may have been seeking cover in the drilling rig to escape a predator and became disorientated due to the activity noise. Based on observations and monitoring conducted to date, it does not appear that wastewater storage represents a significant risk to fauna and is consistent with the current risk rating.

4.2.5.2 Significant fauna

A search of the DITT Protected Matters database of nationally significant fauna (PMST), the NT Government fauna database (NRM Infonet), and records from the Atlas of Living Australia (ALA) was undertaken for the Kyalla 117 N2-1 lease areas and access tracks. The search results indicate the

potential presence of 20 fauna species listed as threatened under the *EPBC Act* and/or the *TPWC Act*. These included 10 birds, 8 mammals and 2 reptiles.

The likelihood assessment of species occurrence is based on the availability of suitable habitat within the permit area, records in the vicinity and distributional data. Therefore, many of the threatened and migratory fauna species indicated in databases as ‘*occurring*’ or ‘*likely to occur*’ have been assessed as ‘*unlikely to occur*’ within the vicinity of the Kyalla 117 N2-1 site. As some areas in the vicinity of the lease area have not been subject to intensive survey and some species are very cryptic, a conservative approach has been taken to assess species presence. A full description of each species, their distribution and habitat associations is outlined in the Land Condition Report (AECOM 2018).

No core habitat for threatened fauna was identified at the sites. However, some species may possibly occur and are known to occur in the wider landscape. Threatened species that may possibly occur include:

- Gouldian Finch *Erythrura gouldiae* (E-EPBC Act, VU-TPWC Act)
- Crested Shrike-tit (northern) *Falcunculus frontatus whitei* (VU-EPBC Act, NT-TPWC Act)

Research has shown that critical components of suitable habitat for the Gouldian Finch include suitable nesting trees during the breeding season (particularly *E. tintinnans*, *E. brevifolia* or *E. leucophloia*), a water source and a diverse range of favoured annual and perennial grasses (DoE, 2015). No nesting habitat was recorded during the surveys and it is unlikely this species breeds in close vicinity of the sites. During the wet season, Gouldian Finches move from breeding habitat on hillsides with suitable trees down to lower lying areas where they forage on perennial grasses such as *Triodia* sp., *Alloteropsis semialata*, and *Chrysopogon fallax* (Palmer et al. 2012). Some of the perennial grasses were recorded during recent surveys so potential foraging habitat is present in the vicinity of the Kyalla 117 N2 site ; however, the level of available habitat across the basin is extensive, with the Gouldian finch likely only to be using a small percentage of those previously occupied (National Recovery Plan for the Gouldian Finch (*Erythrura Gouldian*). It is therefore considered unlikely for the finch’s to travel more than the reported 17kms from their dry season nesting locations in the wet season (National Recovery Plan for the Gouldian Finch (*Erythrura Gouldian*).

Although there is potential wet season foraging habitat, the high level of water availability regionally is likely to remove the driver to access the Kyalla 117 N2 site. Based on the available data, the Gouldian Finch is unlikely to be encountered at the Kyalla 117 N2 site throughout the year. This is confirmed by the current fauna monitoring results, which have not detected the Gouldian Finch onsite.

The Crested Shrike-tit lives in dry Eucalypt forests and woodland where it feeds on insects from the canopy and under bark (Ward, 2008). It has been recorded in wet Melaleuca open woodlands, woodlands dominated by Nutwood (*Terminalia arostrata*), Bloodwoods with flaky bark and Ironwood (DoE, 2014, Ward, 2008). In the NT, nesting has been recorded from September through to January and nests are built in terminal branches at the top of trees (Ward et al. 2009). The stronghold of this species is north of this location and only one old record exists near Borroloola. Although it is possible this species may be present in the area, it is unlikely to represent an important area for this species and the impact of the proposed activities, given their size, would be small.

The Grey Falcon (*Falco hypoleucus*) is a widespread species listed as Vulnerable in the NT that is considered possibly to be present in the study area. The Painted Honeyeater (*Grantiella picta*) has been known to occur in the study area, however, given it does not breed in the NT it would only be present intermittently for foraging. Based on the field assessment there was no breeding habitat recorded, and depending on grass seed and water availability, it is unlikely the study area comprises core habitat for this species.

4.2.5.3 Feral and pest animals

Feral animals known to occur within the region include:

- Pig (*Sus scrofa*)
- Wild dog (*Canis lupus familiaris*)
- Feral cat (*Felis catus*)
- Cane toad (*Bufo marinus*)
- Horse (*Equus caballus*)
- Donkey (*Equus asinus*)
- Water buffalo (*Bubalus bubalis*)
- Camel (*Camelus dromedarius*)
- Black rat (*Rattus rattus*)
- Domestic cattle (*Bos Taurus*)

During the August 2018 survey, evidence of cattle grazing being present, or 1-2 years previously, was recorded. In previous surveys of the permit area, cat tracks were observed as the only non-native species recorded. Based on records many species, especially dogs/dingo, pigs and cane toads will be present in permit area. The disturbance from cattle within the vicinity of the Kyalla 117 N2-1 site was considered to have resulted in less than 5% damage or no damage at all.

4.3 Fire regime

Fire is a natural occurrence in most Australian ecosystems and plays an important role in their ecology. Fire is generally excluded from Mitchell grasslands by pastoral management in order to maintain forage throughout the dry season (HLA, 2005), whereas fire is more frequent in the Stuart Plateau.

Fire disturbance was evident at Kyalla 117 N2 during the ecological surveys, with evidence of an Intensity 4 (some trees and shrubs killed) and Height 1-4m fire present 1-2 years previously. It was noted that the site showed evidence of fire disturbance and was showing signs of regrowth and recovery.

A Bushfire Management Plan (BMP) has been developed to manage bushfire risks associated with the Kyalla 117 N2 site. This plan provides the hazard reduction strategies, resources and response to bushfire emergencies. The BMP is provided in Appendix D.

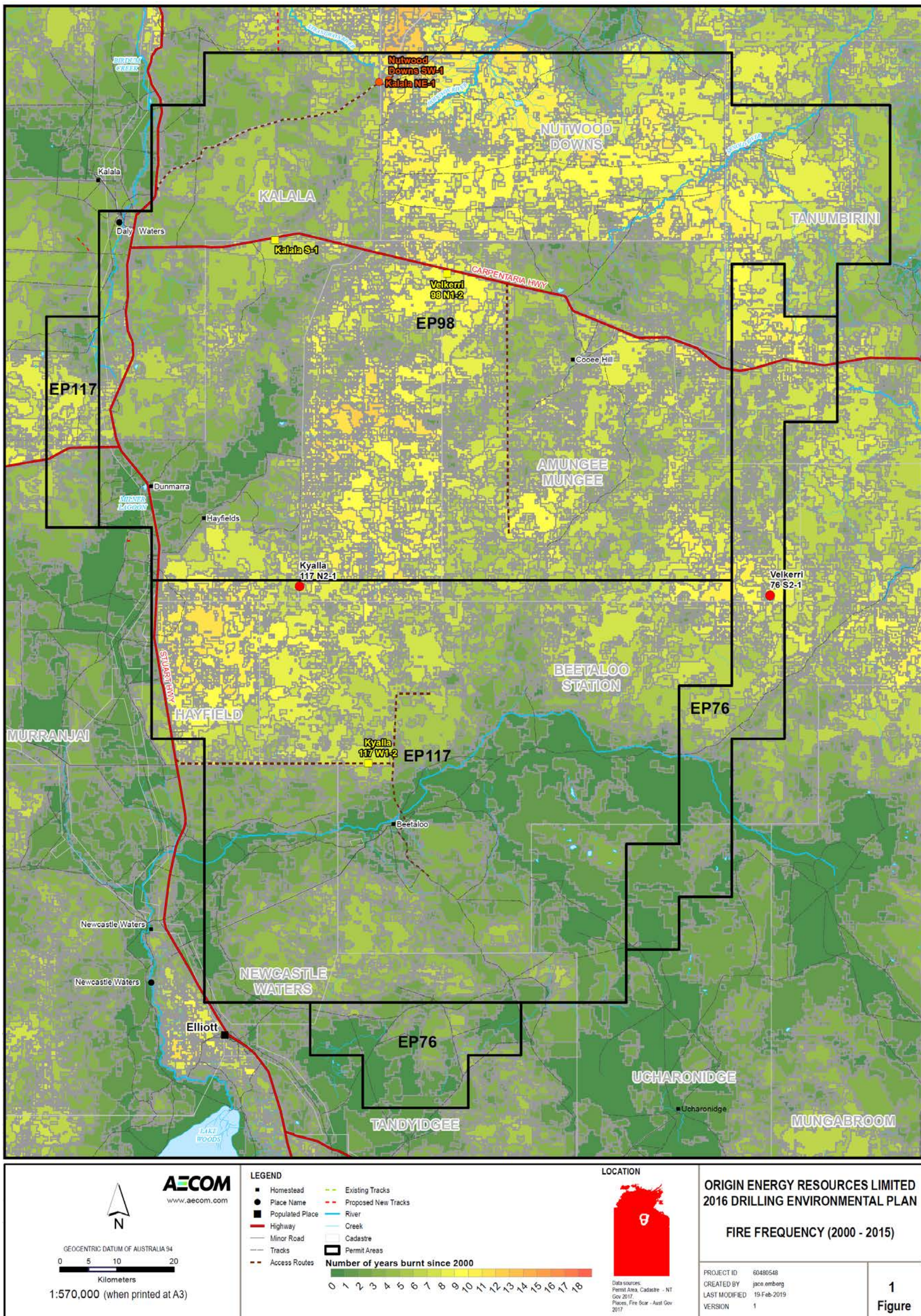


Figure 35: Fire frequency map of the Beetaloo Sub-Basin

4.4 Groundwater Dependent Ecosystems

A search of the National Groundwater Dependent ecosystems (GDE) was conducted on 09/10/2020. The dataset expresses the potential for groundwater interaction/use for river/spring/wetland ecosystems across Australia. It shows the ecosystems that rely on groundwater that has been discharged to the surface, such as baseflow or spring flow. There are no terrestrial or aquatic GDEs identified within the vicinity (50km) of the Kyalla 117N2 site. The closest GDE's are located approximately 100km North of Origin Beetaloo tenure, where the aquifer discharges into the Roper River and supports significant groundwater dependent ecosystems (aquatic, riparian and floodplain) including the Roper River at Elsey National Park and Red Lily/57 Mile Waterhole). The impact on these units from Origins total water extraction was assessed during the granting of WEL GRF 10285.

Stygofauna are a form of GDE that inhabit the interstitial spaces of the cavities of alluvial, sedimentary and karstic aquifers. Limited information is available on the presence of stygofauna within the Beetaloo Sub-basin, with a Gas Industry Social and Environment Research Alliance (GISERA) program currently underway to identify and characterise stygofauna assemblages in the CLA units of the Beetaloo Sub-basin¹⁷. Data is available that can provide an indication of the likelihood of stygofauna presence, with Hose, GC., et al (2015) outlining the following factors affecting the distribution of stygofauna:

- **Formation type:** Stygofauna are predominantly found in aquifers with large (mm or greater) pore spaces, which are more common for alluvial, karstic and some fractured rock aquifers.
- **Depth below ground level:** The abundance and diversity of stygofauna typically decreases with depth below ground, with fauna rarely found more than 100 m below ground level (Hose, GC *et al* 2015).
- **Proximity of exchange and recharge:** Stygofauna are more abundant in areas of surface water-groundwater exchange, compared to deeper areas or those further along the groundwater flow path remote from areas of exchange or recharge

Based upon the above, Stygofauna are anticipated to be present in upper CLA intervals in the vicinity of the Kyalla 117 N2 site, within the Anthony Lagoon formation. This formation is currently not targeted for water extraction by Origin and is present at the upper depth range of stygofauna presence being approximately 70Mbgl. Groundwater extraction for the Kyalla 117 N2-2H and 3H is from the Gum Ridge formation, which is located ~190Mbgl. The depth and limited extraction draw down predicted and observed concludes that impacts to stygofauna from extraction are considered highly unlikely.

