BEETALOO SUB-BASIN AMUNGEE NW-1H

Environment Management Plan

Exploration Permit 98 (EP98)

ORI7-2

Review record

Rev	Date	Reason for issue	Author	Reviewer	Approver
0.1	05/06/2016	Draft for review	S. Dale	C. Christoffersen	D.Schneider
1.0	06/06/2016	Final for issue	S. Dale	C. Christoffersen	D.Schneider
1.1	01/07/2016	Final for issue- post DME review	S. Dale	C. Christoffersen	D.Schneider
1.2	12/07/2016	Final for issue- post DME review 2	S. Dale	E. Wong	D.Schneider
2.0	31/03/2021	5 year revision	M.Kernke	R. Ully	A.Cote
2.1	14/05/2021	Minor update to address DEPWS comments	R.Ully		M.Kernke
2.2	10/06/2021	Minor update to address minor spelling/ gramma errors			M.Kernke

Executive Summary

Origin Energy B2 Pty Ltd (Origin) is a registered holder and the operator of exploration permit (EP) 98, which is located in the Beetaloo Sub-basin (Figure 1). This Environment Management Plan (EMP) forms the basis of Origin's application to the Northern Territory (NT) Minister for Environment for the revision of the existing Amungee NW-1H (Amungee NW) Stimulation EMP (NT-2050-15-MP-34).

The Amungee NW site is an existing site located on the Amungee Mungee pastoral station within EP 98 (Figure 1). Targeting the Velkerri formation, the Amungee NW-1H exploration and appraisal (E&A) well was drilled in October–November 2015, with a hydraulic fracture stimulation (HFS) in September 2016. Following the successful HFS, a 57 day well test was completed prior to the well being suspended in November 2016. The Amungee NW 1H has been suspended since this time, with formation pressure build-up monitoring underway.

This revised EMP covers the proposed regulated activities to be carried out on the Amungee NW site for the forward 2021–2026 period. The revised EMP covers the changes in legislation since the original approval date, including the requirements of the *Petroleum (Environment) Regulations 2016* and the Code of Practice for Onshore Petroleum Activities within the Northern Territory (Code of Practice).

The key outcomes from the forward proposed regulated activities will be used to manage the existing Amungee NW site and associated Amungee NW-1H appraisal well. Data collected through the proposed extended production test (EPT) will be used to understand the technical and commercial viability of the Velkerri dry gas shale resource by:

- maintaining the Amungee NW site and associated appraisal well in a safe, stable and non-polluting manner
- undertaking further extended production test (EPT) operations to evaluate longer term production rates and decline curves of the Amungee NW-1H well
- assessing the effects of a long-term E&A well suspension on production rates (gas and water)
- evaluating the level of production contribution from different stages

The proposed regulated activities covered in this EMP are detailed in Table 1 and can be summarised as:

- civil maintenance of Amungee NW including erosion and sediment controls (ESC), roads and lease pad
- site establishment works, including the construction of wastewater tanks, wastewater bunding and stormwater retention pond
- an EPT on the Amungee NW-1H well, including flaring and wastewater storage
- operation of a temporary camp, offices and equipment storage areas
- reservoir testing and data acquisition using reservoir evaluation tools (and other data collection methods)
- maintenance and monitoring of infrastructure on the Amungee NW site, including well interventions, work overs, completion and general well maintenance and diagnostic activities
- monitoring and recording build-up pressures post EPT
- suspension and/or abandonment of the Amungee NW-1H well.

The EMP has been prepared in compliance with the NT *Petroleum (Environment) Regulations* 2016, the Code of Practice and the Exploration Agreements between Origin, Native Title holders and the Northern Land Council (NLC).

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.

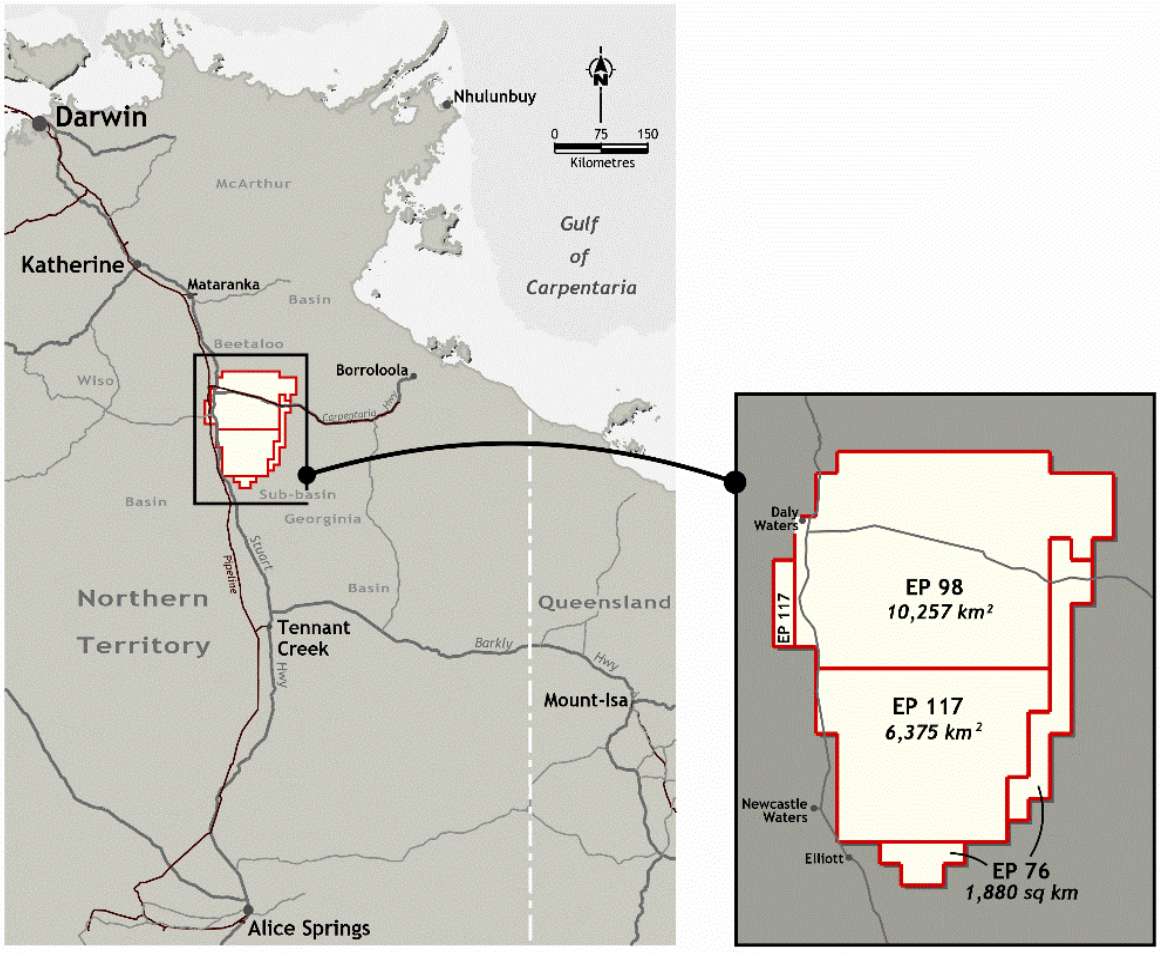

Figure 1: Location of Origin permit area

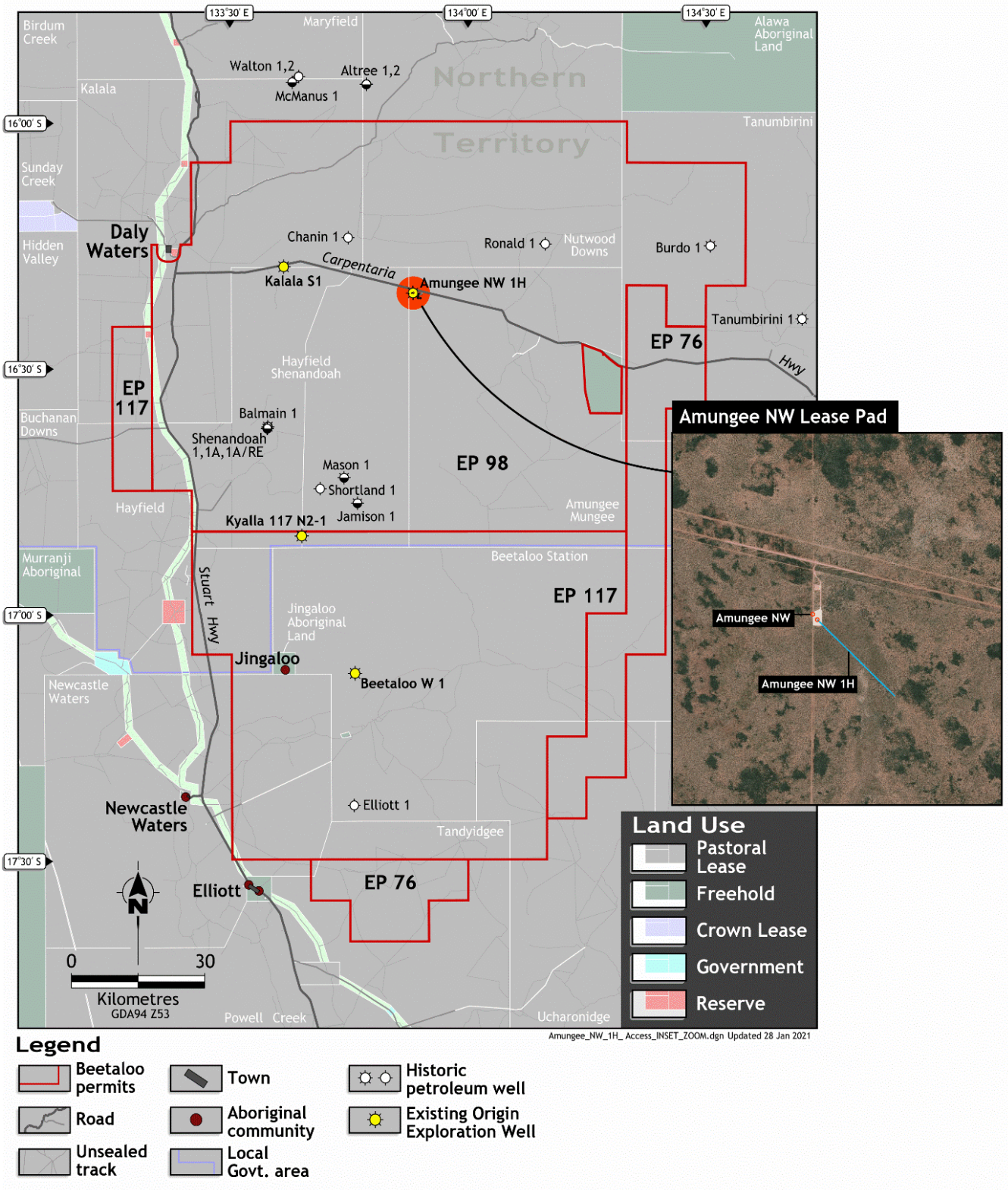

Figure 2: Location of the Amungee NW-1H well and proposed regulated activities on Amungee NW

Table 1: Description of the exploration and appraisal activities

Component	Existing Amungee NW site	Revised EMP scope
General		
Number of E&A wells	1 existing appraisal well: Amungee NW-1H	No change—no drilling proposed
Number of stimulations	1 appraisal well (Amungee NW-1H)	N/A the existing Amungee NW-1H well has been stimulated
Number of water extraction/monitoring bores	3 existing bores	No change—existing groundwater bores will be utilised
Number of gravel pits approved under EMP	0	0
Operational workforce	N/A site suspended	~20 people during operations
Main camp capacity	N/A no camp located at site	~20 people—existing camp pad to be utilized
Disturbance		
AAPA certificate	All works covered under C2020/003	
Total area of disturbance	5.25 ha (3.56 ha lease pad, 0.9 ha camp pad and 1.1 ha access track)	No change to total disturbance values—existing lease pad, camp pad and access tracks to be utilised
Traffic		
Peak traffic movements (per day)	N/A site suspended	<16 vehicles per day peak during mobilisation
Average traffic movements during operations	N/A site suspended	4–6 trucks per day
Truck load-out: wastewater transport	N/A site suspended	~5 B-quad loads
Water use and stormwater management		
Groundwater extraction license	N/A all take previously authorized under the *NT Petroleum Act*	All take covered under existing WEL GRF 10285
Estimated groundwater usage	N/A	~3.2ML
Stormwater retention basin	N/A	Small stormwater retention basin (10x10m) located within wastewater storage area

Component	Existing Amungee NW site	Revised EMP scope
Wastewater management		
Enclosed wastewater tank capacity	N/A	1ML
Open treatment tank capacity	N/A	1ML
Bunded tank pad containment capacity	N/A	1.2ML
Flowback/wastewater volume generated onsite	N/A	1 ML
Flowback/wastewater volume (final predicted for treatment and off-site disposal)	N/A	~0.15ML
Transfer pumps	N/A no wastewater is stored onsite	2x 6-inch pumps up to 12ML/day
Greenhouse gasses and emissions		
Flares	N/A site suspended	Vertical flare
tCO2-e emissions	N/A	2,405 tCO^{2e}-

Figure 3 shows the existing Amungee NW site and the layout of the proposed activities within the existing lease pad.

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.

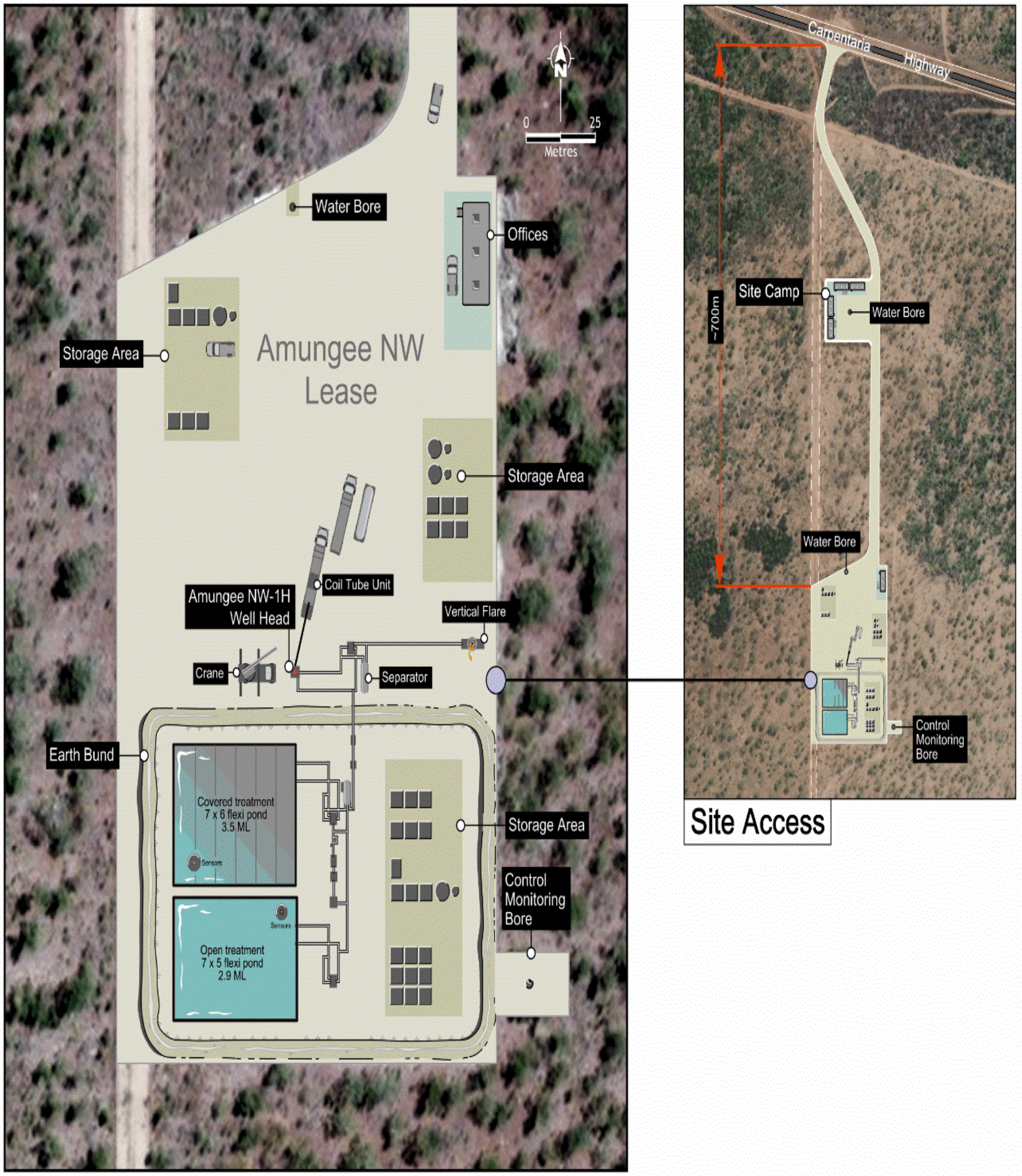

Figure 3: Amungee NW site with conceptual layout of equipment

Description of the existing environment

The Amungee NW site is located on the Amungee Mungee Station, which is subject to pastoral land use. A Land Condition Assessment was completed in 2014, and again in 2018, to review the physical, natural and cultural heritage environment of the existing Amungee NW site. A summary of the existing environment in which the existing lease pad is located is provided in Table 2

The existing Amungee NW disturbance footprint including lease pad, camp pad and access track is approximately 5.25 ha, as shown in Figure 4. The Amungee NW-1H well is located on the existing Amungee NW lease pad, which was constructed in 2015 to enable exploration activities.

The Amungee NW site is located within open *Corymbia* woodland with dense grass and shrub cover. This vegetation type is widespread in the tropical savannas of the Northern Territory and may provide habitat for some threatened species such as the Gouldian Finch *(Erythrura gouldiae)*.

Ongoing routine field weed surveys have been completed at the location since 2014. *Hyptis suaveolens* (Class B & C under the NT *Weeds Management Act 2016*) was found at the Amungee NW site and is subject to active treatment. The low number of weed species in and around the site indicates the surrounding habitat is in good condition. Weed management will continue to focus on preventing the introduction and spread of weeds.

The archaeology assessment did not identify culturally sensitive landforms or artefacts within the vicinity of the Amungee NW site. Aboriginal Areas Protection Authority Certificate 2020/003 has been granted covering the proposed activity area. The closest identified sacred site to Amungee NW is located over 8km away.

Figure 4: Overview of the existing Amungee NW site footprint during the drilling of the Amungee NW-1H appraisal well in 2016

Table 2: Summary of existing environment and surrounds at Amungee NW

Site ID	Amungee NW	Habitat survey photos of the vegetation/habitat of the surrounding environment	
Location	-16°20' 38.17, 133°53' 2.76		
Landform and soil	Two types: laterite, ferruginous rubble, some red soil and sandy and loamy soil with some lateritic material on undulating plain		
Habitat type	Open eucalypt woodland		
Vegetation community	Open woodland with dense shrub cover and grass cover. This vegetation community is considered regionally extensive and not subjected to extensive clearing		
Dominant flora species	Canopy dominated by *Corymbia drysdalensis*, *C. ferruginea* and *Erythrophleum chlorostachys*. Diverse subcanopy/shrub layer including: *Petalostigma pubescens*, *Terminalia canescens*, *Atalaya hemiglauca*, *Hakea arborescens*, *Grevillea pteridifolia*, *Carissa lanceolata*, *Dodonea* sp., *Flueggia virosa*, *Grevillea striata*, *Alphitonia pomaderroides*. Very dense grass cover including *Themeda triandra*, *Chrysopogon fallax*, *Heteropogon contortus*, *Sarga plumosum*. Other		

	species include *Grewia retusifolia*, *Ptilotus polystachyus*, *Evolvulus alsinoides*, *Cleome viscosa*.		
Habitat condition	Previous exploration activities (disturbances include grazing and prior clearing. Amungee NW. No evidence of recent fire. The weed *Hyptis suaveolens* present at the site. Evidence of cattle from wet/early dry season. Very dense grass cover provides cover for small mammals and reptiles. Abundance of shelter sites in the form of hollow logs for mammals and reptiles.	**Hydrogeology**	
Potential listed threatened species	Grey Falcon, Northern Shrike-tit, Plains Death Adder, Gouldian Finch	Groundwater resources and use is from the Gum Ridge Formation. A seasonal perched shallow alluvium system has also been locally identified but is not utilised as a groundwater resource. The Anthony Lagoon formation and undifferentiated Cretaceous are unsaturated.	
Weeds	No *Weeds of National Significance* present. *Hyptis suaveolens* present on access tracks.		

Key environmental risks assessed in the program

The environmental, heritage and social risks associated with the proposed 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 soils, surface water and groundwater through management of wastewater and prevention of spills
- 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 3).

Table 3: Summary of residual risk ratings

	Residual Environmental Risk Level			
	Low	Medium	High	Very High
Total 58	52	6	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
4. Impact to Sacred Site or culturally sensitive site through accidental ignition of fire from exploration 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 the EMP 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 the activities, rehabilitation will be conducted as described in section 3.17.

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.

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1 Introduction

Origin Energy B2 Pty Ltd (Origin) is a registered holder and the operator of exploration permit (EP) 98, which is located in the Beetaloo Sub-basin (Figure 1). This Environment Management Plan (EMP) forms the basis of Origin's application to the Northern Territory (NT) Minister for Environment for the revision of the existing Amungee NW-1 Stimulation EMP (NT-2050-15-MP-34).

The Amungee NW site is an existing site located on the Amungee Mungee pastoral station within EP 98 (Figure 2). The Amungee NW-1H exploration and appraisal (E&A) well was drilled in 2015, with a hydraulically fracture stimulation (HFS) completed in September 2016. Following the successful HFS, a limited 57 day well test was completed prior to the well being suspended in late 2016. The E&A well has been shut in since this time, with formation pressure build-up monitoring underway.

This revised EMP covers the proposed regulated activities for the Amungee NW-1 site between the 2021–2026 period, as well as aligning the EMP with the NT *Petroleum (Environment) Regulations 2016* and the Code of Practice: Onshore Petroleum Activities in the Northern Territory (the Code of Practice). The key outcomes from the forward proposed regulated activities will be used to collect data to:

- maintaining the Amungee NW site and associated appraisal well in a safe, stable and non-polluting manner
- undertaking further extended production test (EPT) operations to evaluate longer term production rates and decline curves of the Amungee NW-1H well
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Table 4: Amungee NW-1 site activity summary table

Component	Existing Amungee NW site	Revised EMP scope
General		
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Wastewater management		

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Greenhouse gasses and emissions		
Flares	N/A site suspended	Vertical flare
tCO_2-e emissions	N/A	2,405 tCO_2^e

1.1 Project boundary

The boundary of this EMP is defined as the area which may be affected by E&A activities within EP 98. The proposed locations of the infrastructure and associated regulated activities are provided in Table 5 and Figure 1. The boundary areas include:

- Existing access tracks to and from the Amungee NW site from the Carpentaria Highway
- Existing Amungee NW lease pad
- Existing Amungee NW camp pad.

Table 5: Amungee NW and associated infrastructure covered under this EMP

Exploration Permit	Infrastructure Name	Station	Zone*	Approx. Easting	Approx. Northing
EP 98	Existing approved and constructed Amungee NW Lease Pad	Amungee Mungee	53	380859	8192299
EP 98	Existing approved and constructed Amungee NW-1H E&A well	Amungee Mungee	53	380859	8192299
EP 98	Existing approved and constructed Amungee NW camp pad	Amungee Mungee	53	380855	8192763
EP 98	Existing access tracks	Amungee Mungee	Not Applicable		

** Geocentric Datum of Australia (GDA) 94.*

1.2 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.

2 Environmental legislation and other requirements

Key NT and Commonwealth legislation, agreements, operating consents, guidelines and Codes of Practice relevant to the activities described in this EMP are summarised in Table 6. This EMP has been prepared in relation to these requirements.

Table 6: Key legislation

Legislation	Requirement	How Origin meets the requirement	Administered by
Northern Territory			
Petroleum Act 1984	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	

Legislation	Requirement	How Origin meets the requirement	Administered by
		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) *NT Petroleum (Environment) Regulations 2016*
	That the EMP is developed in accordance with the *NT Petroleum (Environment) Regulations 2016*	Origin has developed this EMP in accordance with the *NT Petroleum (Environment) Regulation* requirements	
	That stakeholder engagement for the regulated activities is undertaken	Origin has completed stakeholder engagement in accordance with the *NT Petroleum (Environment) Regulations 2016*, as summarised in section 5 of this EMP	
	That activities are conducted in accordance with the Code of Practice: Onshore petroleum activities in the Northern Territory	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	Compliance with total fire bans and fire permitting	Origin will not undertake flaring or the lighting of fires during periods of total fire	Bushfires NT

Legislation	Requirement	How Origin meets the requirement	Administered by
associated regulations		bans and will obtain a permit where flaring occurs during declared fire danger periods	
	Requirements for occupiers to prevent and control fires	Addressed through Origin's Bushfire Management Plan (appendix C) 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 to the NT EA for assessment under the *EP Act*	Origin has completed a self-assessment in Appendix A. The level of potential environmental impact is not considered significant	Northern Territory Environment Protection Authority (NT EPA) DEPWS
Environmental Protection (National Pollutant	Requirement for facilities that trigger a reporting threshold as defined in the Commonwealth National Environmental Protection (National Pollutant Inventory)	Where a threshold has been exceeded, Origin shall provide the required emission estimate report to the	DEPWS

Legislation	Requirement	How Origin meets the requirement	Administered by
Inventory) Objective 2004	Measure to estimate specific contaminant emissions on an annual basis. A report must be submitted to the Chief Executive officer within 3 months of the end of the reporting period.	Chief Executive Officer within 3 months	
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

Legislation	Requirement	How Origin meets the requirement	Administered by
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 controls implemented to limit the impact on wildlife	Parks Wildlife and Heritage Division of the Department of Tourism Sport and Culture
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	NT EPA

Legislation	Requirement	How Origin meets the requirement	Administered by
		consignment authority	
	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 1km 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 1km from the centreline of a pipeline, that causes or threatens to cause material or serious environmental harm.	Origin will report all incidents that causes or threatens to cause pollution beyond the boundary of the 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. 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:	Origin will comply with the requirement of this Act through the implementation of	Weed Management Branch, Department of

Legislation	Requirement	How Origin meets the requirement	Administered by
	• 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	weed prevention, detection and eradication controls through its approved weed management plan (Appendix G)	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
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

Legislation	Requirement	How Origin meets the requirement	Administered by
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) • 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	Prime Minister and Cabinet

Legislation	Requirement	How Origin meets the requirement	Administered by
		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 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 Ara 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 maintain the existing Amungee NW site and undertake an EPT on the Amungee NW-1H E&A well. It also covers the regulated activities associated with the maintenance, monitoring, suspension and abandonment of the E&A well. To accommodate this scope, the activities summarised in Table 7 are proposed to be executed under this EMP.

Table 7: Description of the exploration and appraisal activities for the existing Amungee NW-1H E&A well

Activity	Description
Site set-up and mobilisation to support the Amungee NW-1H EPT	• Use of existing access tracks to and from the Amungee NW site from the Carpentaria Highway • Use of the existing cleared and graded Amungee lease pad, including lease pad, access tracks, camp pads, stockpile storage and laydown areas • Set-up of a 20-person capacity temporary camps • Set-up of a well test spread, including coil tubing unit, wire line unit, separators and vertical flare • Set up of wastewater storage tanks and construction of tank bunding and stormwater retention pond • Installation of workshop, offices, minor chemical storage and equipment storage areas

Activity	Description
Extended Production Test activities on the existing Amungee NW-1H E&A well	• Completion of an extended production test for approximately 30 days • Operation of a coil tubing unit and collection of reservoir data • Operation of the temporary 20-person capacity camp located at existing Amungee NW-1H camp pad • Transportation, handling and storage of bulk fuel (<100,000L) • 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% • Groundwater extraction of approximately 3.2ML under existing groundwater extraction licence (WEL GRF 10285) • Maintenance and monitoring works on Amungee NW-1HE&A wells in accordance with approved WOMP
Monitoring and maintenance	• 12 month pressure build-up test • Monitoring activities (including well head pressure, groundwater, stormwater, soils, leak detection and all other ancillary data collection programs) • Routine maintenance of the Amungee NW-1H well, including surface and sub-surface maintenance and inspections
Civil maintenance	• Regrading existing lease pad, operational areas and access tracks • Maintenance of ESC measures • Maintenance of fence and security • Set up of equipment, tanks, storage units, office, facilities within the lease area as required • Weed management activities
Well suspension and decommissioning	• Suspension and decommissioning Amungee NW-1H well in accordance with the Code of Practice
On-site wastewater management to support the Extended Production Test and regional wastewater management requirements	• On-site wastewater storage, evaporation and treatment of wastewater in accordance with Code of Practice • flowback fluid quality testing in accordance with the Code of Practice

Activity	Description
	• trucking of wastewater to or from an approved Origin location to manage wastewater levels and minimise wastewater tank construction. • Offsite disposal of wastewater in accordance with the *Waste Management and Pollution Control Act*
Site mobilisation and demobilisation	• Mobilisation and demobilisation of well test equipment, including camps, well testing equipment, wastewater storage tanks and various service provider equipment • Approximately 16 traffic movements per day during each mobilisation period
Site rehabilitation	• Decommissioning and removal of all surface infrastructure and wastes from site including the removal of wastewater tanks, cellars, equipment, non-drilling waste, wastewater and all ancillary equipment • Final rehabilitation activities in accordance with the rehabilitation plan (Appendix K).