Changes in groundwater quality may also result in impacts to stygofauna. Impacts to aquifers are mitigated through the following controls:

- Well design and construction to isolate aquifers
- Low toxicity drilling fluid systems utilised
- Groundwater monitoring bores are located within 20m of E& wells to detect changes in groundwater quality

Based upon the above information, the presence of significant assemblages of stygofauna in the area is considered limited and impacts considered unlikely.

¹⁷ Further information is available on the GISERA website: <https://gisera.csiro.au/project/characterisation-of-the-stygofauna-and-microbial-assemblages-of-the-beetaloo-sub-basin-nt/>

4.5 Environmental and cultural sensitivities

4.5.1 Native Title

Two (2) Native Title claims have been determined as non-exclusive and one (1) Indigenous Land Use Agreement (ILUA) are current over the permit areas (see Table 31).

Table 31: Native Title and IULA Agreements current for the permit areas

Type	Well site	Name	Summary
Native Title	Kyalla 117 N2	NTD21/2010 Shenandoah Pastoral Lease	Native Title exists in parts of the determination area and is held by the Kinbinnggu and Bamarrngganja groups
Indigenous Land Use Agreement	All Sites	D12004/014 Jingaloo CLA ILUA	Registered for Community Living Area and Tenure resolution

The Native Title Petroleum Exploration Agreement between Origin and the NLC includes clauses for the protection of sacred sites, objects and sensitive areas related to Aboriginal activities in the area, including cultural, hunting and foraging activities. Site clearance will occur prior to any on ground activities. The Native Title Agreement also includes clauses for the protection of the environment and site rehabilitation.

4.5.2 Archaeology assessment

An archaeological assessment, involving searches of the NT Heritage Register and Australia Heritage Database and a field survey, have been carried out by AECOM archaeologist, Luke Kirkwood, for the exploration sites and associated tracks. It should be noted that this survey covers additional sites that are not in the scope of this EMP.

A search of the NT Heritage Register identified 41 Aboriginal archaeological sites within a 125km by 125km area that encompasses the full proposal area. No archaeological sites are recorded within 15 km of the proposed 2019 lease areas.

A search of the Australia Heritage Database identified that no statutory listed heritage places within the proposed impact areas.

The field survey involved a combination of both pedestrian and helicopter survey of the proposed disturbance areas. During the inspections, notes were taken on landform, ground surface visibility and areas of exposure. The aim of the field survey was to identify any surface expressions of Aboriginal archaeological and cultural heritage values within the exploration area. Photographic records were taken at each proposed location.

No culturally sensitive landforms or artefacts were identified during field surveys of the lease sites covered under this EMP.

The archaeological assessment is provided in Appendix D of the Kyalla Civil Construction EMP approved 6 June 2019. Available at

https://depws.nt.gov.au/_data/assets/pdf_file/0006/706155/ep117-origin-betaloo-basin-kyalla-emp.pdf.

An unexpected finds protocol has been developed to respond to any potential artifact or sacred site finds during Origin's activities. The is provided in Appendix N.

4.5.3 Areas of cultural significance

Sacred sites in the study area are primarily associated with drainage lines; natural landform features and stock routes, but there are also concentrations of sites nearby to old homesteads. The distribution of these sites may reflect historical patterns of Indigenous movements along drainage lines and subsequent development of stock routes on old Indigenous walking trails, or they may merely be indicative of the site clearance work undertaken along roads and tracks in the area. It is suspected that there will be a range of other sites also within the area, either not yet recorded, or known but not reported for cultural reasons.

AAPA certificate C2020/003 have been granted covering all activities covered under this EMP. There are no Restricted Work Areas within the immediate vicinity of Origin's proposed activity.

Other restricted works areas are identified across the entire permit area. Origin has committed to comply with conditions as prescribed by AAPA for the duration of the program.

4.5.4 Natural resources

In addition, previous cultural heritage surveys of the permit areas were undertaken with representatives of the Traditional Owners who identified several natural resources of importance to Aboriginal people of the area (Table 32).

Table 32: Natural resources of importance in the permit areas

Scientific name	Common name	Usage
<i>Grewia retusifolia</i>	Emu-berry/Dog's Balls, Turkey Bush and Diddle Diddle	Fruit eaten. Leaves can be boiled, and body bathed in the liquid for treatment of a number of ailments
<i>Marsdenia australis</i>	Bush Banana/Gillibi	Bush 'fruit' eaten when young, as it matures 'fruit' seeds becomes feathery for dispersal in the wind and are not eaten
<i>Pterocaulon</i> sp.		Used for treating flu
<i>Acacia</i> sp.	Acacia	Leaves boiled and used to treat flu
<i>Acacia holosericea</i>	Soapbush Wattle or strap wattle	Leaves used for washing
	Termite (unknown species)	Mounds pulverised and mixed with water, used to treat diarrhoea

4.5.5 Non-Indigenous heritage

In 1860, explorer John McDougall Stuart was the first European to penetrate the area now known as the 'Centre'. The first written descriptions of the area come from Stuart during his second attempt to cross the continent from south to north (HLA, 2005).

Development in the area began as pastoral lands with an increased interest in land settlement following the completion of the Overland Telegraph Line in 1873. Most attempts were unsuccessful with the Lancewood-Bullwaddy vegetation found to be impenetrable and the lack of surface water making the land unsuitable for cattle. Daly Waters was thus recognised as one of the last watering stops on the Murrarji Stock Route.

It wasn't until the 1930s to 1950s, that the area saw regional economic growth with Daly Waters becoming a significant hub of air and mail services into the Northern Territory. The wartime years saw this role increase with Daly Waters again playing a major role in cross country transport and communication. This role continued until the early 1970s when the airport was closed to commercial traffic. The town and surrounding areas subsequently reverted to a primarily agriculture-based existence following the decline of air travel, but in recent times has seen commercial interest from the exploration for gas in the Beetaloo Sub-Basin and the growth of the 'grey nomad' tourism market.

4.5.6 Historic heritage assessment

A search of relevant historic heritage registers identified several historic heritage sites within a 125km by 125km area that encompasses the full proposal area. Frew Ponds, a reserve paying tribute to the building and joining of the Overland Telegraph Line is located 28km west south-west of the Velkerri Lease pad and approximately 16km south of the access track turn in from the Stuart Highway.

4.5.7 Protected or conservation areas

There are no conservation reserves, national parks, world heritage places, Commonwealth land, heritage places or critical habitat areas listed under the *EPBC Act* located within or adjacent to the proposed exploration area.

The closest area is the Bullwaddy Conservation Reserve, which is located 71km from the proposed activity area. The EBC Listed Lake Woods is located approximately 92km from the site and is a listed on the National directory of important Wetlands.

The risks to these receptors through aquifer contamination, spills, sediment release, habitat destruction have been addressed in the risk assessment presented in Appendix K. the main mitigation measures/factors include:

- As the proposed site is 71km away from the Bullwaddy Conservation Reserve and 92km (direct) from Lake Woods, contamination is not likely to reach the area at any undiluted impactable state.
- Surface water flow is to the south into a tributary of Newcastle Waters. Any spill would need to exceed the capacity of the site bund and travel approximately 110km to reach Lake Woods. A spill cannot impact the Bullwaddy Conservation Area.
- Groundwater depth throughout the Bullwaddy Conservation Reserve and the proposed conservation area is generally 70m of depth with vegetation not being able to access groundwater at this depth. The flow path is generally not in alignment with these two protected places.
- All access tracks are to the south of the Bullwaddy Conservation Reserve with vehicles and workers not interacting with flora and fauna from the site.

4.6 Social environment

4.6.1 Social context

The proposed 2019 work program will occur within the Barkly Regional Council area, which covers 323,514 km². The approximate population is estimated for the Barkly Region of 8,137 people (Barkly Regional Council, 2018).

The potential social and economic effects associated with the proposed exploration activities is considered to be minor and predominantly positive.

The closest neighbouring regional towns and communities identified as being within proximity to Origin's activities include:

- Dunmarra (~30kms)
- Tennant Creek (~290kms)
- Elliott (~80kms)
- Daly Waters (~70kms)
- Newcastle Waters (~60kms)
- neighbouring pastoral leases of Amungee Mungee and Beetaloo.

In 2014, the Tennant Creek Regional Economic Development Committee (REDC) released the *Tennant Creek and Barkly Region Strategic Action Plan (2014-2016)* which identified social and economic development within the region, including mineral and gas development. Origin has met with the REDC annually, with its most recent project update meeting taking place in Tennant Creek on 27 September 2018. Origin also met with the Mayor and Councillors of the Barkly Regional Council (27 September 2018) and Roper Gulf Regional Council (19 December 2018).

4.6.2 Pastoral activity

The current land use in the project area is pastoral with varying stocking rates and varying management practices. Within the permit area there are nine pastoral properties as shown in Table 33. All the land within the permit area is Leasehold Land. There is one small area of Aboriginal Freehold land known as Jingaloo on EP117.

Table 33: Pastoral properties in the permit area

Pastoral property	Permit areas		
	EP76	EP98	EP117
Amungee Mungee		✓	✓
Kalala		✓	✓
Tanumbirini	✓	✓	
Beetaloo	✓		✓
Hayfield/Shenandoah		✓	✓
Ucharonidge	✓		✓
Tandyidgee	✓	✓	
Nutwood Downs		✓	
Newcastle Waters			✓

The project area has been subject to pastoral activities for over 150 years (AECOM, 20). The average size of a Station in the Barkly Region is 8,186 km² (Bubb, 2004), which is large by global standards.

The proposed Kyalla 117 N2 site is located on the Hayfield/Shenandoah Station.

4.6.3 Other land uses in the area

A range of other land uses exist in the permit area or in the larger region, including a range of public utilities and facilities. These include the following:

- **Tourism** – Tourism is an important regional industry with the Stuart Highway being a major thoroughfare for tourists travelling in the area during the dry season. The local townships of Daily Waters, Dunmarra and Elliot provide consumables (food, fuel etc.) and accommodation. Several heritage areas of importance to regional tourism are in the broader region, including Elliott, Newcastle Waters and other heritage listed homesteads.
- **Road networks** – The Stuart Highway and Carpentaria Highway will be used to access the sites. In addition, there are numerous gravel roads connecting properties, and internal property tracks. All properties also have firebreaks on their boundaries and internally.
- **Gas pipeline** – A gas pipeline runs to the west of the Stuart Highway, along the eastern boundary of EP117 and crosses the boundary of one part of EP98. It also runs parallel with the Carpentaria Highway to the Gulf of Carpentaria, through EP98 and EP76.
- **Alice Springs to Darwin Railway** – The railway line runs to the west of the gas pipeline and Stuart Highway, and does not cross into any of the permit areas.
- **Townships** – The townships of Daly Waters and Dunmarra neighbour EP98 to the West.
- **Conservation areas** – including the Bullwaddy Conservation Reserve, which lies within EP98 and Lake Woods and the Junction Stock Reserve just outside the permit area.
- **Heritage** – There are seven (7) heritage sites within the exploration permit area and several heritage areas of importance to regional tourism located in the broader region, including Elliott, Newcastle Waters and heritage-listed homesteads.
- **Archaeological sites** – The permit areas have a long history of Aboriginal association and 41 archaeological sites have previously been recorded within the permit areas, as well as registered sacred sites and areas of significance which are shown in the AAPA Abstract of Record.

5 Stakeholder engagement

5.1 Purpose and objectives

Origin's stakeholder engagement is focused on building respectful relationships with key stakeholders and developing a positive reputation founded on Origin's core values. Origin's consistent approach to stakeholder engagement has been to ensure that those persons and/or groups directly impacted/affected and/or influenced by permit commitments have received Origin's full attention. Origin views the social acceptance and informed consent of these primary stakeholders of critical importance and relevance during this stage of low impact and small-scale exploration activities.

A stakeholder engagement plan has been implemented, which guides the way Origin undertakes stakeholder engagement above and beyond the *NT Petroleum (Environment) Regulations 2016*. This plan has been developed based upon the *International Association for Public Participation (IAP2) (2015) Quality Assurance Standard for Community and Stakeholder Engagement*. A copy of this plan is provided in Appendix O.

5.2 Identification of stakeholders

The NT Petroleum (Environment) Regulations 2016 defines stakeholder as meaning:

- (a) a person or body whose rights or activities may be directly affected by the environmental impacts or environmental risks of the regulated activity proposed to be carried out; or
- (b) an agent or representative of a person or body mentioned in paragraph (a).

This definition aligns with Origin's defined areas of influence described in the Stakeholder Engagement plan in Appendix O.

Origin's directly affected stakeholders have been, and will continue to be, consulted in a respectful, open and consistent manner. This has been the case since 2014, when Origin assumed operatorship of EP98, EP117 and EP76.

For the purpose of this EMP, Origin identifies its stakeholders, in compliance with the *NT Petroleum (Environment) Regulations 2016* as:

- **Host Traditional Owners** recognised as the Native Title holders and/or claimants and their representative, the Northern Land Council, as described in Exploration Agreements between the parties for EP98, EP117 and EP76; and
- **Host pastoralists** recognised as the landholders of the nine (9) Pastoral Lease Stations in Table 33. (With regard to this EMP for the Kyalla 117 N2 location, the owners of the pastoral lease for Hayfield/ Shenandoah Station are recognised as the pastoralist stakeholder directly impacted).

Stakeholder and community engagement for the 2021 work program has been held with host pastoralists and Traditional Owners directly affected by the proposed activities. Activities performed under EP98, EP117 and EP76 will be conducted in a manner consistent with the '*Code of Practice: Onshore Petroleum Activities in the Northern Territory*', which Origin considers an appropriate regulatory instrument for ensuring Origin's activities are in line with community expectations and legislative requirement.

Origin also recognises and engages, where appropriate with a number of other interested parties that are not classified as directly affected under the Petroleum (Environment) Regulations. These include government agencies, Land Councils, local and regional suppliers, non-government organisations, councils and peak industry bodies.

5.3 Pastoralist stakeholder engagement

Origin has engaged with the pastoral stakeholders identified in Table 33 on an ongoing basis, including engagement with the leaseholder and/or representatives of the Hayfield/ Shenandoah pastoral lease regarding the full range of exploration activities outlined in this EMP. Key engagement efforts Origin has undertaken include:

- Engaging in consultation for early works access to Hayfield/Shenandoah Station in preparation of low impact and small-scale exploration activities (water bores and civil activities)
- Ongoing engagement and consultation meetings regarding Origin's proposed exploration activities, including demonstration of the scope and activities part of Origin's Beetaloo Sub-Basin project (Appendix P)

- Providing the landholder with draft copies of a Stakeholder Engagement Pack (SEP) covering exploration activities and providing opportunity for the landholder to comment (Appendix P Part B)

Origin is in the final stages of negotiating the Land Access Agreement with the Hayfield/Shenandoah Station, with the agreement expected to be finalised by the end of 2020 (and prior to the commencement of activities).

Appendix P summarises Origin's engagement with the leaseholders of Hayfield/Shenandoah Station as a relevant stakeholder and provide information in accordance with section 7(2)(a) of the *NT Petroleum (Environment) Regulations 2016*.

Appendix P Part C provides the specific details of communication between Origin and the pastoralist regarding the proposed activities.

5.4 Host Traditional Owner(s) engagement

Origin has undertaken detailed engagement with the host Traditional Owners through the Northern Land Council to facilitate an ongoing relationship between Origin and their host Traditional Owners. Engagement efforts undertaken by Origin include:

- Complying with the Exploration Agreement(s) between Origin, Native Title holders and the Northern Land Council (NLC) for EP117, EP98, EP76
- Ongoing consultation regarding Origin work programs and proposed exploration activities, including the location(s) of all areas of disturbance and answering any questions or comments on the activity and its related impacts.
- In person consultation between Origin, host Traditional Owners and their statutory representative body, the Northern Land Council regarding Origin's proposed exploration activities on 3 September 2018
- Execution of Sacred Site clearance and avoidance surveys on the specific areas of land (~6kms in radius) with the relevant Traditional Owners between 10 September and 19 September 2018. A formal Northern Land Council Sacred Site Avoidance and Anthropological Report was provided to the AAPA to assist with the issuing of an Authority Certificate in compliance with the Northern Territory's Aboriginal Sacred Sites Act
- On country meetings held between NLC, Traditional Owners and Origin in April and May 2019 revisiting Origin's work program submission from July 2018 and field surveys with Traditional Owners in September 2018. The on-country meetings conclude the engagement and consultation necessary with Traditional Owners prior to commencement of each years' activities
- Kyalla 117 N2-1H NLC, Traditional Owners and Origin site tour in September 2020. The tour provided an overview of the Beetaloo exploration project and answered questions regarding hydraulic fracking activities underway
- Ongoing communication between Origin and the Northern Land Council
- Consultation and engagement with host Traditional Owners, to ensure their understanding of the nature and purpose of activities, is executed by the Northern Land Council in

accordance with the Land Rights Act. The approved work program includes the installation of multiple vertical and horizontal E&A wells per lease pad.

- Pursuant to the Sacred Sites Act, Origin has submitted to, and obtained approval from the AAPA for Authority Certificates to provide indemnity against prosecution in respect of the offences under the Sacred Sites Act Origin holds AAPA Authority Certificate C2020/003 and shall comply with the conditions in the Certificate to ensure compliance to the Sacred Sites Act.

The Traditional Owner stakeholder engagement summary is provided in Appendix P.

5.5 Stakeholder activities

Key considerations when understanding the consequences to pastoral operations and Traditional Owners include:

- Understanding pastoralist operations and determined Native Title Holder custodianship of the proposed area to ensure petroleum activities can sustainably co-exist
- Provision of payments and/or benefits to the Pastoral Lessee(s) and Native Title Holders for the impact of regulated activities on the proposed activity area in accordance with the relevant agreements.

A summary of the potential consequences of the activity and mitigation controls are summarised in Table 34.

Table 34: Potential consequences of Origin's activities and control measures which are covered in the SEPs sent to stakeholders

Activity	Potential consequence to activities	Consequence mitigations measures
Land and Stock		
Well pad (and E&A wells) and new access road	• Reduction in grazing area • Restricted access to well lease pads during activity duration	• Exploration Agreement(s) with NLC and Native Title holders and/or claimants • Aboriginal Areas Protection Authority Certification (including RWAs and Work Instructions) • Short term use • Full fencing and bunding of well pad • Industry-proven coexistence of cattle and petroleum industry • End of life rehabilitation to return land back to pre-existing state • Code of Conduct agreed to by Origin and the pastoralists.
Existing access tracks	• Traffic along access track	• Exploration Agreement(s) with NLC and Native Title holders and/or claimants

Activity	Potential consequence to activities	Consequence mitigations measures
	- Temporary access restrictions during rig mobilisations and heavy transport operations - Interference with stock	- Aboriginal Areas Protection Authority Certification (including RWAs and Work Instructions) - Upgrade of the existing road to enable dual carriage - Main traffic movements limited to over a 3-6-month period - Code of Conduct agreed with Pastoral Lessee - Origin pastoral lease notification of large movements - Road remains shared use asset of pastoral lessee
Lease pads	- Contamination of soils from activities - Impact to organic certification	- All activities must comply with <i>Code of Practice for Petroleum activities in the Northern Territory</i>, including spill management, wastewater management and waste management - Site to be rehabilitated back to pre-disturbance level with no harmful contamination permitted. - Site fully bunded - Activity restricted to a small area, with no contaminants released to surrounding areas - Contaminants affecting organic certification for cattle or crops (agrichemicals, GMO, pesticides etc) are typically not associated with petroleum activities. - Exploration Agreement(s) with NLC and Native Title holders and/or claimants - Aboriginal Areas Protection Authority Certification (including RWAs and Work Instructions)
Water		
Groundwater	- Pastoral bores rates and/or quality - Reduction in groundwater availability	- Exploration Agreement(s) with NLC and Native Title holders and/or claimants (<i>Clause 9.2(n)</i>) - No hydrocarbon wells within 1km of pastoral bore unless other wised agreed

Activity	Potential consequence to activities	Consequence mitigations measures
		- Modelling supported extraction limits set by DEPWS through extraction licence RF 10285 - Monitoring of control and impact groundwater levels to detect and respond to water level declines >1m as per section 3.24. - Baseline monitoring of local bores within 10km of petroleum wells - Ongoing control and impact groundwater water monitoring - Aquifer protected through the use of multiple cement and steel casing barriers - Well integrity validated prior to completing stimulation
Weeds		
Weed control	- Noxious weeds - Impacts to vegetation communities	- Exploration Agreement(s) with NLC and Native Title holders and/or claimants - Baseline weeds survey completed - Ongoing weeds surveys and NTG bi-annual monitoring - Vehicle and Equipment to be clean and have valid weed hygiene certificates prior to access - Weed identification training of key personnel - Weed management plans
Air quality		
Dust	Dust	- Exploration Agreement(s) with NLC and Native Title holders and/or claimants - Short period of high-volume traffic movements - Equipment movements to consider time of day to reduce impacts on traffic - Dust suppression utilised during high volume traffic movements and around sensitive features (homesteads, cattle yards etc.)

Activity	Potential consequence to activities	Consequence mitigations measures
Emissions	Increased emissions from flares and wells	- Exploration Agreement(s) with NLC and Native Title holders and/or claimants - Flares are used to reduce the risk associated with vented hydrocarbons - Short period of operations and testing - Baseline emissions monitoring conducted and is ongoing - Emissions monitoring at all locations - No well pad within 20km of a residence
Light, noise and visual amenity		
Light and noise	- Interaction with stock - Reduction in amenity of surrounding site	- Exploration Agreement(s) with NLC and Native Title holders and/or claimants - Site location chosen to minimise impacts on pastoralist operations – including appropriate separation distances between sensitive receptors and activities - Short duration of drilling and stimulation activities
Visual amenity	Pastoral and Traditional Owner visual amenity	- Exploration Agreement(s) with NLC and Native Title holders and/or claimants - Site location chosen to minimise impacts on pastoralist amenity – including appropriate separation distances between sensitive receptors and activities - Short duration of drilling and stimulation activities - Site not located in major thoroughfare and away from the majority of pastoralist activities

5.6 Northern Territory business engagement

Broader engagement has occurred with local and regional business within the local communities of Daly Waters, Elliot, Katherine and the broader Northern Territory region.

Northern Territory businesses have been engaged on the scope of Origin's activities through information sessions and tender opportunities covering a range of material supply and support services, such as:

- people transport and logistics
- accommodation and food

- provision of temporary camps and camp services
- civil construction work
- freight and transport
- water bore drilling
- water carting and waste management
- site maintenance and inspections
- weed management and control
- equipment and materials storage
- oil country tubular goods
- environmental and civil consulting
- surveying and geotechnical assessments
- general provisions of goods and services (such as personal protective equipment and hire cars).

A log of broader community engagement for Origin's Beetaloo Exploration Project is provided in Appendix Q. This information is provided in addition to the requirements outlined in section 7 of the Petroleum (Environment) Regulations.

5.7 Ongoing stakeholder and community engagement

Origin is committed to continuing to engage with stakeholders regarding the exploration activities under EP98, EP117 and EP76 and any associated environmental outcomes prior to, during and after performance of exploration activities.

Origin recognises the growing community interest in ensuring onshore natural gas development takes place in a safe and environmentally sound way and are committed to delivering operational excellence (which encapsulates our health, safety and environmental performance standards).

Origin has further committed to ongoing engagement with the relevant Traditional Owners, including annual work plan meetings and provision of draft work programs for future years of activity.