3.1 Timeframes

The anticipated key activity dates for the EPT and ongoing maintenance are detailed in Table 8 and illustrated in Figure 5. 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.

Table 8: Anticipated activity dates

Activity	Estimated dates
Amungee NW-1 site maintenance	Q2/3 2021
Amungee NW wastewater storage tank and bund construction	Q2/3 2021
Amungee NW-1H well test	Q3 2021
Wastewater Storage	Q3 2021-2022[1]
Wastewater trucking	Q4 2021[2] / 2022
Appraisal well build up test	Q3 2021- Q4 2022
E&A well suspension Amungee NW-1H	Q4 2022

[1] The timing of wastewater storage will depend on operational requirements. Wastewater storage may extend beyond the 2021 wet season as required to support the treatment of water through evaporation.
[2] The timing of wastewater trucking will depend on operational requirements.

Activity	Estimated dates
Ongoing maintenance and monitoring	Q3 2021–Q3 2026

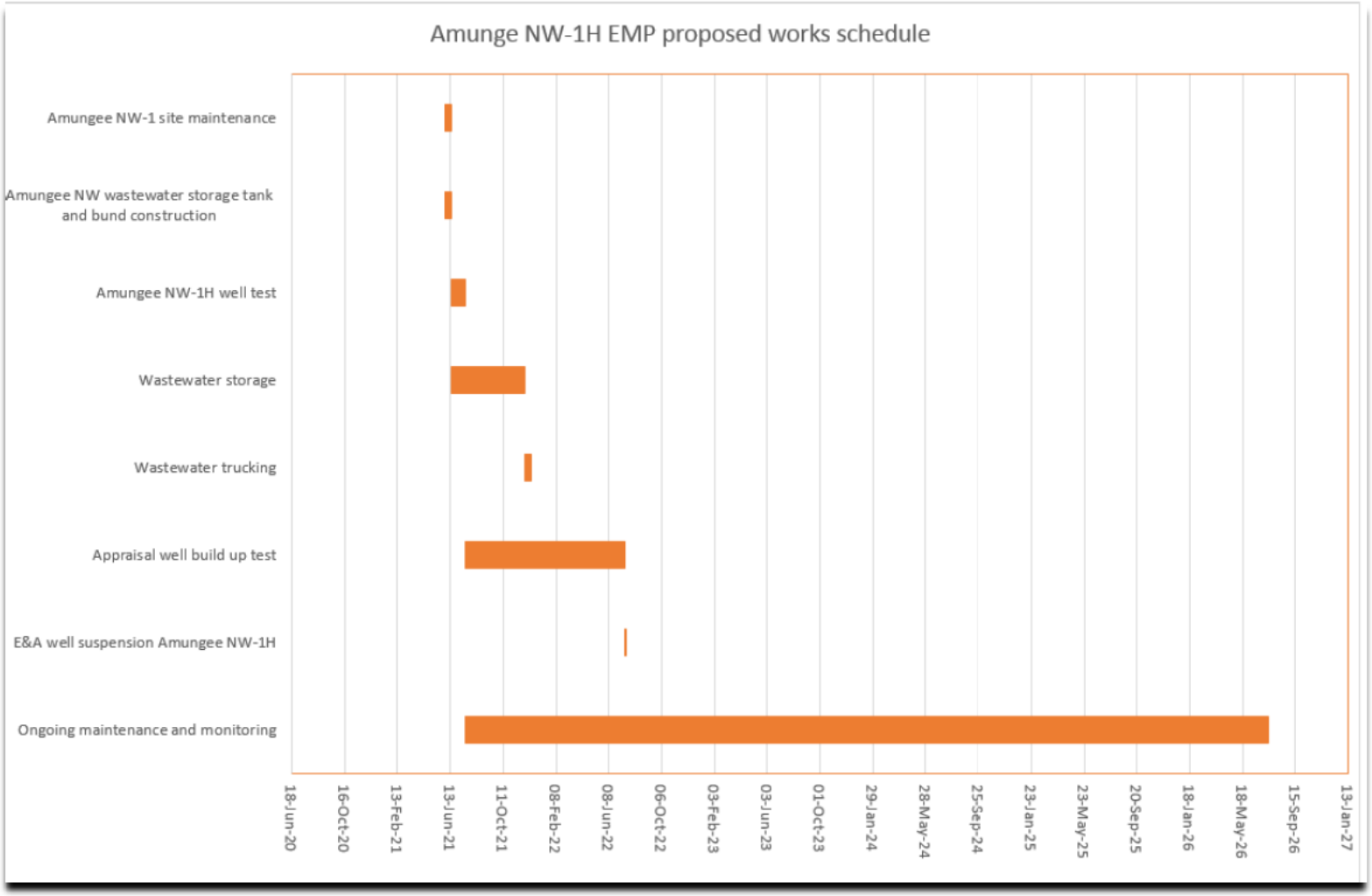

Figure 5: Timeline of Amungee NW-1H activities

3.2 Amungee NW site setting

The Amungee NW site is an existing disturbed location that consists of:

- Existing Amungee NW-1H appraisal well
- 4.1 ha lease pad
- 0.97 ha Camp pad
- 1.1 ha access track
- 3x existing groundwater extraction/monitoring bores

A drone image of the Amungee NW site during drilling in 2015 is provided in Figure 6. Drilling of Amungee NW-1H was completed in 2016 under the Beetaloo Sub-basin, EP98 and EP117 Exploration Drilling Environment Plan (EP) (NT-2050-15-MP-10), with HSF conducted in September 2016 under the Amungee NW-1 Stimulation EMP (NT-2050-15-MP-34).

Figure 6: Drone image of the Amungee NW site during the drilling of Amungee NW-1H drilled in 2015/16

The Amungee NW site was originally 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.

A description of the existing environment is provided in section 4. The site is located in open woodland with dense shrub cover dominated by *Corymbia drysdalensis* and *Corymbia. ferruginea*. This vegetation community is regionally extensive, not threatened and in good condition.

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

- 12km from the closest pastoralist bore
- ~1km from the Carpentaria Highway
- 27km from the nearest homestead
- 56km from the nearest community (Daly Waters)
- 40km from the closest conservation area (Bullwaddy Conservation reserve)
- 20km from the closest mapped watercourse (un-maned tributary of Ross Creek)
- 161km from Lake Woods.

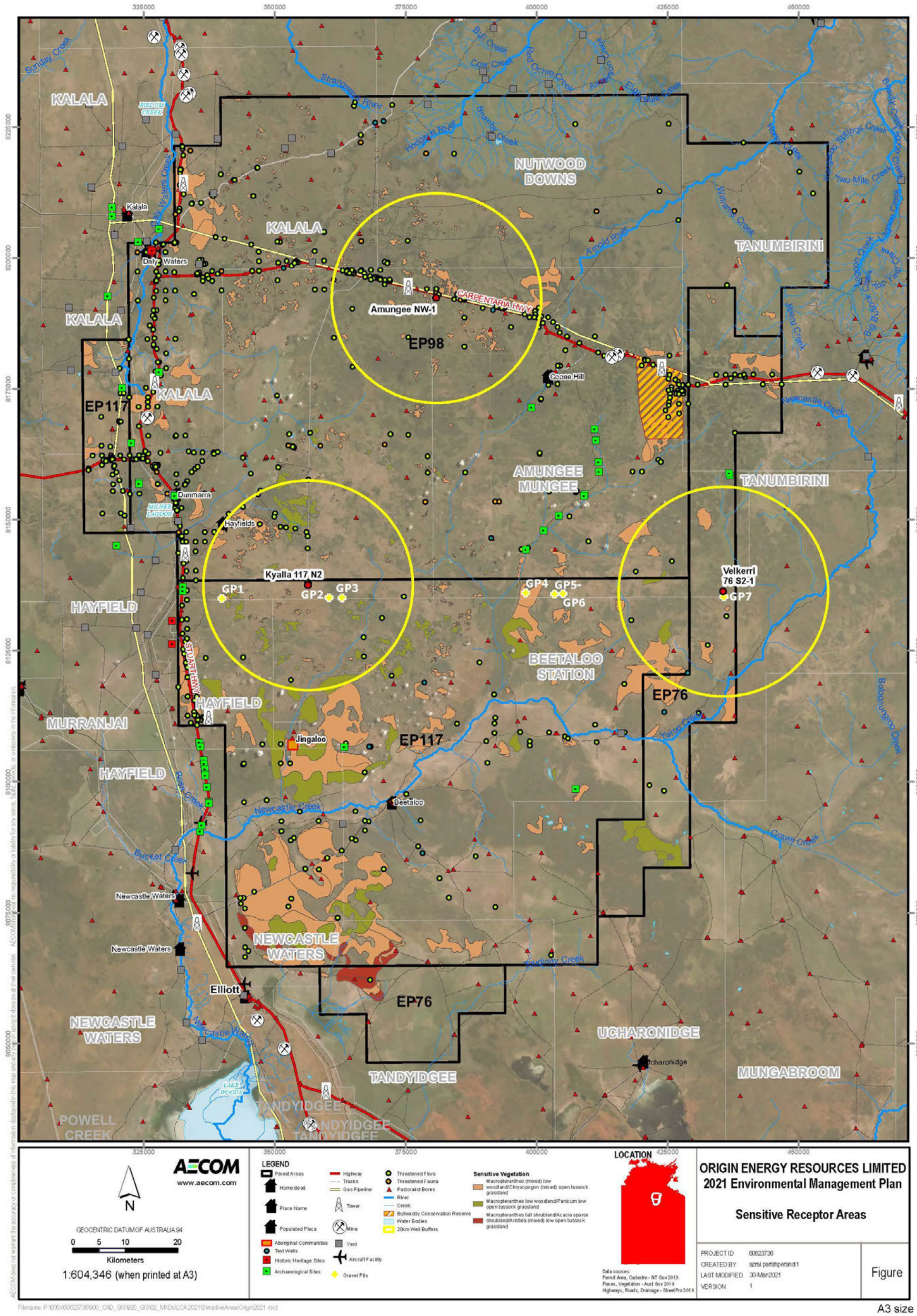

Figure 7: Origin active exploration sites (including Amungee NW-1) proximity to sensitive receptors

3.2.1 Existing Amungee NW-1H exploration well

A schematic of the existing Amungee NW-1H well is provided in Figure 8. The Amungee NW-1H well was drilled in two parts. The vertical section of the well was drilled to a total depth of 2,611 m below ground level (mbgl), with a 1,229m horizontal section completed in 24 of November 2015. The well was re-entered, cased and cemented from the 16 June 2016 to 11 July 2016 in preparation for a hydraulic fracture stimulation (HFS).

Verification of the well integrity of the Amungee NW-1H E&A well was completed via:

- a CBL completed on the surface casing section of the well confirming the isolation of the Anthony Lagoon formation (unsaturated) and Gum Ridge formation from the intermediate casing
- a CBL/VDL completed on the 4" production casing. The CBL/VDL, as illustrated in Figure 9, demonstrates that the well had in excess of 500m of good quality cement separating the Velkerri B shale from the rest of the E&A well
- a casing pressure test of the 4.5" production casing section prior to stimulation. A 10,000 psi casing pressure test, as illustrated in Figure 10, confirmed that integrity of the E&A well was sufficient to commence Hydraulic Fracture stimulations.

Following verification of well integrity, a HFS was successfully executed from 25 August 2016 to 8th of September 2016. A total of 11 HFS stages were pumped into the Amungee NW-1H lateral section, effectively placing 1,100 tonnes of proppant and 10.640 ML of fluid. Following stimulation, a 57 day well test initiated. The well produced an average of 1.1TJ/day of hydrocarbon, with a flowback recovery of 3.1ML (~18% of the stimulation volume). The well was subsequently suspended in November 2016, with the site demobilised. The Amungee NW-1H E&A well has been suspended since this time, with formation pressure build-up monitoring underway.

A well completion report was submitted to the DITT and is available at https://geoscience.nt.gov.au/gemis/ntgsjspui/handle/1/87095.