Detailed community and stakeholder engagement are underway, covering future exploration activities. This includes the following engagement activities:

- Pastoralists:
 - Weekly-monthly engagement with host pastoralists for which activity is proposed within the 2019/20 time period. With the engagement frequency agreed to with the pastoralist
 - Quarterly engagement with future host pastoralists for which activity is proposed within the 2020 time period
 - Annual consultation with all pastoralists, including surrounding pastoralists with no immediate proposed activities
- Native Title holders of the area in which the activity is occurring

- o Ad hoc updates for the Northern Land Council when required, informing them of progress of exploration activities underway
- o Quarterly project status updates to the Northern Land Council informing them of progress of exploration activities underway
- o Site visits by Traditional Owners during exploration activity so that Traditional Owners can have first-hand observation of key activities
- o Work program surveys conducted by Traditional Owners, with the support of the NLC, to review work programs and ensure protection of sacred sites and objects
- o Annual on country meetings with Native Title Holders to discuss current work program status and future exploration activities

Several of Origin Beetaloo Sub-Basin Project series sheets have been created to provide information on Origin's activities and broader shale exploration (Appendix R).

Broader community engagement that is in addition to the requirements outlined in section 7 of the Petroleum (Environment) Regulations will continue.

6 Environmental risk assessment

6.1 Origin's risk management approach

Origin utilises a robust risk management process for all its activities to achieve the following key outcomes:

- Risks are understood, eliminated or reduced and controlled to an acceptable level
- Controls are owned, assured and continuously reviewed for effectiveness
- All activities are compliant with regulatory standards and are guided by best practice
- Origin and its stakeholders are confident in the way activities are conducted to manage risks
- The approach aligns with the findings of the NT Inquiry Final Report and associated recommendations (as implemented via the Petroleum Code of Practice or legislation).

Origin's risk assessment process is undertaken in accordance with section 5.4.3 of ISO 31000. Risk management is mandated through the Origin Risk Management Policy and Directive, which includes a risk rating toolkit that is utilised from the Board through to frontline activity owners (Figure 41).

Assessment of risk is completed using Origin's Risk Matrix (Figure 36) to assess and rate risks by assessing the combination of frequency of occurrence and the severity of the outcome of a potential event, including a worst-case scenario event. This allows quantification of a risk and determination can then be made about whether the risk can be accepted, or whether further mitigation is required.

Origin risk management processes requires regular assessment of unmitigated¹⁸ risk from an activity, the residual risk once controls are applied, the effectiveness of controls (provided in Table 35) and the

¹⁸ Unmitigated" risk ratings include applying existing controls, such as compliance with regulatory requirements which are mandatory (e.g. the Code of Practice, Regs Schedule 1, etc).

likelihood and consequence of a risk event. A residual risk is either accepted in accordance with strict delegations of authority or the activity does not proceed.

Origin also includes site specific controls for each identified risk, which further demonstrates how it achieves a residual risk that meets its ALARP and acceptable criteria. In applying the existing controls during the risk analysis (as per ISO 31000), there is very often little material change to most risk profiles identified in the risk register (Appendix K). This is a function of the comprehensive nature of the Code of Practice, which was designed to mandate a high level of environmental performance and minimise environmental risk.

Table 35: Risk control effectiveness definition

Rating	Explanation
Effective	- Controls are well designed and address the root cause(s) of the risk. - Controls are recognised industry best practice. - All controls operate at the required level. - All controls are within the power of Origin, with few external factors beyond control. - Ongoing monitoring required.
Can Be Improved	- Majority of controls are well designed and address the root cause(s) of the risk. - Majority of controls operate at the required level. - Some controls are outside the power of Origin, with multiple external factors beyond control. - Ongoing monitoring required. - Certain controls can be improved or have elements below industry best practice.
Must Be Improved	- Most controls are not well designed and do not address the root cause(s) of the risk. - Most controls are not operating to the required level. - A large number of controls are outside the power of Origin, with multiple external factors. - The majority of controls require improvement and are well below industry best practice.

Risk Management

Directive

Appendix 1 – Origin Risk Rating Toolkit



Control Assessment Ratings

Rating	Explanation
Effective	- Controls are well designed and address the root cause/s of the risk. - Controls operate to the required level. - Ongoing monitoring required.
Can be improved	- Majority of controls are well designed and address the root cause/s of the risk. - Majority of controls operate to the required level. - Certain controls can be improved. - Ongoing monitoring required.
Needs to be improved	- Majority of controls are not well designed and do not address the root cause/s of the risk. - Majority of controls do not operate to the required level. - Majority of controls require improvement.

Risk Treatment and Acceptance Criteria

Level of risk	Action required	Acceptance authority
VERY HIGH	- Risk treatment must be in place immediately - Review risk quarterly at a minimum	ELT member*
HIGH	- Risk treatment must be considered (having regard to current business priorities) - Review risk annually at a minimum	General Manager
MEDIUM	- Risk treatment may be considered - Review risk two yearly at a minimum	Group/Asset (EM)/ Project Manager/ Manager/Lead (IG)
LOW	- No risk treatment required - No ongoing review required unless determined by the relevant Group Manager	Site/Activity Manager/ Manager/Lead (IG)

* CEO acceptance required for risks with a Catastrophic consequence and Likely or above Likelihood

Figure 36: Origin's risk toolkit which describes the approach to identify, assess, control, treat and accept risks

6.2 ALARP

Origins risk management process requires risks to be management to ALARP. A risk can be considered to have been reduced to ALARP when all reasonably practicable control measures (both preventative and mitigative) have been identified and implemented to reduce the risk of identified events. A key element of demonstrating ALARP is that good practice is followed, where good practice is defined as the recognised risk management practices and measures that are used by competent organisations to manage well understood hazards arising from their activities. This definition incorporates good practice as defined in codes and standards, and a consensus of good practice within the industry. ALARP is not a final position over the life of an asset or project.

The practicability and the reasonability of control measures can change over time due to changes in technology (that can make measures more readily available), industry standards (that can commoditise once-cutting-edge technology) and the socio-technical landscape (that can modify societal expectations).

In the NT context, ALARP and the definition of acceptable risk levels was a key feature of the NT Inquiry Final Report. For each aspect, acceptability criteria were defined, with recommendations outlined to reduce the potential risk to below the acceptable level. With the adoption of all recommendations by the NTG, the new Code of Practice and associated regulatory changes provides a high level of inherent protection to ensure activities are undertaken in a safe and consistent manner.

Origin considers ALARP to be achieved where the residual risk is low, whereby any additional control measures applied will not reduce the risk any further.

If the residual risk of low is not achieved, Origin considers ALARP to be achieved where the following criteria have been met:

- 1 the requirements of the code of Practice have been met
- 2 all reasonably practicable site-specific controls have been identified and implemented and
- 3 the cost of further reducing the risk is unreasonable compared to the environmental benefit gained from implementing the control measure.

6.3 Risk acceptability

Origin uses a series of criteria provided in Table 36 to determine the acceptability of a residual risk. Each residual risk event outlined in Appendix K is assessed against these criteria to determine whether Origin believes the residual risk is acceptable. The outcome of the residual risk acceptability assessment and outcome is provided in Appendix K.

Table 36: Residual risk acceptability criteria

#	Criteria	Origin's acceptance threshold
1	Residual risk level	Consistent with Origin's risk acceptance criteria: Very high risk – Not acceptable High risk – Residual risk may be conditionally accepted where the residual risk is ALARP and the risk is signed off by a General Manager with risk treatment applied to improve, control or further modify risk. Risk reviews are to occur annually with the intent to reduce the risk severity lower.

#	Criteria	Origin's acceptance threshold
		Medium-Low risk – Residual risk is accepted when ALARP is demonstrated
2	Legislative requirements and regional strategies and conservation plans	1. Consistent with legislative requirements, including Code of Practice 2. Consistent with regional strategies and conservation/threat abatement plans
3	Stakeholder expectations	Consistent with the commitments made in stakeholder engagement and/or agreements
4	Industry guidelines and best practice	Is consistent with petroleum standards (such as API and the Oil and Gas UK standards), best practice and controls used in other NT industries
5	Scientific uncertainty in the data used to determine the environmental impact or risk	Low uncertainty: Accepted Risks are well understood and uncertainty is minimal Moderate uncertainty: Accepted using well-established data and assessment methods. Some uncertainty exists, with routine monitoring and performance criteria in place to detect and respond to any impacts arising from a risk. High: Conditional acceptance – Significant uncertainty exists with data and assessment methodologies unproven. A precautionary approach will mean that uncertainty is replaced by conservative assumptions that will require additional control measures being implemented to prevent, detect and respond to any impacts arising from a risk.
6	Ecological Sustainable Development Principles	Risk is consistent with the principles of ESD as defined in section 2.1. This also includes weighting to consider the social and economic benefits of the project

6.4 Assessment of Scientific Uncertainty

The Petroleum (Environment) Regulations requires an assessment of uncertainty as a part of the risk assessment process. The assessment of potential impacts and effectiveness of controls must demonstrate that the activities are carried out in a manner consistent with the Principles of Ecologically Sustainable Development (ESD) and the Precautionary Principle.

Impact and risk identification must include consideration of uncertainty regarding impacts and risks for the activity where a precautionary approach is appropriate. Uncertainty is high where confidence in the available information is low in identifying risk or the effectiveness of a management control. Additional baseline studies or other safeguards may be required to increase the accuracy of an assessment to determine the acceptability of a risk.

As per the Draft EMP Guidelines, scientific certainty is qualitatively assessed using a generic means of ranking the data available in accordance with Table 37. Considerations of uncertainty have been included in the risk assessment discussed in Section 6.5.

Table 37: Scoring system for Scientific Uncertainty (DEFRA, 2013)

Ranking Scientific Uncertainty	
Score	Description
Low (1)	- Comprehensive data with strong evidence in multiple peer reviewed data - Little disagreement between authors or experts - Considerable and consistent on-ground experience and/or monitoring
Medium (2)	- Some or incomplete data available - Evidence provided based on a small number of references - Authors or experts conclusions vary - Limited on-ground experience and/or monitoring
High (3)	- Scarce or no data available; evidence provided in unpublished reports - Few on-ground observations - Authors and experts conclusions vary considerably

6.5 Risk assessment outcomes

The environmental, heritage and social risks associated with the activities covered under this EMP have been assessed utilising the Origin risk assessment framework described in Section 6.1. The detailed risk assessment presents the range of potential impact-causing activities, corresponding mitigation measures and residual risk ratings based on their assessed worst-case consequence and likelihood of occurrence. The assessment also cross-referenced the various risk assessment outcomes in the NT Inquiry Final Report, to ensure consistency.

Site specific conditions and cumulative impacts have also been considered during the assessment. Cumulative impacts have included the following:

- A total of five (5) future Origin E&A wells for the 2020-2022 period as per the current approved tenure work plan (this includes the two (2) covered under this plan).
- Existing land users (predominately pastoralists).

There were no residual risks above a 'Medium' risk ranking, with 23 risk scenarios. Within these risk scenarios, the assessment considered 72 risk sources which may potentially result in a risk occurring. Of the 72 risk sources, eight (8) were ranked as 'Moderate' with the remaining ranked as 'Low'. The medium residual risks sources identified through the risk assessment include:

- Loss in soil productivity and viability due to soil erosion from cleared areas (existing access tracks, lease pad and camp pad)

2. Impact to fauna habitats and threatened flora and fauna through the introduction and spread of weeds in the area
3. Impact to fauna habitats and threatened flora and fauna through accidental ignition of fire from exploration activities (drilling, HFS, flaring, general access)
4. Disturbance of sacred site or culturally sensitive area and decline in environmental value of area used for cultural purposes through the accidental ignition of fire by site activities
5. Reduction in agriculture productivity through the introduction and spread of weeds in the area
6. Reduction in agriculture productivity through bushfire from accidental ignition by site activities or site personnel
7. Increased nuisance from dust emissions associated with the activities
8. Increased nuisance from dust due to accidental ignition of bushfire during the site activities

The ‘Medium’ risks identified were consistent with standard construction or pastoralist activities carried out across the NT, being the potential spread of weeds, erosion and sediment control, and ignition of bushfires from the proposed activities. The reduced risk profile associated with stimulation activities (such as potential spills and groundwater contamination) is reflective of the stringent regulatory requirements within the Petroleum Code of Practice.