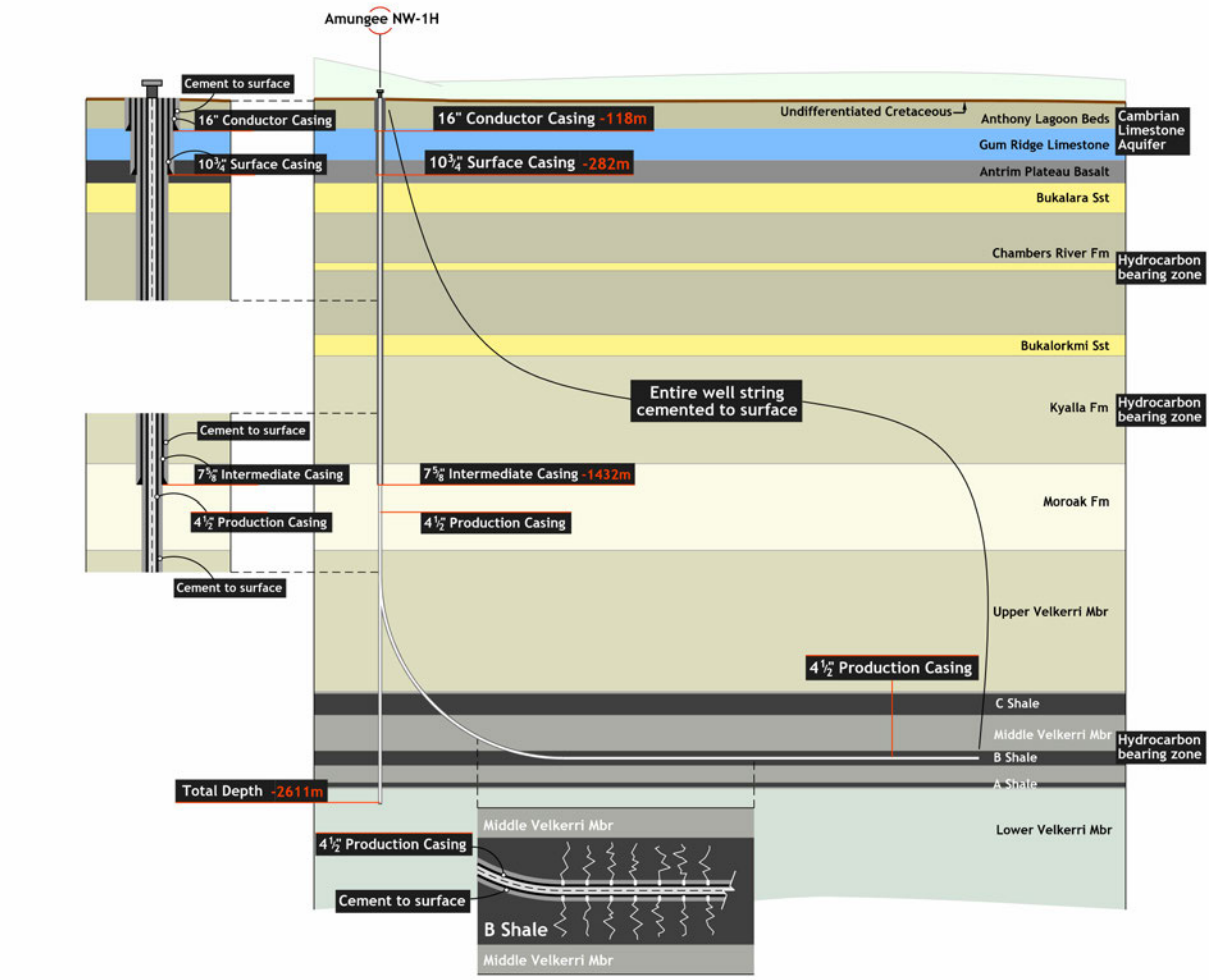

Figure 8: Schematic of the Amungee NW-1H E&A well

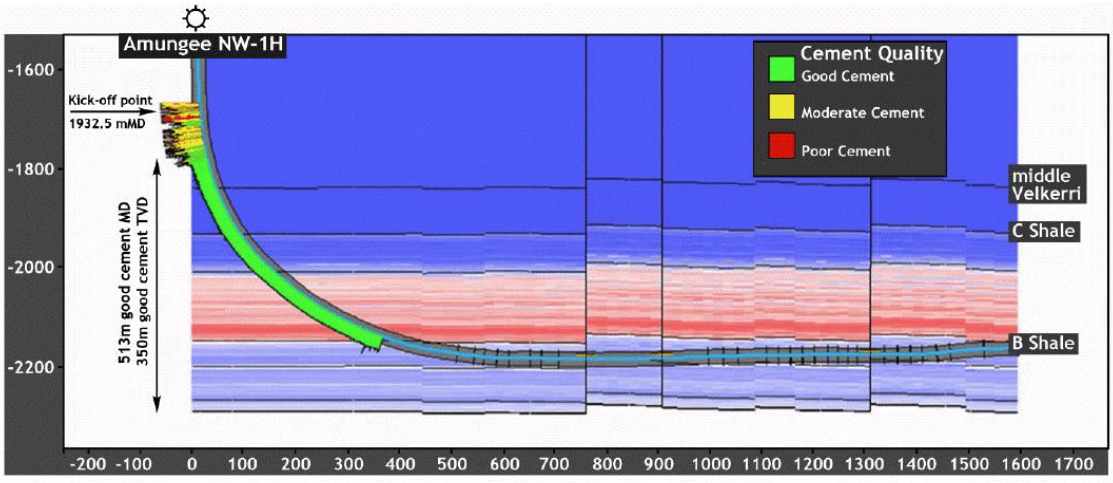

Figure 9: Illustrates the quality of cement on the Amungee NW-1H E&A well. The CBL confirmed over 500m of good quality cement segregates the production zone from the upper formations

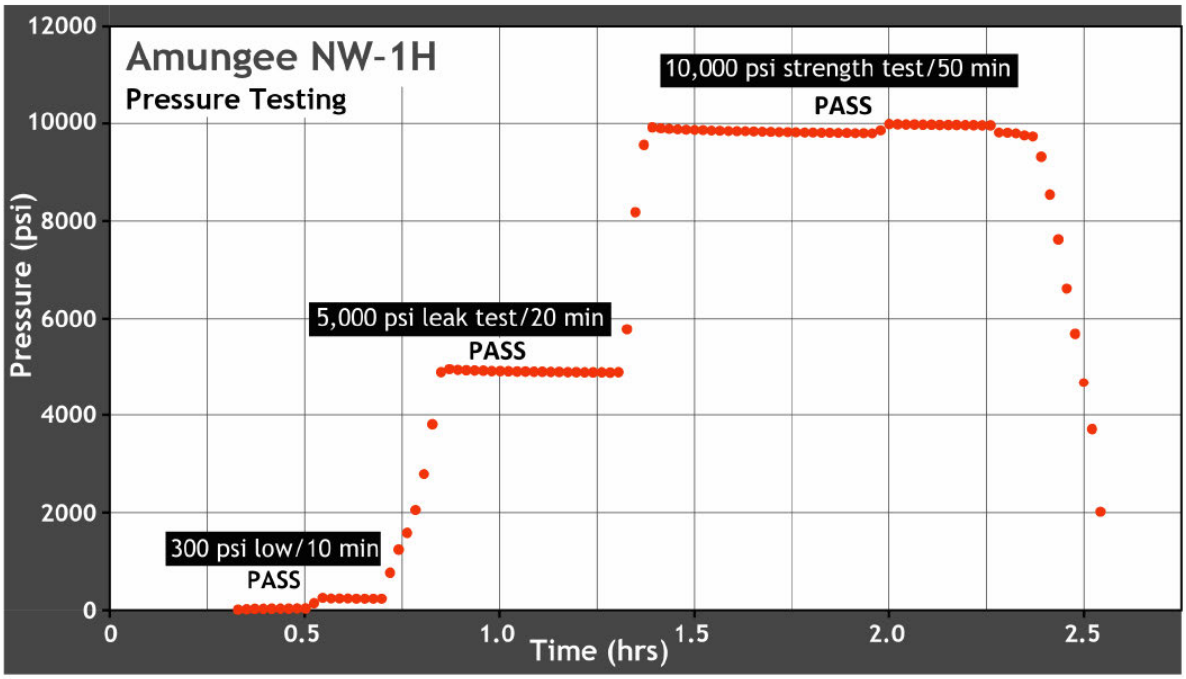

Figure 10: Illustration of the Amungee NW-1H E&A well production casing pressure test prior to stimulation

3.3 Extended production testing activities

An EPT involves the production of hydrocarbons from a well to understand the gas and water rates from a target reservoir. The EPT proposed under this revised EMP consists of:

- flowback of fluids (wastewater) and hydrocarbons
- separation of hydrocarbons from wastewater
- measurement of hydrocarbons
- storage and treatment of flowback wastewater
- ongoing quality sampling of flowback and hydrocarbons
- disposal of gaseous hydrocarbons via flare.

The Amungee NW-1H well will be brought back online and tested for approximately 30 days. Additional time may be required to account for unexpected issues or operational requirements.

When the Amungee NW-1H E&A well is brought online, the well will produce both gas (C1-C4 hydrocarbons) and flowback water. All production water 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.

Gaseous hydrocarbons will be directed to an onsite vertical flare as described in section 3.3.1. Flowback wastewater will be discharged directly to the enclosed wastewater tank as described in section 3.3.4.

During well testing, a coil tube unit will be run within the Amungee NW-1H E&A well to collect data on the water and gas flows from the various stimulated stages within the Velkerri shale formation. This data will provide an understanding of whether certain stages are producing more or less water/ gas, to enable the optimisation of future stimulations and provide more robust resource estimations.

Once sufficient data has been obtained, the Amungee NW-1H well may be shut-in to complete a pressure build-up test to further characterise the respective reservoirs for a period of 12 months, or greater where additional information is required. Build up tests are executed by having the well shut in at surface to allow pressure in the production casing build up (i.e. there is no flaring or wastewater production). Upon finalisation of the build-up test, the well will be either suspended or plugged and rehabilitated as per section 3.8.

An overview of the proposed well testing equipment layout is provided in Figure 11.

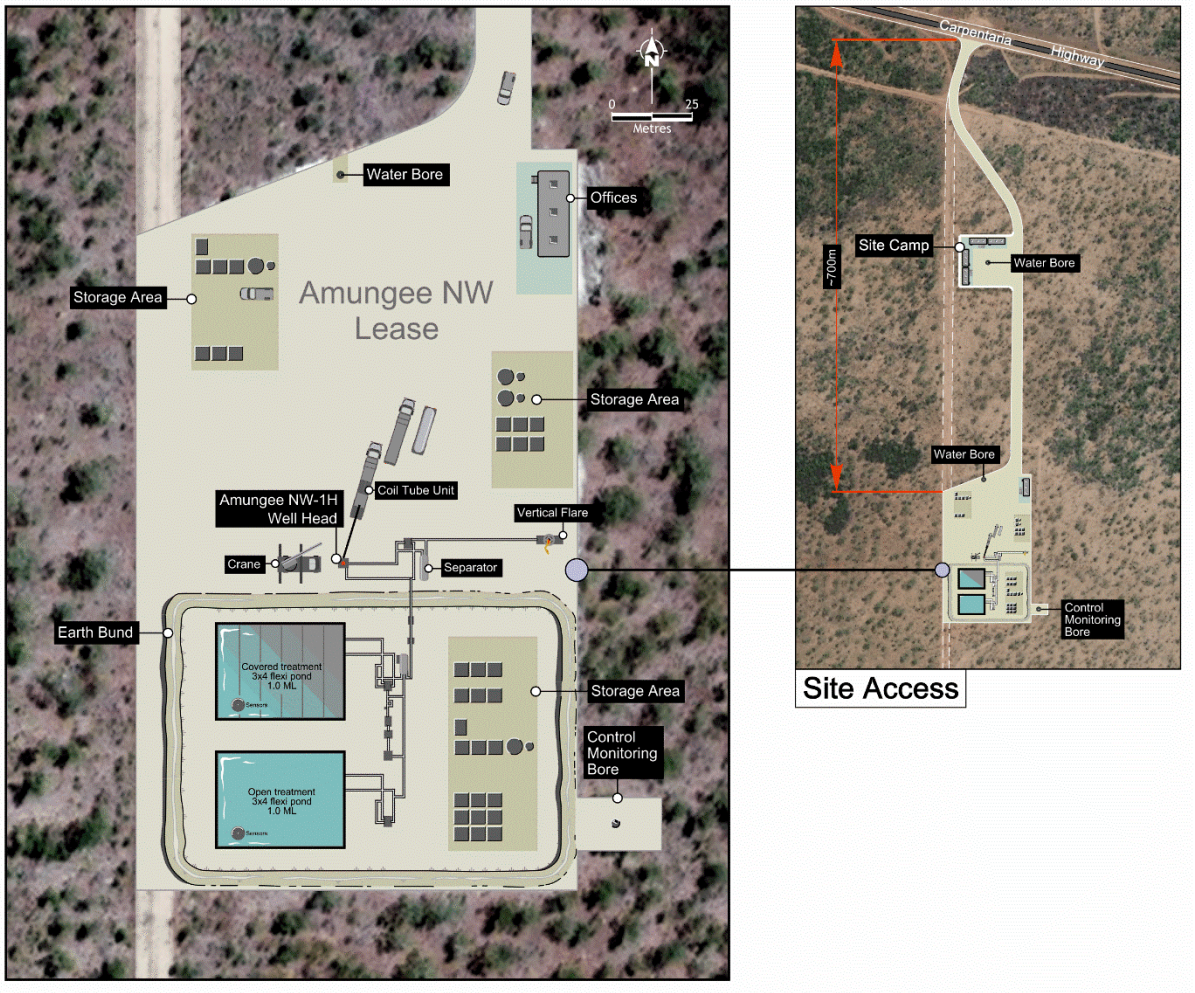

Figure 11: Amungee NW EPT site set up conceptualisation

3.3.1 Site preparation

Prior to the commencement of EPT activities, the Amungee NW access tracks, camp pad and lease pad will be prepared. Activities are expected to commence in the dry season (subject to operational requirements) and will include:

- Minor lease pad civil construction preparation works, including reinstatement of fire breaks resurfacing and maintenance of the lease and camp pads
- Construction of 1 x enclosed and 1 x open wastewater tanks
- Construction of the wastewater tank compound bund capable of managing 120% of the volume of the largest wastewater tank
- Construction of a ~10x10m stormwater retention basin within the wastewater tank compound to capture stormwater prior to testing and release.

3.3.2 Wastewater tank construction

Two (2) wastewater tanks will be constructed during site preparation works to manage flowback wastewater, one (1) enclosed and one (1) open, each with a capacity of around 1ML. The tanks 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 installed with 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 tank 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 12):

- 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 $1x10^{-7}$m/s
- Each tank panel is transported to the site in flat packs
- 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 hydrotested by filling with fresh water and allowed to site for a 24-hour period. If moisture and pressure is detected via the leak detection system, the tank is drained to the other storage tank on-site and leakage point repaired. Once both tanks are hydrotested, the water is discharged to the surrounding area as per section 3.3.2.1.

1. Panel Transportation

2. Panel assembly

3. Tank assembly

5. Geomembrane installation

9. Tank commissioning (hydrotesting)

8. Cover installation

7. secondary liner installation

6. Primary liner installation

Figure 12: Wastewater tank construction steps

3.3.2.1 Hydrotest water management

Groundwater will be utilised to perform hydrotesting on each of the wastewater tanks to confirm the integrity of the primary liner and rectify any leaks prior to storing flowback wastewater. Hydrotesting involves the filling of each tank to approximately 75% capacity for a period of 24 hours.

Once a tank has been hydrotested, the groundwater in the wastewater tank will be recycled to perform a hydrotest on the adjacent wastewater tank and will also be used for dust suppression. The majority of the water will be released through a controlled discharge to the area surrounding the lease pad.

The quality of the hydrotest water is anticipated to be similar to the groundwater, with a pH of between 6.5 to 9, and an Electrical conductivity of less than 2000 us/cm.

Releases will be undertaken in a manner that prevents erosion or the discharge of groundwater directly to surface waters (which are absent in the immediate vicinity of the Amungee NW location).

3.3.3 Flaring

During well testing, produced gas will be separated to split out gas and flowback fluids. The Amungee NW-1H E&A well is located in the dry gas window, with condensate not anticipated. Gas will be sent to a vertical flare for combustion.

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

- The flare has 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 flare has been conservatively designed to manage up to 5TJ/day of gas. This is higher than the ~1.1TJ/day gas volume encountered during the initial production test on the well
- The existing flare is designed with consideration of the gas stream composition (net heating value) and maximum tip velocity (V^{max}) to ensure the optimal flare efficiency
- The flare will be 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 C).

Refer to Figure 13 for an example of the vertical flare.

Figure 13: Vertical flare

3.3.4 Wastewater management

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

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 WWMP attached in Appendix D.

3.3.4.1 Quality

The Amungee NW-1H flowback wastewater was tested and analysed during the 2016 HFS, with comprehensive data available on the flowback chemistry. The water quality of the flowback during the ETP is anticipated to be identical, with a summary of monitoring results provided in Table 9.

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

Table 9: Flowback quality based on Amungee NW-1H HFS flowback results

Parameter	Flow back levels
BTEX compounds	BTEX levels ranged between 2 and 15 µg/L
Total nitrogen (as N)	Maximum value of 62.1mg/l observed
Salinity (TDS)	Saline with total dissolved solids level averaging 49,000mg/L
pH	Slightly acidic with a median value of 6.74
Major ions	Na and Cl dominated
Dissolved metals	All detected dissolved metal concentrations were low, with the exception of Barium and Boron which were present at a maximum level of 54.5mg/l and 80.1 mg/l respectively
Polycyclic Aromatic Hydrocarbons	All values below laboratory Limit of Detection (LOD)
Petroleum Hydrocarbons	All fractions of TPH are anticipated to be elevated
Phenolic Compounds	Trace level of phenolic compounds detected
Radionuclides	Maximum Gross Alpha Activity and Gross Beta Activity of 12.4Bq/L and 18.3Bq/L respectively. The primary component being Radium-226.

3.3.4.2 Flowback storage

An overview of the proposed tank set up is provided in Table 10. 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 is anticipated to have 2ML of available wastewater storage available to support the proposed activities. This includes approximately 1ML of enclosed tank capacity and 1ML of open treatment capacity. The available enclosed tank capacity of 1ML exceeds the total predicted flowback wastewater volume of 0.7ML.

Trucking of wastewater between Origin's exploration sites (such as Kyalla 117 N2 and Velkerri 76 S2) may also be undertaken to manage flowback volumes if required. This will provide flexibility to maximise the use of available wastewater storage capacity and minimise the construction of new tanks. This may result in wastewater to or from one of Origin's alternative approved location across the Beetaloo (such as the Kyalla 117 N2 or Velkerri 76 S2).

As an example, a picture of the enclosed tanks currently installed on the Kyalla 117 N2 site is provided Figure 14. It is anticipated that the wastewater tanks at Amungee NW will be similar.

Table 10: anticipated tank operating capacity and freeboard levels

Tank type	Wet season		Dry season	
	Maximum operating capacity	Freeboard volume	Maximum operating capacity	Freeboard volume
1x 1ML enclosed tank (3x4 panel tank)	1ML	N/A[3]	1ML	N/A[3]
1x 1ML Open tank (3x4 panel tank))	0.35ML	0.65ML	0.85ML	0.15ML

[3] Freeboard not required for enclosed tanks as these tanks have a cover installed.

Figure 14: Example of covered water storage tanks located on the Kyalla 117 N2 site that will be utilised

3.3.4.3 Wastewater operating strategy

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

- The enclosed tank is the primary storage tank, with enough covered storage on-site at all times to manage all stored wastewater
- Wastewater levels and the interstitial space between the tank liners are monitored continuously with electric probes to prevent overtopping and leaks
- Where sufficient enclosed tank capacity is unavailable, the well 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
- The open wastewater tank will be used as an evaporation tanks to treat wastewater and reduce final disposal volumes
- Mechanical enhanced evaporators will be utilised within the evaporation tanks to maximise evaporation rates
- All wastewater stored within open working evaporation tanks will be transferred to enclosed storage at least eight (8) hours before the onset of a significant rainfall event (defined as a 300m rainfall event predicted over four (4) days as per the WWMP)
- All open tanks will be 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 to and from other approved locations within the Beetaloo Sub-basin, as a method to manage wastewater volumes and new minimise tank construction.

Mechanical enhanced evaporators will be utilised in the open wastewater treatment tank to enhance natural evaporation. It is anticipated that 3 to 5 evaporator units will be deployed on each tank, with a combined water treatment rate of up to 1,000L/minute. An estimated diesel consumption of 21L/hour will be required while the units 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 approach was successfully used during the HFS operations at the site in 2016.

Where a significant rainfall event is predicted, 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 two (2) x 6-inch transfer pumps on-site capable of transferring up to 23ML/day each. The on-site pumping capacity is significantly 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 a bunded compound. The earthen bund around the wastewater tanks will be constructed with the capacity to manage approximately 1.2ML of wastewater (120% of the wastewater tank volume). Where a tank fails, water will be pumped from the bund into the second wastewater storage tank on-site. The 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.*

3.3.4.4 Wastewater monitoring

The following wastewater monitoring strategies will be implemented during extended production testing and wastewater storage:

- 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 (for open tanks) during operations
- Weekly tracking and storage forecasting will be undertaken to ensure freeboard requirements are not exceeded
- Weekly wastewater tank integrity inspections to identify any liner or tank defects
- Monitoring for of flowback quality will be undertaken in accordance with Section 3.16.

3.3.4.5 Flowback disposal

Flowback volumes will be reduced through evaporation. Once wastewater levels are evaporated down to approximately 0.2ML, all wastewater is anticipated to be trucked to either an existing approved location for further treatment (such as the Kyalla 117 N2 site) or transported offsite to an approved wastewater handling facility.

The Westrex facility as the default disposal option, with all final truck movements directed to Queensland via the Carpentaria, Stuart and Barkly highways. At the predicted 0.2ML of residual wastewater, it is estimated that approximately 5 B-quad trucks would be utilised to transport the produced volume.

It is currently anticipated that all wastewater will be trucked offsite by the 2021 wet season. However, as noted previously, Origin may utilise the Amungee NW wastewater storage to assist in managing regional wastewater volumes for operational purposes. This allows Origin flexibility in managing it's wastewater volumes regionally and reduces the need to construct new wastewater storages. In such a case, the storage of wastewater beyond the 2021 wet season may be undertaken.

It should be noted that the above timelines and operational strategy are indicative and is subject to operational change.

3.3.4.6 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 utilises average monthly rainfall and evaporation rates for the region to calculate the rainfall inputs and evaporation outputs from open tanks.

The water balance includes the make-up water and wastewater generated during the extended production well testing, as well as from hydrostatic test and camp activities. The water balance does not include the transfer of wastewater to and from other sites. Where such an activity is proposed, the wastewater balance will be updated.

An overview of on-site water management is provided in Table 11.

Table 11: Site water balance

Summary			2021				
Activity	Month	Total	Aug	Sep	Oct	Nov	Dec
Groundwater water used per month							
Camp	ML	1.20	0.30	0.60	0.30	0.00	0.00
Hydrotesting	ML	2	2	0.00	0.00	0.00	0.00
Total	ML	3.20	2.30	0.60	0.30	0.00	0.00
Wastewater generated per month							
Well testing	ML	0.72	0.00	0.72	0.00	0.00	0.00
Nett evaporation (rainfall – evaporation)							
Evaporation	ML	0.5	0.00	0.4	0.1	0.00	0.00
Wastewater stored on-site per month							
Total flowback Wastewater onsite	ML	0.22	0.00	0.32	0.20	0.00	0.00
Offsite trucking to Kyalla 117 N2 (or other approved Origin site)							
Volume of flowback transport offsite	0	0.2	0	0	0.20	0	0

3.3.4.7 Fauna and bird access

The use of open top working evaporation tanks could, if consumed, represent a risk to fauna due to the salinity and chemistry of the flowback. Previous operations at the Amungee NW and Kyalla 117 N2 site have not identified any significant interaction of fauna with open wastewater storages. This is supported by various pieces of literature which highlight the role of the salinity in deterring birds and fauna from consuming/interacting with wastewater (Bartholomew and Cade 1963; Ohmart and Smith, 1970; ANZECC, 1992; Griffiths et al, 2009).

The Amungee NW-1H flowback wastewater is hypersaline, with total dissolved solids (TDS) > 50,000mg/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).

Monitoring of flowback storages and surrounding areas will be implemented as per section 3.16.

3.3.5 Stormwater

The Amungee NW site will be operated in a manner that minimises the contamination of stormwater and overland flow. 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 wastewater storage areas will be bunded from the rest of the well site and designed to divert stormwater to prevent contamination
- A stormwater retention basin within the wastewater storage areas will allow collected stormwater to be tested prior to release/re-use/ disposal in accordance with Section 3.16
- Clean stormwater that meets the quality outlined in Table 12 will be discharged off-site in controlled manner 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 treated as wastewater and managed accordance with Section 3.3.4.5
- Once all work on the site has ceased and all contaminant sources have been removed from the lease pad, the site will be left in a stable, non-polluting state with appropriate erosion and sediment controls in place
- Erosion and sediment control plan (Appendix H) implemented.

Table 12: 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

Monitoring parameter	Release limit	Limit basis
		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[4] and Table 8.2.8 of the ANZECC Guidelines 2000 volume 2 Aquatic ecosystems-rationale and background information.

3.4 Routine site maintenance

Civil maintenance will be performed periodically to ensure the site remains functional, safe and non-polluting. Activities to be completed periodically include:

- Vegetation management on the lease pad, camp pad and access tracks
- Firebreak maintenance
- Access track resurfacing and maintenance
- Lease and camp pad resurfacing
- Water extraction bore maintenance
- Erosion and sediment control maintenance and repair
- Weed management

3.5 Ongoing Amungee NW-1H monitoring and integrity management

The ongoing monitoring and well integrity management of the Amungee NW-1H appraisal well is illustrated in Figure 15. Origin's Operations team manage the ongoing integrity of the well through 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.

[4] HLA 2005 report summarising the Beetaloo Basin Surface water quality monitoring completed for Sweetpea Petroleum

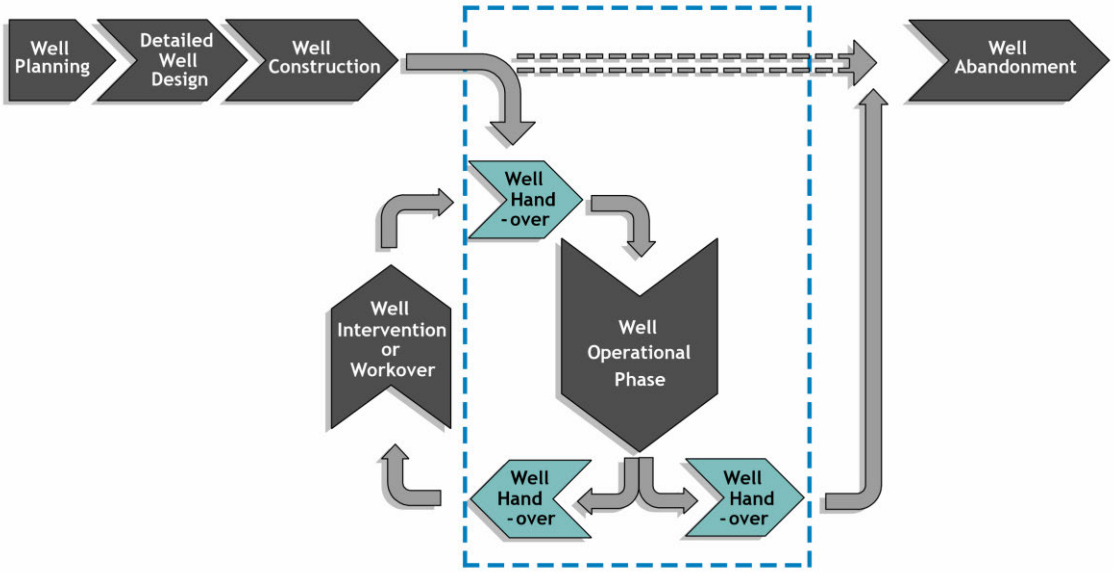

Figure 15: Well lifecycle with operational phase highlighted where well integrity monitoring is a key activity

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.

Additional routine maintenance and diagnostic testing under this EMP includes:

a. Wellhead maintenance—a truck and a 4WD with approximately three (3) people to do 1-2 days of work on pressure testing, and maintaining the wellhead
b. Completion rig—a small rig with 6-7 trucks to pull tubing and potential recompleted the well if required
c. Wireline/Slickline—one (1) truck to either set a plug downhole or run additional logs.

3.6 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 December 31, 2021. The WEL will be renewed periodically (i.e. beyond the 2021 licence period), to ensure sufficient water is available to support operations.

It is estimated that a maximum of 3.2ML of water will be extracted from the Gum Ridge Formation to support the EPT and general maintenance program. A water balance for the activity is provided in Table 11. The breakdown per activity is as follows:

- 2ML for the EPT—primarily consisting of tank commissioning
- 1.2ML camp activities dust suppression and general activities

Water sourced for the EPT activities will be extracted from the Gum Ridge extraction bores RN040894, RN38493 and RN39896. 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. 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 Origin's Beetaloo exploration activities. A copy of the WEL statement of reason is available from DEPWS Water Resources at http://www.ntlis.nt.gov.au/walaps-portal/report/current/gwel.