The level of uncertainty for each risk was also assessed. There was no uncertainty level above ‘Low’, which is consistent with the scale of the activity and the knowledge of impacts associated with shale exploration activities demonstrated in the Inquiry Final Report and through the various reports published by the US EPA (such as USEPA 2016- U.S. EPA. Hydraulic Fracturing for Oil and Gas: Impacts from the Hydraulic Fracturing Water Cycle on Drinking Water Resources in the United States (Final Report)).

Table 38 provides a count of the post-treatment environmental risks associated with this EMP. A copy of the risk assessment is provided in Appendix K.

Table 38: Count of Residual Environmental Risks for the drilling and stimulation program

	Residual Environmental Risk Level			
	Low	Medium	High	Very High
Total 72	64	8	0	0

6.6 Environmental outcomes, performance standards and measurement criteria

The following section provides the environmental outcomes, performance standards and measurement criteria of each environmental aspect, based on the risk assessment presented in Appendix K. Tables 39 to 45 provide the environmental outcomes, performance standards and measurement criteria to demonstrate whether controls have been effective during the activity and that the stated environmental outcomes have been achieved.

6.6.1 Soils

Table 39: Environmental outcomes, performance standards and measurement criteria– Soils

Environmental performance measures- Soil				
Environmental outcome	Environmental performance standards		Measurement criteria	Records
No significant impact to the ecological function and productivity of soils surrounding Kyalla 117 N2 as a result of Origin's exploration activities	S-1	No releases of contaminants (chemicals, hydrocarbon, drilling wastewater or flowback wastewater) outside of Origin's lease pad	Weekly site inspections completed during chemical and wastewater storages confirm no releases of chemicals, hydrocarbons and wastewater outside of Origin's lease disturbance area	Weekly records of site inspections retained
				OCIS incidents of off-site releases retained
	S-2	No reportable spills, including wastewater tank/sump overtopping events, resulting from Origin's exploration activities	Weekly site inspections during hydrocarbon, wastewater and chemical storage activities confirm no reportable spills	Weekly records of site inspections retained
				OCIS incidents of reportable incidents relating to spills
	S-3		Zero reportable incidents resulting from chemical or waste transportation accidents	OCIS incidents of reportable incidents relating to transportation accidents and spills
	S-4	Erosion and sediment control in place and working effectively	6-monthly site stability inspections confirm ESC in place and working effectively. No erosion or sediment releases present that cannot be rectified during routine site maintenance.	ESC inspection records retained

	S-5		Evidence of maintenance performed on all material erosion and sediment control events	Maintenance records retained
Risk Sources	• Soil compaction from access tracks and leases (Risk ID 23) • Soil erosion from cleared areas (access tracks, lease pads and camp pads) (Risk ID 24) • Spills/leaks from the on-site storing and handling of fuels (condensate, hydrocarbons, drilling additives, stimulation additives, drilling fluids, flowback fluid, solid wastes, storage and transportation of wastes) (Risk ID 25) • Drill sump and flowback tank overtopping (Risk ID 26) • Chemical and waste transportation accident (Risk ID 27) • On-site disposal of drill muds and cuttings (Risk ID 28) • Failure of a flowback tank (Risk ID 29) • Wastewater evaporation mist transported off-site during wastewater treatment (Risk ID 30) • Greywater and sewerage disposal (camps) (Risk ID 31)			

6.6.2 Surface water

Table 40: Environmental outcomes, performance standards and measurement criteria – Surface water

Environmental performance measure- Surface water				
Environmental outcome	Environmental performance standards		Measurement criteria	Records
No significant impact on surface water quality as a result of Origin's exploration activities	SW-1	During chemical and wastewater storage activities, no off-site release of contaminants from chemical, hydrocarbon and waste storage	All stormwater discharges monitored by operators prior to release, with results confirm stormwater is within the approved limits listed in Table 16	Discharge monitoring results retained for each stormwater release
	SW-2	No seismic events over Ml 3.5 attributable to Origin's activities	No seismic events over Ml 3.5 recorded in vicinity of a hydraulic fracture operation measured at the Warramunga seismic monitoring station during period that hydraulic fracture stimulations have occurred resulting in surface subsidence and impacting surface hydrology.	Monitoring results available at https://earthquakes.ga.gov.au/
	SW-3	No reportable spills, including offsite releases of contaminants resulting from Origin's exploration activities	Weekly site inspections completed during chemical and wastewater storages confirm no releases of chemicals, hydrocarbons and wastewater outside of the Kyalla 117 N2 project area	Weekly records of site inspections retained
				OCIS incidents of off-site releases retained
	SW-4	Erosion and sediment control in place and working effectively	All material erosion and sediment control events are rectified as soon practicable upon identification	OCIS incidents of reportable incidents relating to spills



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- Failure of flowback storage tank (Risk ID 14)
- Overtopping of drilling sumps and flowback tanks (including wet season operations) (Risk ID 15)
- Transportation accident releasing chemical or wastewater (drilling fluid and flowback) (Risk ID 16)
- Storage and handling of drilling and stimulation chemicals and hydrocarbons (Risk ID 17)
- Release of stormwater from activities to surface water (Risk ID 18)
- Runoff from sewage treatment irrigation areas (Risk ID 19)
- Infrastructure located on regional flow path resulting in changes to surface water flow (Risk ID 20)
- Changes to terrestrial ground surface levels associated with seismic activity (Risk ID 21)

6.6.3 Groundwater

Table 41: Environmental outcomes, performance standards and measurement criteria – Groundwater

Environmental performance measure-Groundwater				
Environmental outcome	Environmental performance standards		Measurement criteria	Records
Origin's exploration activities do not reduce the environmental values of the underlying groundwater resources	GW-1	All regional aquifers isolated through cement and casing	Isolation of the Gum Ridge Formation and Anthony Lagoons Formation is confirmed through cement bond logs and casing pressure tests	Well completion report
	GW-2	No failure of wastewater tank secondary liner	All leak detection alarms investigated within 24hour, with no incidents of secondary liner failure	Records of leak detection alarms and investigations retained on site
				Incidents of secondary liner failure documented in OCIS and reported to regulator.
	GW-3	No seismic events over Ml 3.5 attributable to Origin's activities	No seismic events over Ml 3.5 recorded in vicinity of a hydraulic fracture operation measured at the Warramunga seismic monitoring station during period that hydraulic fracture stimulations have occurred.	Monitoring results available at https://earthquakes.ga.gov.au/
	GW-4	No long-term (>12 month) reduction in quality of an impact groundwater monitoring bore that is attributable to Origin's activities. A decline is defined as a change in water chemistry that exceeds the ANZECC guidelines for Livestock (the primary Environmental Value) of groundwater in the region.	Quarterly groundwater monitoring data collected and analysed against baseline data demonstrates no material decline in groundwater quality	Quarterly groundwater monitoring results retained

	GW-5	No long term (>12 month) reduction in groundwater level observed in the impact monitoring bore that results in >1m decline in groundwater water level	Quarterly groundwater monitoring data collected and analysed against baseline data confirms no material (>1m) decline in groundwater level	Quarterly groundwater monitoring results retained
	GW-6		Total groundwater extraction volume below the Water extraction level of 175ML/year	Groundwater take records retained
Risk Sources	• Sub-surface loss of drilling fluids during drilling (Risk ID 1) • Sub-surface cross flow of formation through inappropriate well barrier design and construction (Risk ID 2) • Sub-surface crossflow through fracture growth into aquifer from stimulation activities allowing the migration of fluid and gas (Risk ID 3) • Stimulation activity induces seismic activity that enables cross formational flow between shallow aquifers (Risk ID 4) • Sub-surface migration of fluid and gasses via fractures intersecting with offset wells (including the adjacent horizontal wells) or intersecting an existing geohazard (Risk ID 5) • Crossflow/well integrity caused by the deviation of an E&A well into the adjacent well during drilling (Risk ID 6) • Leakage of either flowback, produced water, or hydrocarbons (liquid and gaseous) from suspended or abandoned wells (Risk ID 7) • Surface spills/contamination from the storage and disposal of drilling fluids, additives, muds and cuttings on-site (Risk ID 8) • Surface spills from the storage, handling and transportation of produced hydrocarbons (condensate) (Risk ID 9) • Surface spills from storage, handling and transportation of flowback water (Risk ID 10) • Surface spills from the storage, handling and transportation of chemicals, fuels and wastes (Risk ID 11) • Surface spills from the overtopping of drilling sumps and flowback tanks (including during wet season) (Risk ID 12) • Surface spills from the failure of flowback storage tank (Risk ID 13) • Over extraction of groundwater for exploration activities (Risk ID 22) • Cumulative impact from regional groundwater take exceeds the natural recharge rate of the Basin (Risk ID 68)			

6.6.4 Ecology – flora, fauna and habitats

Table 42: Environmental outcomes, performance standards and measurement criteria – Ecology

Environmental performance measures- Ecology				
Environmental outcome	Environmental performance standards		Measurement criteria	Records
No significant impact to high valued habitats and threatened flora and fauna as a result of Origin's exploration activities	EC-1	No releases of wastewater (drilling fluid and flowback) off the lease into the surrounding vegetation	Weekly site inspections confirm no loss of containment (structural failure, overtopping or major spills) resulting in off-site releases of wastewater	Weekly site inspection completed during wastewater storage
	EC-2	<7 individual fauna deaths per week for 2 consecutive weeks caused by flowback water storage	Daily checks of wastewater tanks for fauna mortality	Fauna interaction log retained
	EC-3		Weekly checks of area immediately surrounding lease pad for fauna deaths	Fauna interaction log retained
	EC-4	<0 threatened fauna deaths caused by flowback storage	Daily checks of wastewater tanks for fauna mortality	Fauna interaction log retained
	EC-5		Weekly checks of area immediately surrounding lease pad for fauna deaths	Fauna interaction log retained
	EC-6	No uncontrolled bushfires caused by Origin's exploration activities	Zero reported incidents of uncontrolled bushfire caused by Origin's activities	Fire incident data to be retained for all Origin unplanned fires
	EC-7	Weed surveys completed on all Origin disturbed areas	6-monthly pre- and post-wet season weed surveys completed on all Origin controlled disturbed areas	Annual weed monitoring and management report

	EC-8	Year-on-year decline in the size and density of all weed infestations introduced as a result of Origin's activities	Annual report demonstrates weed infestation size and density of weed outbreaks introduced by Origin's activities are reducing each year	Annual weed monitoring and management report
Risk Sources	• Activity (vehicle and machinery) noise and lighting on well pads and access tracks (Risk ID 32) • Structural failure and overtopping of flowback storage tanks and drilling sump (Risk ID 33) • Introduction and spread of weeds in the area (Risk ID 34) • Accidental ignition of fire from exploration activities (drilling, stimulation, flaring and general access (Risk ID 35) • Poor rehabilitation of the site reduces regional habitat and promotes weed invasions (Risk ID 36) • Trapping and drowning of fauna in storage tanks and sumps (Risk ID 37) • Contaminants in water and soil pass through the food chain and bioaccumulate in fauna causing detrimental impacts to local species and communities (Risk ID 38) • Vehicle collisions with fauna – fauna mortality results in a localised decline in species abundance (Risk ID 39) • Encouragement of feral animals and other pest species increases leading to competition with native species. This includes the introduction of cane toads (Risk ID 40)			

6.6.5 Air Quality and Greenhouse Gas emissions

Table 43: Environmental outcomes, performance standards and measurement criteria – Air quality and GHG emissions