3.7 Chemical and fuel management

The chemicals and fuels that will be utilised/generated during EPT activities are summarised in Table 13. No drilling or stimulation chemicals will be utilised during the EPT. A summary of the main chemical types to be utilised during the program include:

- Bulk diesel (to fuel equipment and generate power)
- Camp cooking wastes (cooking oil etc.) and wastewater (sewage) (discussed in section 3.13)
- Degreasers and domestic cleaning chemicals
- Typical workshop and maintenance chemicals including hydraulic oil, coolant, greases, paints, solvents and engine oils
- Incidental well maintenance chemicals and fluids, such as lubricants, biocides, anti-scale chemicals and well suspension fluids
- Wastewater (discussed in section 3.3.4).

Only the volumes required (plus contingency, depending on storage container size) for the EMP activities will be stored on site (i.e. no excessive storage volumes).

Table 13: Anticipated chemical volume and storage used in the EPT and maintenance process

Material name	Anticipated volume	Maximum volume	Unit	Storage area
Completion fluid (salt or polymer) weighted fluid	200	500	KL	Chemical storage area
Degreasers	100	300	L	Workshop
Diesel	50	100	KL	Diesel storage tanks

Material name	Anticipated volume	Maximum volume	Unit	Storage area
Completion fluid (salt or polymer) weighted fluid	200	500	KL	Chemical storage area
Engine oil	1,000	3,000	L	Workshop
Flowback	1	<3	ML	Flowback tanks
Hydraulic oil	1,000	3,000	L	Workshop
Incidental chemicals (biocides, anti-scale, pH controls etc)	<100	500	Kg	Chemical storage area

3.8 Well suspension and decommissioning

The Amungee NW-1H well will be suspended upon completion of the well testing activities. 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 WIMS to confirm well integrity is intact.

Where there is no further requirement to keep the Amungee NW-1H well to support future E&A activities, the well will be decommissioned. To decommission the well, cement plugs will be installed as permanent barriers to flow prior to cutting off the wellhead. The cement plugs will be set and tested prior to decommissioning, as per Origin Standards and Section B.4.15.2 of the Code of Practice.

3.9 Greenhouse gas emissions

Total greenhouse gas (GHG) emissions generated during exploration activities are summarised in Table 14.

Emissions from the activities covered under this EMP are estimated to be 2,405tCO_2^e (30-day EPT) This estimate is based upon the previous production rate of 1.1TJ/day encountered during the original Amungee NW-1H EPT completed in 2016. The total greenhouse gas emissions are small when compared to the total 2018 greenhouse gas emissions for the NT (16,000,000 t$CO_2^{e)}$ and for Australia (536,500,000 tonnes) (Department of Industry, Science, Energy and Resources, 2020). Emission proposed under this EMP represent 0.015 % of NT 2018 GHG emissions and 0.00046% 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 emission generation will be mitigated through adoption of the Code of Practice and implementation of a Methane Emission Management Plan (MEMP Appendix E). Mandatory requirements include:

- Restrictions on venting (D.5.9)
- Use of a Reduced Emissions Completion (REC) (D.5.9)
- 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 14: Greenhouse gas (GHG) summary for the proposed activities

Activity	Anticipated volume	Total—30 day well test tCO_2e^	Estimate methodology and assumptions
Diesel combustion-camps	500L per day	61	Diesel estimate using forecasted camp usage at 500L/day assuming 45-days of camp use. Diesel usage multiplied by Table 3: Fuel combustion emission factors—liquid fuels and certain petroleum-based products for stationary energy purposes, Part 3 of Schedule 1 of the NGER Determination (July 2020): 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_2O Factor 0.2 $kgCO_2$-e/
Fugitive emission-wastewater storage	0.7 ML of flowback per well	7.64	Assumed flowback recovery of 25,000L/day based upon previous Amungee NW-1H well test results. Emissions multiplied by Table 5-10: Produced saltwater tank methane flashing emission factors—Compendium 50kl of Greenhouse Gas Emissions Methodologies for the Oil and Gas Industry; American Petroleum Institute (API), 2009 emission factor of 0.39tCH4/ML multiplied by NGERS Global Warming Potential (GWP) of $28tCO_2e/tCH_4$.

Activity	Anticipated volume	Total—30 day well test tCO_2e^	Estimate methodology and assumptions
Well testing-flared natural gas emissions	1.1Tj per day of natural gas per E&A well (19.3 tonnes per day)	2,145	Flared estimate using forecasted success case production rates multiplied by Table 9: Oil or gas exploration emission factors, Section 3.44 of the NGER Determination (July 2020): CO_2 Factor 2.8 tCO_2-e/ t unprocessed gas CH_4 Factor 0.933 tCO_2-e/ t unprocessed gas N_2O Factor 0.026 tCO_2-e/ t unprocessed gas
Well testing-stationary sources (diesel combustion)	500Lper day	49	Diesel estimate using historic well testing data of 500L/day for 45-days (30-days well test, and decommissioning allowance) multiplied by Table 3: Fuel combustion emission factors—liquid fuels and certain petroleum-based products for stationary energy purposes, Part 3 of Schedule 1 of the NGER Determination (July 2020): 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_2O Factor 0.2 $kgCO_2$-e/ GJ of diesel
Transportation emissions (diesel combustion)	50kl	143	Diesel usage multiplied by NGERS emission factor from Table 4: Fuel combustion emission factors—fuels used for transport energy purpose, Division 4.2, Part 4 of Schedule 1 of the NGER Determination (July 2020): Energy Content Factor (GJ/kL) 38.6 CO_2 Factor 69.9 $kgCO_2$-e/ GJ of diesel CH_4 Factor 0.01 kgO_2-e/ GJ of diesel N_2O Factor 0.5 $kgCO_2$-e/ GJ of diesel
Total		**2,405**	

^ Based on Global Warming Potential (GWP) of 28tCO_2^e/tCH_4 (Clean Energy Regulator 2020)

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

3.9.1 GHG cumulative emissions

The total emissions for Origin's current approved, remaining and proposed activities are anticipated to be between 8,087 tCO_2^e to 57,622tCO_2^e spread over the 2021-2023 period (Table 15). The potential emissions of Origin's activities represent between 0.05% and 0.36% of the total NT GHG emissions for 2020 or 0.0015% to 0.01% of Australia's total emission.

Table 15: Greenhouse gas emission estimates from the Beetaloo Sub-Basin—all Origin approved activities 2021–2023

Activity	2021	2022	2023
Amungee NW-1H EMP	2,405	0	0
Kyalla 117 N2-1 drilling, stimulation and well testing[5]	4,865[6]	0	0
Velkerri 76 S2-1 drilling, stimulation and well testing	817	17,998	0
Kyalla 117 N2-2&3 drilling, stimulation and well testing[7]	0	30,398	30,397
Future (potential, not approved) 2 additional E&A wells and associated water bores, civil construction and drilling, stimulation and 3-months well testing (this assumes ongoing E&A success).	0	0	27,225
Forecasted annual emissions	**8,087**	**48,396**	**57,622**

When considering the broader emissions from the Beetaloo Sub-basin oil and gas explorers, 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 16), the foreseeable emissions from the onshore oil and gas industry in the Beetaloo sub-basin is substantially lower than that of Stationary Energy (7,015,000tCO_2^e), land use, land use change and forestry (5,507,000 tCO_2^e) and agriculture (3,192,000 tCO_2^e) (Department of Industry, Science, Energy and Resources, 2018).

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

[5] Assumes a total of 9 months of well test

[6] This is based upon the estimated remaining 2021 Kyalla 117 N2-1H scope.

[7] Assumes a 6 month well test of all 3 E&A wells on the Kyalla 117 N2 site with activities split across the 2021/22 calendar year

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

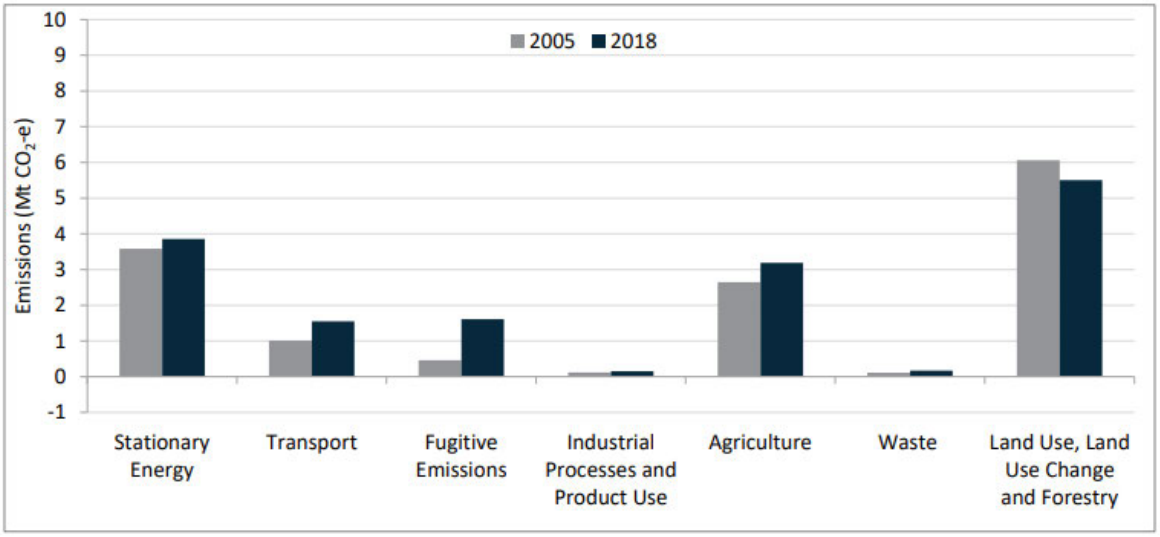

Figure 16: Exert from State and Territory Greenhouse Gas Inventory 2020 showing Northern Territory tonnes of CO2 equivalent by sector

3.10 Wet season operations

Although currently not anticipated, extended production testing and wastewater storage operations may occur over the wet season to accommodate operational requirements. Where wet season operations are undertaken the following risk controls will be implemented:

- Chemicals, fuels, equipment, tanks and materials required for ongoing operations will be preferentially stored on-site prior to the onset of the wet season to minimise transportation risks
- All equipment required to respond to emergency situations will be on-site; this includes earth moving equipment, pumps, well control equipment etc., and equipment and materials 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 will have enough freeboard to manage an entire 1:1000 ARI wet season event (not just one (1) rainfall event but an entire season's rainfall total)
- Wastewater levels and the interstitial space between the tank liners are monitored continuously with electric probes to prevent overtopping and leaks
- Personnel will be located on-site during the extended production test and regionally (at Daly Waters or an operating site within the Basin such as Kyalla 117 N2 or Velkerri 76 S2) at other times

- During wastewater storage, inspections of the site will be performed weekly, using continuous monitoring of level, interstitial space and/or cameras to satisfy Code of Practice daily wet season inspection requirements
- High/low wastewater and leak alarms to trigger prompt site inspections (with target site visit within 6 hours, but no later than 24 hours[8])
- 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 task specific risk assessment is completed prior to the transport (to ensure site conditions are constantly updated) that demonstrates the risk is ALARP and acceptable (as per the Code of Practice)
- Wastewater tank storage area is bunded, which will prevent all off-site release of wastewater
- All stormwater collected in the wastewater tank storage area will be retained on-site via a small sediment retention pond and tested prior to release.

3.11 Helicopter operations

If access to the site is prevented during operations, helicopters will be utilised to move people and supplies in and out of the site. Helicopter activities ensures the site can be accessed 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.

3.12 Waste management

Waste management methods for the proposed exploration program are summarised in Table 16. 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 for all listed waste will be retained and provided to DEPWS upon completion of the project. Historically, this has largely been restricted to waste oil and contaminated soils as most other regulated waste is either recycled or due to its insignificant volumes, backloaded

[8] Unless unsafe to access the site due to weather. In such an event, Origin will notify the DEPWS

with contractors who collectively dispose of this at their own facilities (i.e. a contractor will wait for multiple batteries to be ready for disposal rather than sending a waste collector out to recycle a single battery).

Flowback produced during the extended production test will be managed in accordance with Section 3.3.4.

Table 16: Waste and disposal methods

Activity	Disposal method
Chemical container and cardboard packaging materials	**Recycled:** Compacted and collected at the site for transport to a licenced recycling centre
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
Wastewater tank liners	**Disposal:** Used liners will be disposed of off-site at a licenced facility
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.
Scrap metals	**Recycled:** Collected in designated skip for recycling at an approved location
Sewage and grey water	**Treatment:** Grey water and sewage treated and disposed of on-site in an approved, portable treatment system accordance with 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.
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 3.3.4.7. Stormwater will be tested and either released off-site or recovered and either

Activity	Disposal method
	recycled within the drilling process or disposed of at a licenced wastewater treatment facility in accordance with the *NT Waste Management and Pollution Control Act 1998*.
Timber pallets (skids)	**Recycled:** Recycled at an approved facility
Vehicle tyres	**Disposal:** Disposed of at an approved landfill

3.13 Camps

A 20-person camp located on the existing Amungee NW site will be utilised for EPT activities, with accommodation in Daly Waters used for all other activities. 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 camp has its own sewage treatment plant and wastewater treatment plant. A wastewater works design approval will be sought by the NT Department of Health prior to the operation of a camp where the throughput exceeds 2,000L per day (currently the default option).

Treated water will be dispersed via drainage away from the camp to the designated irrigation area. The designated irrigation areas are located adjacent to the camp pad. These areas will be approximately 50x50m and will have a fence to exclude livestock access.

The camp will be supplied with potable water sourced from the existing groundwater bores onsite. A temporary reverse osmosis water treatment plant is utilised, which produces approximately 5KL of potable water per day. Water will be treated to comply with the Australian Drinking Water Guidelines (2011 NHMRC Australian Drinking Water Guidelines). Approximately 1,000L of RO reject is likely to be produced per day, which will have an Electrical Conductivity of approximately 1,500–2,000 µs/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.

3.14 Traffic

The access to Amungee NW site is via the Carpentaria Highway, approximately 55km east of the town of Daly Waters as illustrated in **Figure 2**The Highway has a 110km/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 Highway has a section of single lane two-way road, which is likely to be the main factor constraining the capacity of the road. A conservative 700 vehicle/hr/figure was used to determine the vehicle movement capacity of the Carpentaria Highway.

The periods of highest traffic generated from the Amungee NW activities will generally occur over a short duration and are associated with the mobilisation and demobilisation of the extended production testing equipment. Equipment is likely to be largely mobilised from within the Beetaloo sub-basin, meaning the majority of traffic will be sourced regionally. The peak maximum anticipated traffic flow increase associated with the activity is conservatively estimated at approximately 16 vehicles per day during the mobilisation demobilisation of equipment from site. This volume is insignificant when compared to the estimated LOS. Due to the limited increase in traffic volumes proposed by this activity, the risks associated with traffic is considered low.

3.15 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 17.

Table 17: 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 3.3.4
Flora and fauna	No additional clearing is proposed under this EMP. All other petroleum operators and pastoralists required to have a weed management plan.	Section 4.2
Greenhouse gases	Cumulative emissions from all of Origin's 2021-2023 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 3.9

Aspect	Summary	EMP section
Traffic	Impacts of traffic are anticipated to be minor, with no reduction in level of service of the Carpentaria Highway. Maximum peak traffic level assessment considers cumulative user traffic load, with project movements anticipated to be 16 movements per day during demobilisation.	Section 3.14
Social	Risk associated with increased competition for labour from exploration activities, including 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.	Appendix I and Section 4.6

3.16 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 18.

Table 18: 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 **Analytical suite:** Appendix J	**Field Chemistry:** Weekly **Analytical Suite:** Monthly [9]	N/A	Code of Practice C.5.4
Groundwater quality		RN39896 RN38493 RN40894	Level	6 monthly	+/-1m water level change observed at the impact monitoring bore	Code of Practice
			temperature, electrical conductivity, pH.		EC >200us/cm change pH >1 unit change	
			Appendix J		BTEX and Dissolved Methane—outside of	

[9] Noting flowback characterisation was completed in 2016 during the initial 57 day well test

Monitoring program	Purpose	Monitoring points	Parameters	Frequency	Investigation thresholds	Reference document
					baseline interquartile range	
	Pastoralist bore monitoring	Pastoralist bores within 10km of an exploration well	Level	Annual—post well test	1m sustained water level decline against baseline	N/A bore has been baselined as a part of Origin's regional program
Groundwater take	Groundwater volume	Each groundwater extraction bore	Kilolitres	Continuous flow meter	Total extraction <10ML	*NT Water Act*
Stormwater	Manage stormwater collected during activities	Sediment retention 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
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 infrastructure and erosion and 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)

Monitoring program	Purpose	Monitoring points	Parameters	Frequency	Investigation thresholds	Reference document
Fauna-	Collect data on fauna interactions with wastewater	Wastewater tank and sump inspections	Inspection records	Weekly 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 2. An increase in existing weed density and spatial extent	Origin's Weed Management Plan NT-2050-15-MP-0016.
Methane emission	To identify and remediate gas leaks	Each exploration well	Methane (PPM)	6 monthly	>500PPM	Methane Emissions Management

Monitoring program	Purpose	Monitoring points	Parameters	Frequency	Investigation thresholds	Reference document
monitoring program						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 3.17

3.16.1 Water sampling methodology

Water samples will be collected in accordance with Table 19. 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 19: Monitoring program methodologies

Program	Sampling methodology
Flowback monitoring	• *Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000* (ANZECC Guidelines) 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*
Groundwater monitoring	• AS/NZ5667.11: 1998. *Water Quality Sampling Part 11: Guidance on Sampling of Groundwaters* • 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* • Origin Groundwater purging and sampling procedure CDN/ID8212543 • Geoscience Australia 2009: Groundwater Sampling and Analysis

3.16.2 Investigation and response framework

Where an exceedance of a monitoring program investigation trigger is observed from one of the monitoring programs outlined in Table 18, an investigation and response will be implemented as summarised in Figure 17.

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 8.7.

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.

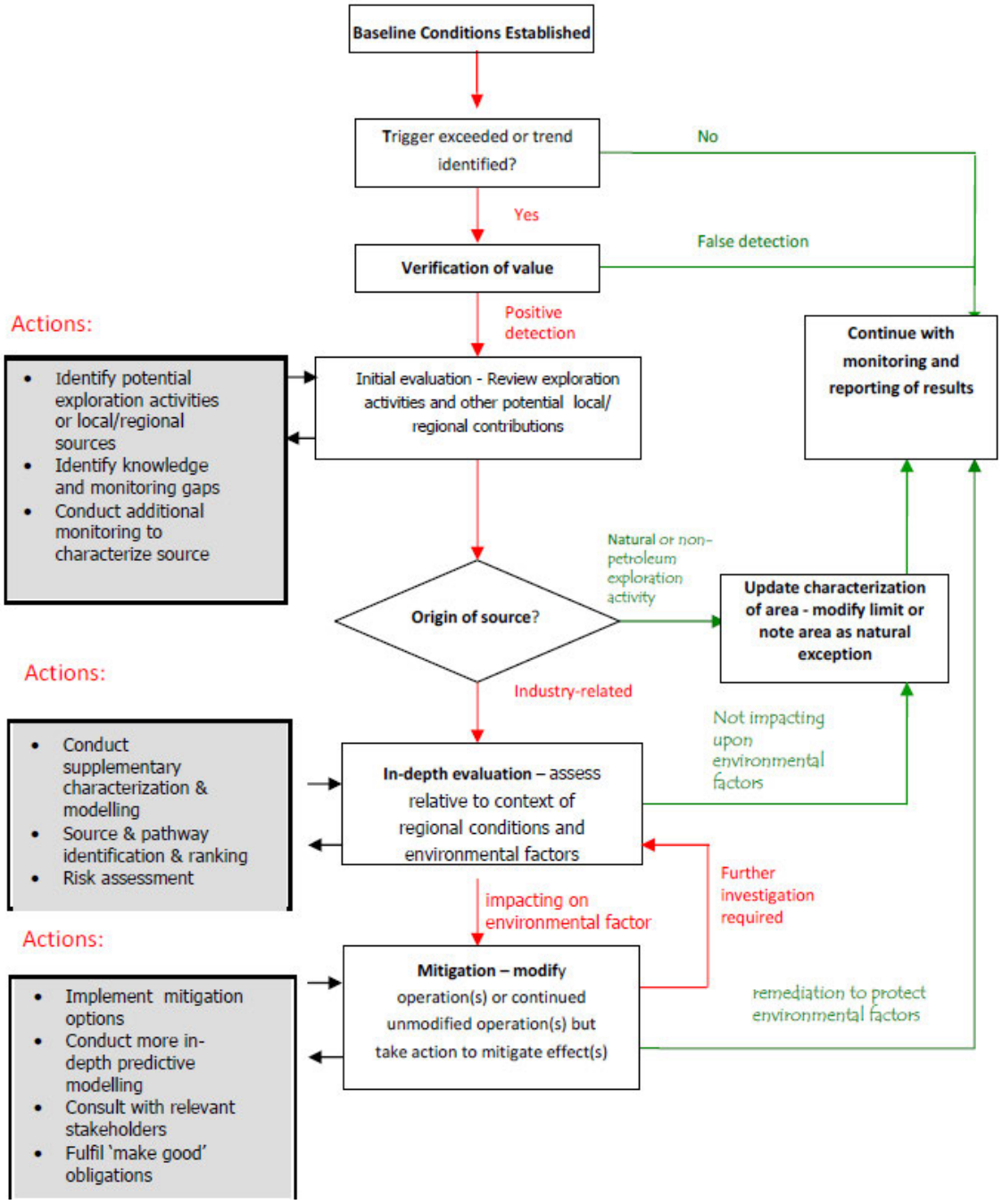

Figure 17: Investigation and response process

3.17 Rehabilitation

The Amungee NW lease forms part of Origin's ongoing exploration program, with ongoing activities beyond the scope of this EMP likely in the future. Once a determination has been made to decommission this site, the Amungee NW-1H E&A well will be plugged and decommissioned, with the site rehabilitated in accordance with the Rehabilitation Management Plan (Section 7.5) and the Code of Practice.

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 summer between October and March, and a dry winter season between May and August. September and April are transitional months with occasional rainfall.

Rainfall in the north of the Beetaloo exploration 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.

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 18) and 3-month dry season (Figure 19). 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.

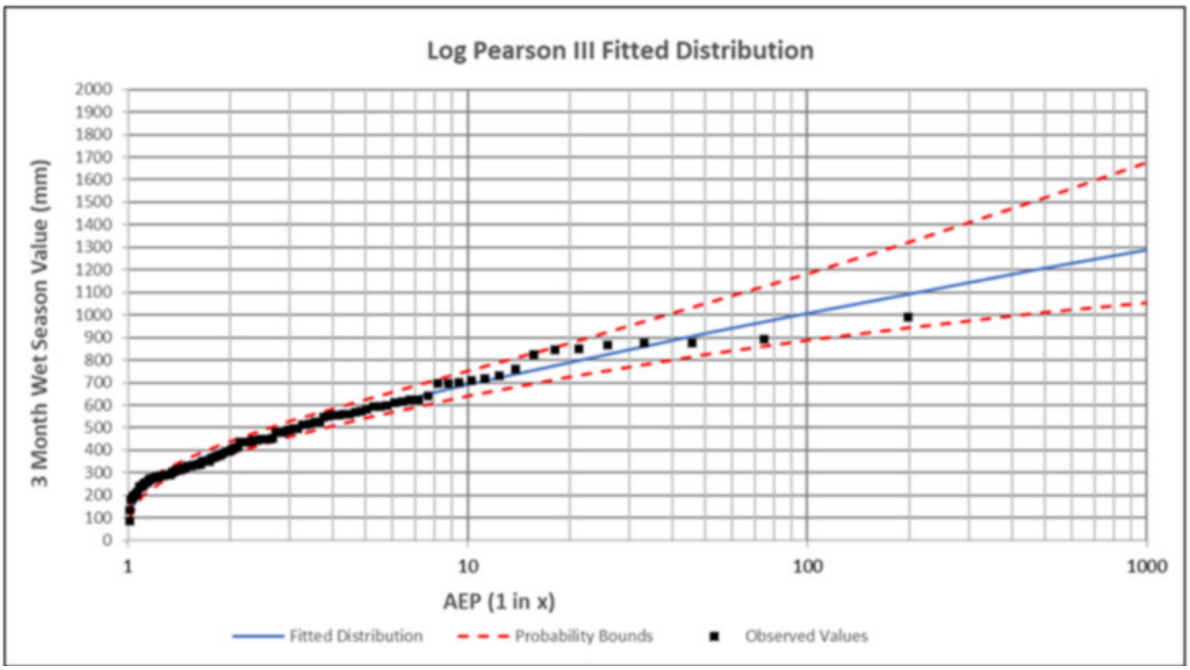

Figure 18: Log Pearson determination of 1:1000 wet season ARI

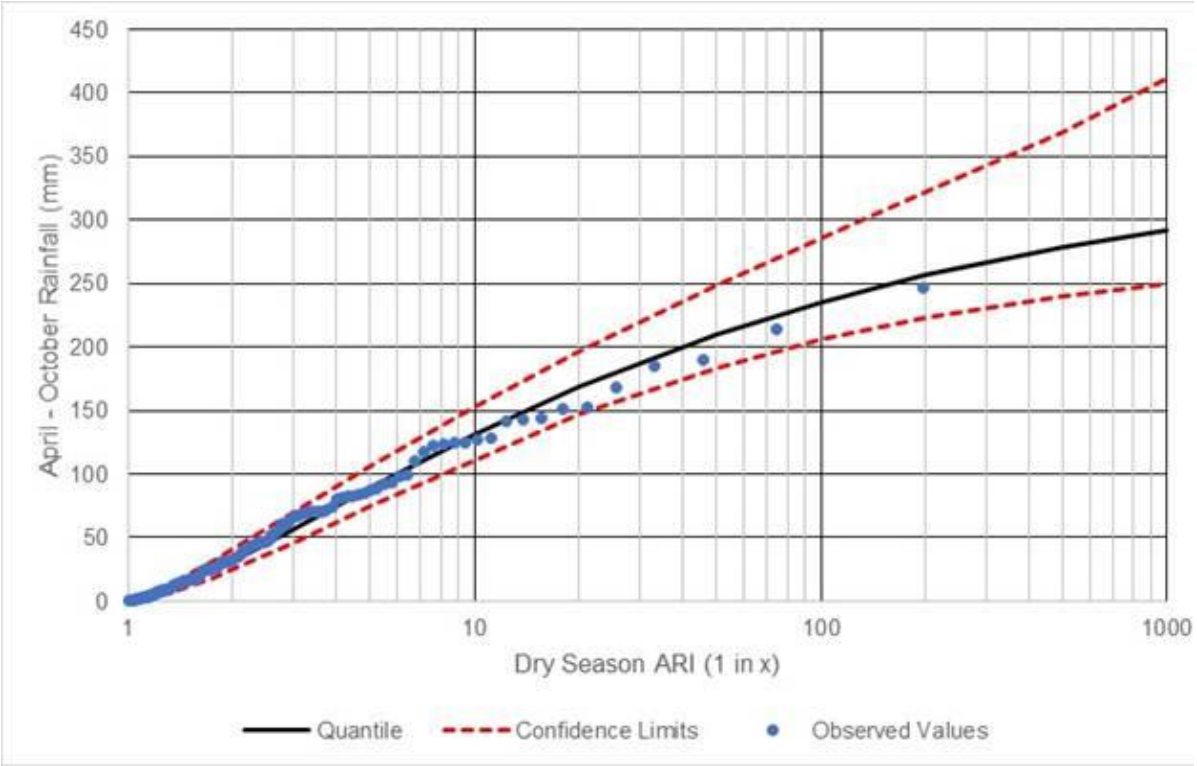

Figure 19: Log Pearson determination of 1:1000 dry season ARI

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 21). 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 CLA comprises Anthony Lagoon Formation (upper CLA) and Gum Ridge Formation (lower CLA). 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 Amungee NW-1H appraisal well is completed in the Velkerri formation. Organic richness within the Velkerri formation is generally confined to three main shale intervals, the A, B and C shale. The Amungee NW-1H appraisal well has been completed in the-the Velkerri B shale. The Velkerri Formation Amungee Member is overlain with thick series of low permeability units (mudstone, siltstones, tight sandstone and Volcanic units) which include the Velkerri Formation Wyworrie Member Kyalla Formation, Hayfield formation and Antrim plateau Volcanics. These formations provide an effective geological barrier, with the Gum Ridge formation separated from the target formation by 2,353m.