Environmental performance measure- Air quality and GHG emissions				
Environmental outcome	Environmental performance standards		Measurement criteria	Records
No significant impact on air quality and no excess greenhouse gas emissions as a result of Origin’s exploration activities	AQ-1	Venting to be eliminated as far as reasonably practicable	Daily reports confirm all technically recovered hydrocarbons sent to the flare is metered and recorded	Gas flow volumes recorded
	AQ-2	All greenhouse gasses reporting in accordance with NGERS requirements	All emissions related data (fuel use, flaring volumes etc.) reported in accordance with NGERS requirements	Emission related data (fuel use, flare volumes, etc.) retained
	AQ-3	All leaks detected and repaired in accordance with code of practice	6-monthly leak detection program completed on surface equipment.	Leak detection records retained
	AQ-4		Minor leaks rectified as per Code of Practice within 30 days	Leaks and management recorded in OCIS
	AQ-5		A significant leak is repaired as per the Code of Practice within 72-hours	Leaks and management recorded in OCIS
Risk Sources	• Emissions from the combustion of diesel (Risk ID 58) • Air emissions from gas and condensate flaring (Risk ID 59) • Air emissions from chemical releases during drilling and stimulation activities (Risk ID 60) • Dust from truck movements, drilling operations, stimulation and well testing (Risk ID 61) • Bushfire from accidental ignition by site activities (civil works, drilling, flaring, grinding) or personnel (Risk ID 62) • Combustion of diesel for exploration activities (Risk ID 63) • Avoidable GHG generation through flaring of gas and condensate during well testing (Risk ID 64) • Uncontrolled release of gas encountered during drilling, stimulation, barrier failure, operator error or vehicle collision under a multi-well scenario (Risk ID 65) • Leak of gas from wells (Risk ID 66) • Uncontrolled release of gas from well due to sabotage (Risk ID 67)			

6.6.6 Community

Table 44: Environmental outcomes, performance standards and measurement criteria – Lighting, noise, vibration and visual amenity

Environmental performance measures-Community				
Environmental outcome	Environmental performance standards		Measurement criteria	Records
No significant negative impacts to the community as a result of Origin's exploration activities	CO-1	All valid community complaints of nuisance investigated and resolved	All valid community complaints responded to within 24 hours with actions to remedy nuisance implemented as soon as practicable (depending on the nature of the complaint)	OCIS records of community complaints and actions completed
	CO-1	>60% of addressable spend ²⁰ to be from NT businesses	19Project expenditure data confirms the NT business spend on the Beetaloo exploration project exceeds >60% of addressable spend ²⁰ of the project	Data on NT business spend retained.
Risk Sources	• Industrialisation of landscape (Risk ID 45) • Increased traffic (Risk ID 46) • Light emissions impact on sensitive receptor (such as pastoralist) (Risk ID 47) • Influx of workers to region (Risk ID 48) • Noise emissions from activities (Risk ID 49) • Introduction and spread of weeds in the area (Risk ID 50) • Over extraction of groundwater (Risk ID 51) • Impact to surface hydrology reduces water capture (Risk ID 52) • Bushfire from accidental ignition by site activities (civil works, drilling, flaring grinding) or personnel (Risk ID 53) • Poor rehabilitation of exploration infrastructure (Risk ID 54) • Exploration activities compete with agricultural industry for resources (Risk ID 55) • Increased risk of vehicle accident (Risk ID 56) • Exploration activities compete with agricultural industry for resources (Risk ID 57)			

²⁰ Addressable spend is defined as a service or material that can be reasonably provided by an NT business at similar quality, timeliness and cost.

6.6.7 Cultural heritage

Table 45: Environmental outcomes, performance standards and measurement criteria – Community

Environmental performance measures- Ecology				
Environmental outcome	Environmental performance standards		Measurement criteria	Records
No significant impact on sacred sites and environmental values as a result of Origin’s exploration activities	EC-1	No non-compliances with AAPA certificate conditions	No unauthorised work within Restricted Work Areas (RWA)	OCIS incidents retained where unauthorised activities are identified
	EC-2		No impacts to sacred sites	OCIS incidents retained where unauthorised activities are identified
	EC-3		Site inductions completed on all employees and contractors which include information on RWA’s and approved activity areas	Records of inductions retained
Risk Sources	• Sites disturbed directly by exploration activities (Risk ID 41) • Accidental ignition by site activities (civil works, drilling, grinding) or site personnel (Risk ID 42) • Flowback tank structural failure (Risk ID 43) • Personnel unauthorised access to sacred site (Risk ID 44)			

7 Implementation strategy

7.1 Corporate Environmental Policy

Origin's activities are governed by the Origin Health, Safety and Environment Management System (HSEMS). This system is underpinned by Origin's Health, Safety and Environment (HSE) Policy (Figure 39) which is designed to **“Conduct our business in a way that causes no harm to the health and safety of people and has no unforeseen impacts to the environment”**.

7.2 Environment, Health and Safety Management Systems

Origin has a mature HSEMS which contains the policies and procedures that Origin has in place to manage and minimise the impact from its activities. In addition to meeting legal requirements, Origin's activities are also governed by several additional internal directives and risk control directives designed to ensure best practice in environmental risk management.

An overview of the Origin HSEMS and the associated directives is provided in Figure 38.

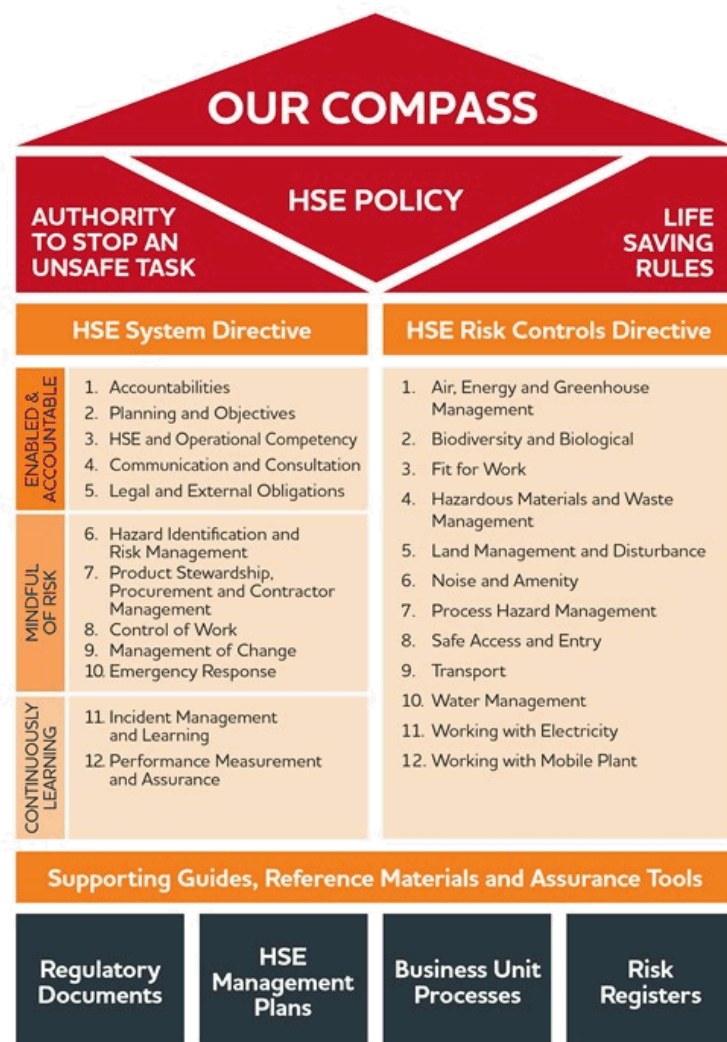


Figure 38: Origins HSEMS structure

OUR HEALTH, SAFETY AND ENVIRONMENT POLICY



OUR PRINCIPLE OF DUE CARE

We care about the wellbeing of our people and our impact on the environment.

OUR HSE ASPIRATION

To conduct our business in a way that causes no harm to the health and safety of people and has no unforeseen impacts to the environment.

OUR HSE ACTIONS

We all believe that our HSE aspiration is achievable and we embrace our responsibility for supporting it by:

Always mindful of risk

Recognising that risk is present in every task we do and taking the time to identify and understand these risks and manage them safely and responsibly.

Enabled and accountable

Taking ownership and using our authority, resources, systems and competencies to manage the risks associated with our work. We stop work when confronted by an unknown hazard and proceed only when satisfied we can continue safely and responsibly.

Continuously learning

Being open and transparent about how well we are doing and relentless in learning from our experience to manage our risks. We work together effectively, welcome any feedback and recognise that we can always do better.

Our Compass and HSE Management System set out how we will implement this policy.

A handwritten signature in black ink, appearing to read "Frank Calabria".

Frank Calabria
CEO
Origin Energy

ORG-HSE-POL-001 November 2016

Figure 39: Origin's Health, Safety and Environment (HSE) Policy

7.3 Roles and responsibilities

The following sections describe, in detail, the management strategies for specific components of the landscape, such as soil, groundwater and vegetation, and the cultural and social environment, in relation to the different impact-causing activities that may occur.

The management hierarchy is illustrated in Figure 40. Each management area has been assigned to specific positions within the exploration team as follows:

- **Asset Manager:** Responsible for the overall operations in the Origin's activities in the exploration permit area.
- **Project Manager:** Oversees the whole planning and execution of the exploration program and is the person ultimately responsible for ensuring all other parties are working within the HSE guidelines. The Project Manager's role is predominantly office-based. The Project Manager will be responsible for notifying the Minister, the occupier of the land on which the activity is to be carried out and the owner of the land on which the activity is to be carried out (unless the owner is also the occupier).
- **Civil Construction Superintendent:** Person based in the field responsible for ensuring all areas of operations and construction are carried out in accordance with the EMP and Origin's HSE Policy. All contractors report to this position, who is responsible to the Project Manager.

This role will also cover the role of the **Weeds Officer**, who will be responsible for:

- Planning and execution of weed monitoring requirements, including baseline weed assessments and ongoing monitoring both during periods of gas-related activities as well as during the target identification period of February to May.
 - Facilitate training all workers (including contractors) in weed management requirements, with support from the Northern Territory Government Regional Weed Officer - Onshore Shale Gas Development.
 - Oversight of implementation of weed control mechanisms including but not limited to wash-downs and proactive weed control programs.
 - Ensuring all reporting requirements are met.
 - Act as the designated point of contact for, and rapidly responding to, any civil-related complaints and incidents in accordance with the pre-determined strategies in this EMP or relevant ERP.
 - Review and update of WMPs to remain effective in communication with relevant landholders and Regional Weed Officer - Onshore Shale Gas Development in consideration of monitoring results and emerging weed issues for both gas and pastoral operations.
- **Drilling and Completions Lead:** Person responsible for ensuring the drilling, stimulation and well testing activities are designed and implemented in accordance with the NT legislation and Code of Practice.
 - Ensures all drilling, completion and stimulation activities are undertaken in accordance with the NT Petroleum Code of Practice.
 - Selection and design of equipment and practices to manage environmental risk.
 - Responsible for selecting and engaging drilling, stimulation and well testing contractors.
 - Ensuring all contractors comply with the contract terms including compliance with the EMP requirements.

- **Drilling and Completions Superintendent:** Person responsible for ensuring the drilling, stimulation and well testing activities are executed in accordance with the works program, EMP and Origin's HSE Policy. This role reports to the Growth Assets Drilling and Completions Lead.
 - Ensures all drilling, completion and stimulation activities are undertaken in accordance with the NT Petroleum Code of Practice.
 - Selection and design of equipment and practices to manage environmental risk.
 - Responsible for selecting and engaging drilling, stimulation and well testing contractors.
 - Ensuring all contractors comply with the contract terms including compliance with the EMP requirements.
- **Well Site Representative:** Person based at the well pad responsible for ensuring all areas of drilling, completion and well testing are carried out in accordance with the EMP and Origin's HSE Policy. All drilling, stimulation and well testing contractors report to this position, who reports to the Drilling and Completions Superintendent.

This role reports to the Drilling and Completions Superintendent and is responsible for:

- Planning and execution of the drilling, stimulation and well testing activities when on-site, including understanding and communicating the environmental requirements of this plan.
 - Facilitate training of all workers (including contractors) in accordance with the management of weeds, spills, waste, emissions and other aspects.
 - Ensuring all reporting requirements are met.
 - Act as the designated point of contact for, and rapidly responding to, any drilling, stimulation and well testing environmental incidents and emergencies in accordance with the pre-determined strategies in this EMP or relevant ERP.
 - Undertake field inspection and assurance activities.
- **Lead Contractor:** A nominated member within each contracting company (Drilling, Stimulation, Well Testing service providers) that are responsible for delivering the commitments outlined in this plan. The Lead Contractor for each service provider will comply with the nominated contractual terms and work instructions issued under this EMP. The Lead Contractor must ensure all staff are aware of their obligations, are approximately trained and that procedures and controls are fully implemented and complied with.
 - **Civil Design Engineer:** An individual or organisation that provides professional or expert advice in the field of civil engineering and design. They determine the best locations, design, materials and construction techniques for undertaking a project to ensure it meets the needs of the end user.
 - **Health Safety and Environment Representative (HSE Representative):** Origin representative providing guidance and advice to site personnel on the day-to-day management of the environment. This role will also support the nominated Weeds Officer, specifically in the planning and reporting phases.
 - **Field Personnel:** All staff including Origin and contractors that are working in the exploration permit areas. Responsible for day-to-day management and reporting of environmental aspects.

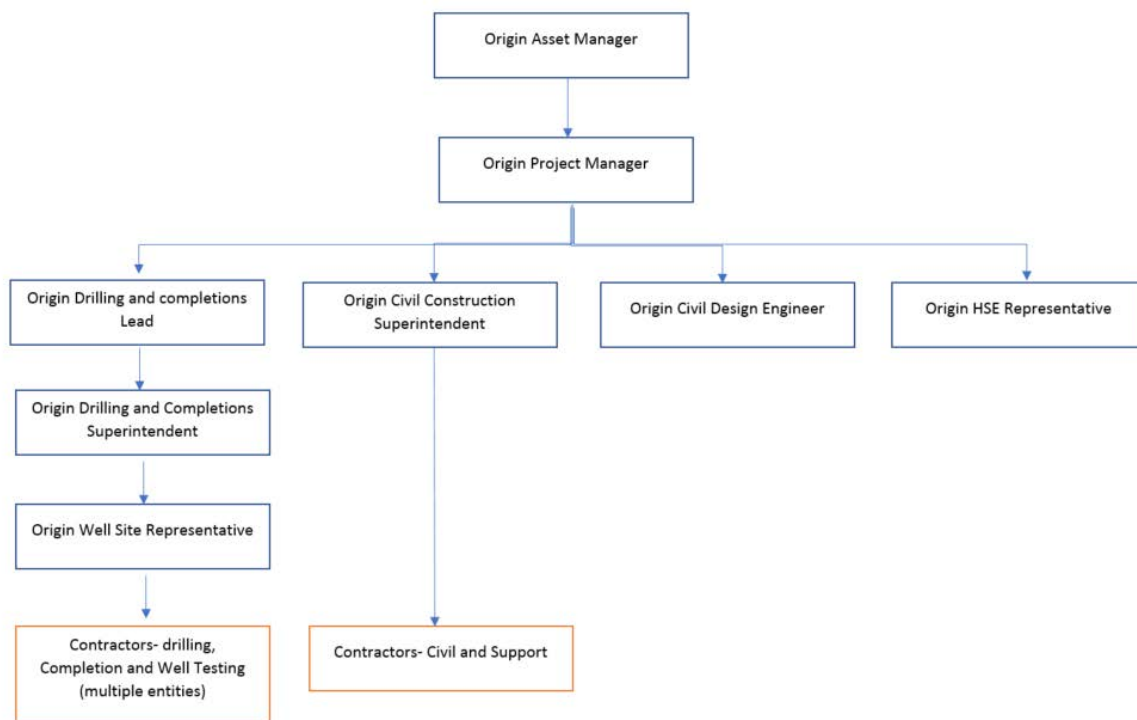


Figure 40: Beetaloo Project Organisation Chart

7.4 Training and awareness

Origin's HSEMS outlines the policies and procedures governing the training and competency of all personnel (staff and contractors) to ensure they can fulfil their obligations under this EMP and the broader Origin HSEMS.

The majority of work undertaken under this will be via contractors under supervision of Origin staff. Assuring the level of training and competency of the selected contractors and supervisors is therefore a major focus of the HSE EMS implementation strategy.

These systems include:

- General Origin HSE induction
- Contractor HSE prequalification process
- Contractor management system
- Site-specific inductions
- Task-specific training, procedures and competency requirements

Contractors will be required to demonstrate they have appropriate systems, procedures and training to manage specific risks covered under this EMP prior to award. The following aspects will be considered during tender award:

- Maturity of HSE systems and process
- Previous HSE performance
- Existing procedures and training:
 - Weed identification and management

- Refuelling procedures
- Procedures for avoidance of potential fauna habitat and any identified heritage sites
- Hazardous material and waste management procedures
- Spill management
- Incident notification and management processes
- Internal training programs
- Internal auditing processes

All staff and contractors entering the site will be required to attend a site-specific induction. The induction covers the following aspects:

- Regulatory requirements for the area, including specific conditions on the exploration permits and agreements with the NLC
- Environmental considerations and special procedures to be used for environment protection, as well as protection of archaeological and cultural sites within the permit areas
- Safety procedures covering the safe use of vehicles, equipment and explosives first aid and HSE in remote area operations
- Emergency response training
- Landowner sensitivities, including Aboriginal communities and their specific cultural requirements
- Procedures for handling any culturally or archaeologically sensitive materials that may be discovered
- Provide training in safe storage and handling of flammable and combustible liquids

7.5 Environmental commitment summary

The responsibility for general environmental monitoring rests with all personnel engaged on the project. More specifically, Origin's Drilling Completion Lead and Well Site Representatives are responsible for delivering the relevant components of this plan.

The program environmental commitments outlined in Appendix S are sourced from the risk assessment (Appendix K) and environmental outcomes, performance standards and measurement criteria tables (Tables 39 – 45). The implementation and compliance against these risk controls will be assessed as part of the annual environmental report (refer in Section 7.10).

Specific commitments will be to:

- record information to track performance, including non-conformances and corrective actions
- inspect and monitor operational controls on-site via regular environmental monitoring
- assess the level of conformance with objectives and targets detailed in this EMP

The Operating Company Representative will undertake random site inspections and direct such action as may be considered necessary to protect, minimise or rectify any environmental concerns.

7.6 Work instructions

The work covered under this EMP will be executed by external contractors with Origin oversight. Efforts are therefore focused on effective contractor management, to ensure third-parties are compliant with the relevant EMP commitment and contractual requirements. An overview of Origin's EMP implementation strategy is provided in Figure 41.

An instrument referred to as a 'work instruction' is the main mechanism by which Origin cascades the relevant environmental commitments to each contractor. The work instructions are designed to be a contractual document that outlines the minimum compliance requirements for a specific activity. The work instructions contain:

- Key compliance and system documents
- A list of compliance commitments and responsible person for a specific activity
- A list of inspections, procedures and other tools required to implement the content of the EMP
- Monitoring and reporting requirements
- 'Hold Points' which require a deliverable to be completed prior to entry into a new activity phase (i.e. prior to mobilisation, operation and demobilisation)
- Maps illustrating the approved disturbance areas and any restricted work areas.

The work instructions form a critical implementation and assurance tool in that an Origin representative must sign off the 'Hold Points' to ensure the various commitments have been achieved. This provides a clear, documented approach to demonstrate compliance which can be audited against.

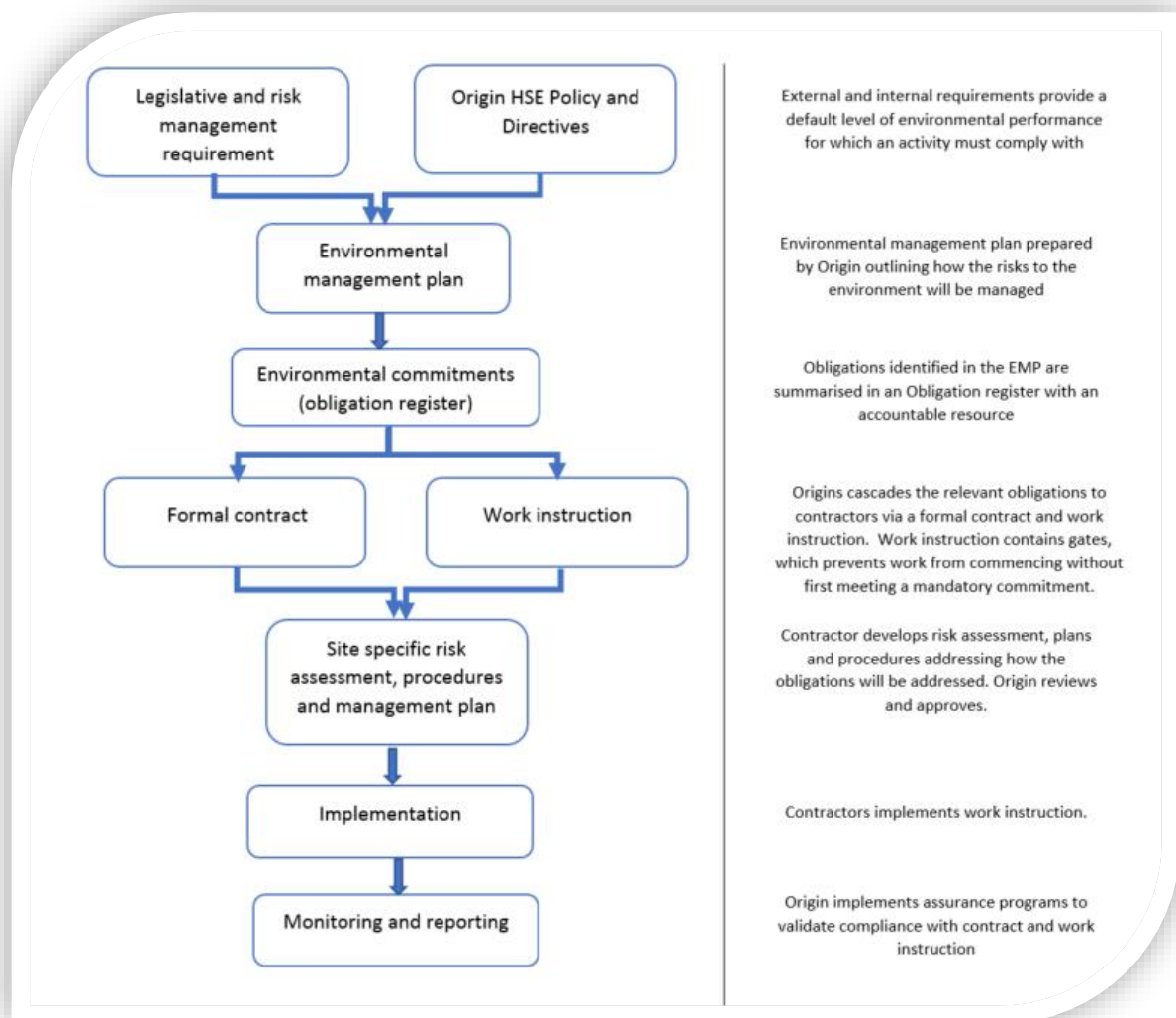


Figure 41: EMP implementation overview flowchart

7.7 Incident reporting

Incident reporting and investigation provides the mechanism to prevent a recurrence. All personnel are required to proactively report all incidents, near-misses and identification of potential hazards.

Origin utilises an online incident management and reporting system. Any environmental incident, near miss or observation is reported through the online incident reporting system. All personnel are encouraged to report minor events to act as an alert to environmental risks and to maintain a program of continual improvement.

When an incident occurs, an environmental professional will assess whether the statutory reporting threshold has been triggered.

7.7.1 Reportable Environmental Incident Reporting

The NT Petroleum (Environment) Regulations 2016 define a reportable incident as an incident arising from a regulated activity that has caused, or has the potential to cause, material environmental harm or serious environmental harm as defined under cl. 117AAB(1) the Petroleum Act.

Origin will identify and assess incidents continuously to determine if they are reportable. Where an incident is reportable, DEPWS will be contacted (this may be verbal or in writing) as soon as practicable but no later than two hours after the first occurrence of the incident or after the time the interest holder becomes aware of the incident.

Notification will be via the DEPWS Onshore gas non-compliance hotline on 1800 413 567.

Any verbal report to DEPWS will be followed up by a written report from the Project Manager within 24-hours after giving verbal notice in accordance with the NT Petroleum (Environment) Regulations 2016 (reg 33(4)). An initial report about a reportable incident must be given as soon as practicable, but not later than three days after the incident occurs (reg 34(3)). A final report must be given as soon as practicable but no later than 30-days after the clean up or rehabilitation is complete. This must include a root cause analysis (reg 34(4) and 34(5)).

7.7.2 Recordable incidents

The *NT Petroleum (Environment) Regulations 2016* define a recordable incident as an incident arising from a regulated activity that:

- I. Has resulted in an environmental impact or environmental risk not specified in the current plan for the activity; or
- II. Has resulted in a contravention of an environmental performance standard specified in the current plan for the activity; or
- III. Is inconsistent with an environmental outcome specified in the current plan for the activity; and
- IV. Is not a reportable incident.

Origin will notify (this may be oral or in writing) DEPWS of a recordable incident as soon as practicable but no later than 15-days after the reporting period (agreed period or each 90-day period after the day on which the EMP is approved).

7.7.3 NT Waste Management and Pollution Control Act 1998 incident reporting

In accordance with the *NT Waste Management and Pollution Control (WMPC) Act 1998*, where contaminants or waste is not confined within the land on which the petroleum activities are undertaken (i.e. the approved disturbance areas where the petroleum activity is occurring), Origin has a duty to notify of incidents causing or threatening to cause pollution as soon as practicable, but no less than 24-hours after becoming aware of the incident.

A notifiable incident is defined as an incident that causes, or is threatening or may threaten to cause, pollution resulting in material environmental harm or serious environmental harm.

A notification must include:

- (a) the incident causing or threatening to cause pollution
- (b) the place where the incident occurred
- (c) the date and time of the incident
- (d) how the pollution has occurred, is occurring or may occur

(e) the attempts made to prevent, reduce, control, rectify or clean up the pollution or resultant environmental harm caused or threatening to be caused by the incident

(f) the identity of the person notifying

Origin shall make all notification under the WMPCA via the NT EPA Pollution Hotline 1800 064 567.

7.7.4 Gas Leak reporting

Each gas leak shall be classified, repaired and reported in accordance with Table 46.

Table 46 Leak classification and remediation summary

Classification	Threshold	Notification	Comments
Minor Leak	>500ppm measured at the surface of the component in accordance with section 6.4.1	All minor leaks must be documented	A minor leak is an unplanned release that does not occur during commissioning or bringing equipment back into service. These leaks should be corrected immediately as a part of commissioning
Significant Leak	>5000ppm (or 10% of the Lower Explosive Limit) when measured at 150mm above the leak source. Or A Liquid Petroleum (condensate/oil) loss of containment that exceeds 200L. Or The leak is too large or not safe to measure.	In the case of an emergency situation, DITT must be notified within 24 hours via the emergency response hotline number 1300 935 250. Notification must include the date of identification, nature and level of the leak, infrastructure name, number and location as well as the initial actions to minimise the risk. The land owner or occupier of the property in which these leaks are occurring must be notified in the following circumstances: i) if the leak cannot be repaired immediately; and ii) if the leak is likely to affect any of the land owner's or occupiers facilities or activities. A written close-out report must be submitted within 5 business days of the remediation of	A significant leak is an unplanned release that does not occur during commissioning or bringing equipment back into service. These leaks should be corrected immediately as a part of commissioning

Classification	Threshold	Notification	Comments
		the leak, specifying the date of identification, nature and level of leak, location and name of the operating plant, and the rectification actions taken. If finalising the remediation is delayed more than 7 business days from the identification of the leak an update must be submitted on that day. The final close out report shall be provided when all work is completed. Where environmental impacts have occurred notification to DEPWS is undertaken as described in Section 7.7.1 or 7.7.2 as appropriate.	

7.8 Monitoring, assurance and non-conformance management

In addition to regular monitoring as set out in this document, audits assessing compliance with this EMP and associated work instructions will be undertaken by Origin during the commencement of the activity. System deficiencies, adverse or potentially adverse environmental conditions arising from site activities may be subject to the issue of environmental non-conformances or corrective action requests. These non-conformances or corrective actions shall be logged, and remedial actions identified and implemented. The status of corrective actions will be tracked and reported annual in the annual environmental report.

Audits of implementation of the EMP commitments will be completed for each activity or at least annually. The results will be included in the annual environmental report.

Table 47: EMP audit schedule

Audit Type	Scope of Audit	Frequency	Responsibility
Operational assurance	Operational compliance checks to ensure risk management controls are implemented	Monthly	Origin HSE Representative
Annual Assurance	Compliance against EMP commitments and risk management controls	Annually	Origin HSE Representative

7.9 Emergency Response Plan

An Emergency Response Plan has been developed covering the proposed activities within the EMP. The ERP provides a broad framework for managing potential emergency incidents to minimise the potential risk to human safety and the environment.

The ERP covers the following aspects pertinent to the drilling and stimulation activities and associated infrastructure:

- Spills and loss of containment
- Bushfires
- Medical emergencies
- Flooding
- Emergency incident reporting

The ERP will be reviewed every three (3) years to ensure the content is continually kept up to date. A copy of the ERP is provided in Appendix T.

7.10 Reporting

Internal and government reporting on performance standards will be carried out by the Origin authorised representative, and distributed to Origin management and the DEPWS, in accordance with Section 35 of the *NT Petroleum (Environment) Regulations 2016*. Quarterly and annual reports will be completed to summarise the compliance with this EMP, whether the environmental outcomes and performance standards in the plan were met and the details of any recordable and reportable incidents.

Table 48: EMP reporting schedule

Frequency	Report detail	Recipient
Prior to the commencement of construction and drilling	A commencement of construction or drilling activity notification	a) The Minister for Environment b) The occupier of the land in which the activity is carried out c) The owner for the land for which the activity is to be carried out
Only if required	Incident report summarising reportable incidents	DEPWS
Monthly	Monthly activity summary report	DEPWS
Quarterly	Quarterly incident report summarising recordable incidents during the period (during operational activities) and groundwater monitoring data	DEPWS
Annually	An annual environmental report will be prepared and submitted to the Minister covering the following: • Summary of the works completed under the EMP during the reporting period • Summary of performance against measurement criteria • A summary of environmental incidents that occurred during the year (i.e. reportable and recordable incidents that occurred) • Any environmental studies or research associated with the activity • Technical improvements	Origin management DEPWS

Frequency	Report detail	Recipient
	• Consultation undertaken • Annual weed management performance reporting against NT-2050-15-MP-0016 • Results of related research or of an ongoing monitoring program • The relevant records outlined with Section 6.6 Environmental Risk Management Summary tables	
Report about flowback fluid	A report regarding flowback is required within 6 months of the flowback commencing, in accordance with section 37A of the <i>NT Petroleum (Environment) Regulations 2016</i>	a) The Minister for Environment

7.11 Record keeping

The following records will be retained within Origin's Document Management system for a period of five (5) years:

- Records linked to measurement criteria, commitments and statutory reporting requirements
- Induction records
- Waste records
- Hazardous goods manifests
- Fuel usage
- Weed inspections
- Non-compliances and corrective action records
- Internal audits and inspection records
- Management of change records.

To the extent these documents are 'prescribed records' for the purpose of the *NT Petroleum (Environment) Regulations 2016*, they will be kept for the longer of five (5) years following the period during which the petroleum interest is in force and 15-years after the record comes into existence.

7.12 Management of change

A management of change process will be implemented to ensure any changes to activities are appropriately assessed and communicated to ensure no additional un-intended risks or impacts are introduced. This allows adaptive management and the ability to use appropriate technologies.

It should be noted that changes can only be implemented to optimise environmental outcomes or to improve operational efficiency where no new regulated activity, risk (including risk level) or impact is introduced. Where a new regulated activity, risk (including risk level) or impact is introduced, then a Revision of the EMP is required under the PER's

7.13 EMP Review

Implementation of this EMP will be continually monitored and revised as required based on monitoring and audit results, complaints, employee and stakeholder feedback, change to the proposed work program or a material increase in risk level.

A formal review, update and resubmission of this EMP will be undertaken every five (5) years.

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9 Acronyms & Abbreviations

Acronym	Meaning
°C	Degrees Celsius
%	Percentage
AAPA	Aboriginal Areas Protection Authority
ABS	Australian Bureau of Statistics
AICS	Australian Inventory of Chemical Substances
ALA	Atlas of Living Australia
ALARP	As Low As Reasonably Practicable
ANZECC	Australian and New Zealand Environment Conservation Council
API	American Petroleum Institute
APPEA	Australian Petroleum Production and Exploration Association
AS	Australian Standard
BMP	Bushfire Management Plan
BPESC	Best Practice Erosion and Sediment Control
CAS number	Chemical Abstracts Services number
CEEVNT	Critically Endangered, Endangered, Vulnerable and Near Threatened
CLA	Cambrian Limestone Aquifer
COP	Code of Practice
Cth	Commonwealth
DAWE	Department of Agriculture, Water and the Environment (DAWE) (Commonwealth) (formerly Department of The Environment and Energy (DoTEE) (Cmwth))
DEPWS	Department of Environment, Parks and Water Security (formerly Department of Environment and Natural Resources (DENR))
DITT	Department of Industry, Trade and Tourism (formerly Department of Primary Industries and Resource (DPIR))
DoH	Department of Health (NT)
EC	Electrical Conductivity
EIS	Environment Impact Statement
EMP	Environmental Management Plan
EP	Exploration Permit (e.g. EP76, EP98 and EP117)
EPA	Environment Protection Authority (NT)
EPBC	Environment Protection and Biodiversity Conservation Act

Acronym	Meaning
ERS	Emergency Response Plan
ESC	Erosion and sediment controls
ESCP	Erosion and Sediment Control Plan
GDE	Groundwater Dependent Ecosystems
GHG	Greenhouse Gas
GPS	Global Positioning Device
Ha	hectare
HFS	Hydraulic Fracture Stimulation
HSE	Health, Safety and Environment
HSEMPs	Health, Safety and Environmental Management Plans
HSEMS	Health, Safety and Environment Management System
IBA	Important Bird Area
IECA	International Erosion Control Association
ILUA	Indigenous Land Use Agreement
ISO	International Organisation for Standardisation
JV	Joint Venture
Km	Kilometre
km ²	Square Kilometres
km/hr	Kilometres per hour
LAG	Local Aboriginal Group
LOS	Level of Service
m	metre
Ma	Millions of years ago
MD	Measured Depth
MEMP	Methane Management Plan
MI	Local Magnitude
Mm	millimetre
mMDRT	Meters measured depth below rotary table
MNES	Matters of National Environmental Significance
SDS	Safety Data Sheet

Acronym	Meaning
mTVDGL	metre True Vertical Depth below ground level
NATA	National Association of Testing Authorities
NEPM	National Environmental Protection Measure
NGERS	National Greenhouse and Energy Reporting Scheme
NICNAS	National Industrial Chemicals Notification and Assessment Scheme
NLC	Northern Land Council
NORMs	Naturally Occurring Radioactive Materials
NPI	National Pollutant Inventory
NT	Northern Territory
OHS	Occupational Health and Safety
PER	Public Environment Report
RWA	Restricted Work Area
SPMP	Spill Management Plan
SWL	Standing Water Level
tCO ₂ ^e	tonnes of carbon dioxide equivalent
TDS	Total Dissolved Solids
TIA	Traffic Impact Assessment
TMP	Traffic Management Plan
TO	Traditional Owner
TVDSS	True Vertical Depth from Surface Sea level
<i>TPWC Act</i>	<i>Territory Parks and Wildlife Conservation Act</i>
TRH	Total Recoverable Hydrocarbons
TSS	Total Suspended Solids
VOCs	Volatile Organic Compounds
WBIV	Well barrier integrity verification
WEL	Water Extraction Licence
WIMP	Well Integrity Management Plan
WMP	Weed management Plan
WOMP	Well Operations Management Plan
WoNS	Weed of National Significance

Acronym	Meaning
WWMP	Wastewater Management Plan