4.1.3 Soils

The Stuart Plateau bioregion covers an area of 103,857 km^2 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, 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

Table 20 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 with no additional clearing proposed. All civil construction activities will be conducted on the existing disturbed lease pad and are planned for the wet season. The overall risk of erosion is considered very low.

Table 20: 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 Hydrology

The existing Amungee NW lease site falls 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 85km to the south of the lease pad and ultimately flows into Lake Woods, which is located approximately 161km to the south west. 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 and is listed on the NT Government Sites of Conservation Significance and on the Directory of Important Wetlands in Australia (HLA, 2006b).

There are no major creeks in proximity of Amungee NW site that are likely to be directly impacted by the activities, with the nearest streams (Stream Order 1 and 2) are located ~25km from the site.

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). However, the Amungee NW lease is likely to remain dry as it is higher than surrounding areas at 263 mAHD.

4.1.5 Hydrogeology

Within the Beetaloo exploration area, 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 21 summarises the encountered stratigraphy confirmed during the Amungee NW-1H 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 documented 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 Amungee NW site, the Anthony Lagoon Formation is interpreted as being eroded by the Base Cretaceous unconformity. At Amungee NW the Gum Ridge Formation is a water bearing aquifer unit with a standing water depth of approximately 106 metres. The limestone in the CLA is commonly fractured and cavernous; regionally bore yields of up to 100L/s have been recorded from this aquifer. High yielding sections were encountered when drilling the Amungee NW E&A well.

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 of drinking water quality. A schematic of the Amungee NW-1H within the underlying geological formations is provided in Table 21.

Table 21: Summary hydrostratigraphy at the Amungee NW 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-86m	0.3-4	1,800
GEORGINA BASIN	CAMBRIAN	Cambrian Limestone Aquifer (CLA)	Anthony Lagoon Formation	Regional aquifer	86-104m	1-10	1,600
			Gum Ridge Formation	Regional aquifer	104-221m	0.3- >20	1,400
		Antrim Plateau Volcanics		Regional aquitard	221-305m-	0.3-5	900
		Bukalara Sandstone		Regional aquifer	305-418m	0.3-5	1,000
Undefined – Under NTGS Review	NEOPROTEROZOIC	Hayfield Formation		Regional saline aquifer	418-869m	ID	32,000
		Jamison Sandstone		Local saline unit	869-948m	ID	138,000
BEETALOO SUB-BASIN (ROPER GROUP)	MESOPROTEROZOIC 1,300-1,500 Ma	Kyalla Formation		Regional aquitard	948-1348m	ID	ID
		Moroak Sandstone		Local saline unit	1348- 1668	0.5-5	131,000
		Velkerri Formation		Regional aquitard	1668 – 2831 (Base Velkerri estimated from offset well thicknesses)	-	-

Province	Period/Age	Formation	Aquifer status	Encountered Depths (top and bottom) (m)	Regional Yield (L/s)	Avg regional EC (ms/cm)
		Bessie Creek Sandstone	Local aquifer (not regionally connected)	2831 (Top Bessie Creeks Sandstone estimated from offset well thicknesses)	0.5-5	-

ID - insufficient data

4.1.5.1 Groundwater monitoring results

Baseline monitoring data has been collected from the groundwater bores located at the Amungee NW site since commencing in 2016 until present. A summary of the baseline monitoring data is provided in Table 22. Additionally, data collected during Origin's Beetaloo exploration program can be accessed via the DEPWS website located at: https://depws.nt.gov.au/onshore-gas/onshore-gas-in-the-northern-territory/industry-compliance-and-reporting/groundwater-monitoring-results.

Table 22: Summary of groundwater monitoring results collected at the Amungee NW site

Analyte	Unit	EQL	RN039896			RN038493		RN040894		
			Count	Average	Max	Count	Result	Count	Average	Max
Alkalinity (Bicarbonate) as CaCO3	mg/L	1	8	389.875	422	1	426	4	376.75	398
Alkalinity (Total) as CaCO3	mg/L	1	9	394.57778	432.2	1	426	4	376.75	398
Anions Total	meq/L	0.01	8	13.396432	14.3	1	13.8	4	12.775	13.5
Calcium	mg/L	1	2	118.721	119	0	-	-	-	-
Calcium (Filtered)	mg/L	1	7	115.71429	123	1	129	4	117.25	122
Cations Total	meq/L	0.01	8	13.253924	14.4	1	13.7	4	13.025	13.5
Chloride	mg/L	1	9	103.11111	144	1	91	4	84	101
Electrical Conductivity (Lab)	µS/cm	1	8	1208.75	1340	1	1170	4	1132.5	1160
Fluoride	mg/L	0.1	5	0.64	1.2	1	0.5	4	0.55	0.6
Magnesium	mg/L	1	2	49.00065	51	0	-	-	-	-
Magnesium (Filtered)	mg/L	1	7	47.857143	51	1	50	4	47.75	49
Methane	mg/L	0.001	1	0.002	0.002	1	<0.001	-	-	-
pH (Lab)	pH_Units	0.01	7	7.6614286	8.11	0	-	4	7.2575	7.45
Potassium	mg/L	1	2	10.6685	12	0	-	-	-	-
Potassium (Filtered)	mg/L	1	7	10	11	1	11	4	9.75	10
Sodium	mg/L	1	2	74.695	77	0	-	-	-	-
Sodium (Filtered)	mg/L	1	7	75.857143	103	1	67	4	68.5	72
Sulphate as SO4	mg/L		1	127	127	0	-	-	-	-
Sulphate as SO4 (Filtered)	mg/L	1	8	131.375	142	1	132	4	137.25	139
Total Dissolved Solids	mg/L	10	7	761.28571	848	1	759	4	706.75	728
Total Dissolved Solids (Filtered)	mg/L	10	1	1550	1550	0	-	-	-	-

4.2 Biological environment

The description of the biological environment of the existing Amungee NW-1 site has been described previously in the Beetaloo sub-Basin, EP98 and 117 Exploration drilling EMP, approved 30/06/2015. A summary of the plan is available at: https://depws.nt.gov.au/__data/assets/pdf_file/0010/258607/Origin-2015-Environmental-Plan-SummaryBeetaloo-Sub-Basin.PDF

An additional environmental survey of the Beetaloo exploration area (EP76, EP117 and EP98 containing Amungee NW site) was completed in August 2018 (AECOM, 2018). The following section draws on previous reports and surveys, along with updated (March 2021) EPBC Protected Matters Search Report (PMSR) and searches of the NT NR Maps databases for the Amungee NW site.

4.2.1 Bioregions

The Amungee NW lease site falls within the Stuart Plateau Bioregion. The bioregion is characterised by 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 and more recently in August 2018 (AECOM, 2011; 2014; 2016 and 2018). Surveys at the existing Amungee NW site were completed in August 2014, April 2016 and August 2018.

The Amungee N 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 open *Corymbia* woodland. The access track to the lease pad is characterised with the same vegetation unit, with limited Bullwaddy and Lancewood communities present. The vegetation communities are considered regionally extensive and not subjected to extensive clearing. A summary of the survey of the existing site is shown in Table 23.

Table 23: Amungee NW-1 summary of existing environment

Site ID	Amungee NW	Habitat survey photos of the vegetation/habitat of the surrounding environment	
Location	-16°20' 38.17, 133°53' 2.76		
Landform and soil	Two types: laterite, ferruginous rubble, some red soil and sandy and loamy soil with some lateritic material on undulating plain		
Habitat type	Open eucalypt woodland		
Vegetation community	Open woodland with dense shrub cover and grass cover. This vegetation community is considered regionally extensive and not subjected to extensive clearing		
Dominant flora species	Canopy dominated by *Corymbia drysdalensis*, *C. ferruginea* and *Erythrophleum chlorostachys*. Diverse subcanopy/shrub layer including *Petalostigma pubescens*, *Terminalia canescens*, *Atalaya hemiglauca*, *Hakea arborescens*, *Grevillea pteridifolia*, *Carissa lanceolata*, *Dodonea* sp., *Flueggia virosa*, *Grevillea striata*, *Alphitonia pomaderroides*. Very dense grass cover including *Themeda triandra*, *Chrysopogon fallax*, *Heteropogon contortus*, *Sarga plumosum*. Other species include *Grewia retusifolia*, *Ptilotus polystachyus*, *Evolvulus alsinoides*, *Cleome viscosa*.		

Habitat condition	Previous exploration activities (Amungee NW-1H). Habitat disturbances include grazing and prior clearing. No evidence of recent fire. The weed *Hyptis suaveolens* present at the site. Evidence of cattle from wet/early dry season. Very dense grass cover provides cover for small mammals and reptiles. Abundance of shelter sites in the form of hollow logs for mammals and reptiles.		
Potential listed threatened species	Grey Falcon, Northern Shrike-tit, Plains Death Adder, Gouldian Finch	**Hydrogeology**	
Weeds	No *Weeds of National Significance* present. *Hyptis suaveolens* present at the site	Groundwater resources and use is from the Gum Ridge Formation. A seasonal perched shallow alluvium system has also been locally identified but is not utilised as a groundwater resource. The Anthony Lagoon formation and undifferentiated Cretaceous are unsaturated.	

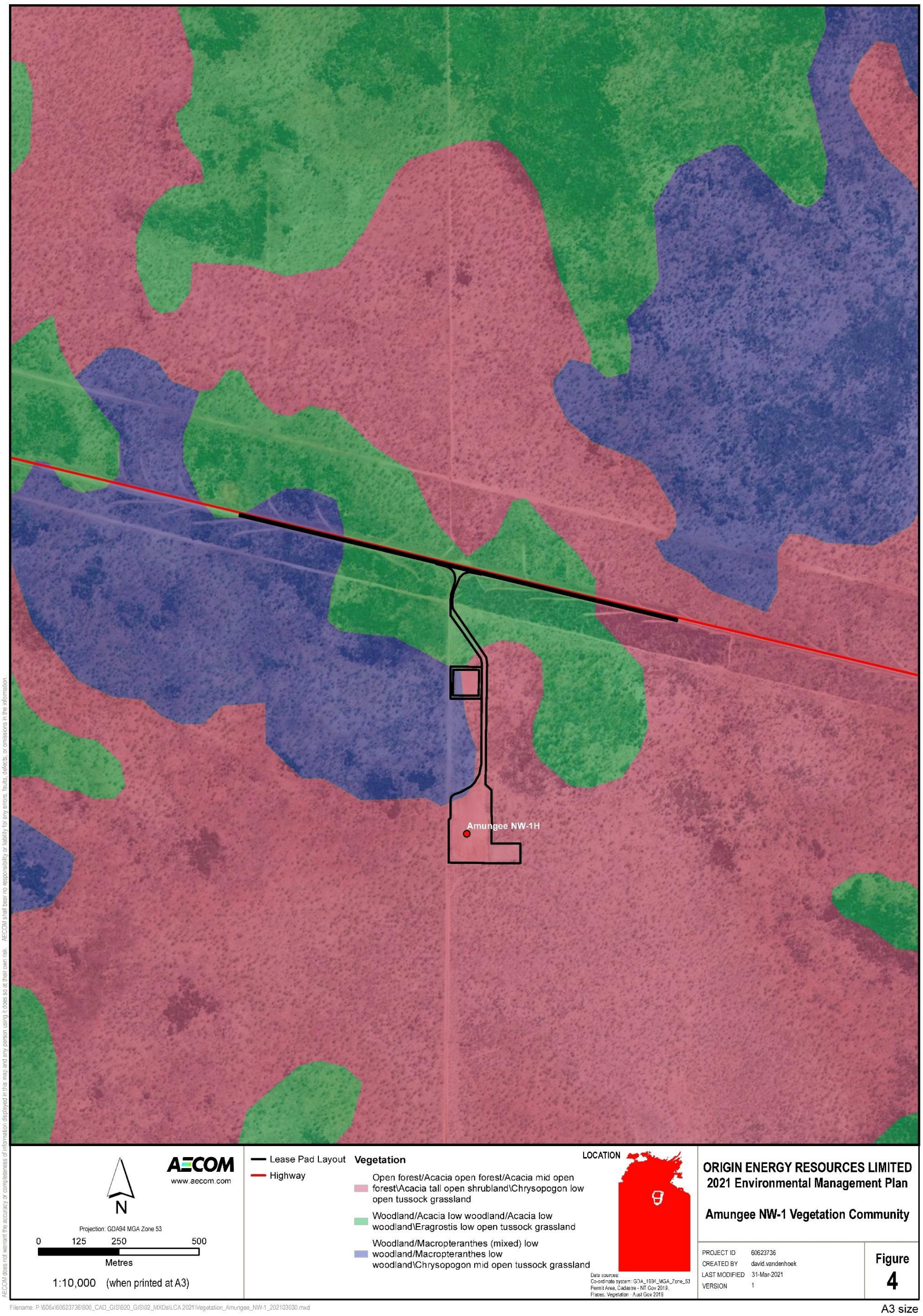

Figure 20: Vegetation communities surrounding the proposed Amungee NW site

4.2.3 Flora

A total of 805 plant species have been recorded within the Beetaloo exploration area, and during the most recent 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.

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 area is far more extensive in the Beetaloo exploration area than that indicated by the NT Herbarium records.

No Commonwealth or NT threatened plant species were identified as occurring within a 15km buffer of Amungee NW by the Commonwealth Protected Matters Search Report (PMSR) or NT NR Maps 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 wider exploration area. The species has been recorded within 20km of the Amungee NW lease on the NT Significant Flora database, however it has not been identified in previous and current field surveys.

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 area.

The weed species of high risk of introduction or spread through Origin's activities are listed in Table 24. 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 the Amungee NW-1 site and access tracks. Further surveys have been completed every 6 months since the original 2018 baseline exercise. These surveys have been completed with the DEPWS Weed Officer. The known locations of weeds on the Amungee NW (from recent 2020 surveys) is provided in Figure 21.

Hyptis suaveolens has identified previously within the Carpentaria Highway road corridor and the existing Amungee NW-1 site (access track, camp pad and lease pad). Hyptis is a class B (growth and spread to be controlled) and Class C (not to be introduced) weed in the Northern Territory. The Hyptis found at the site is under active management, with 6 monthly treatments applied to individual weeds identified.

Parthenium hysterophorus, a declared Class A weed species, has been identified in the broader region. Areas of known parthenium outbreaks will be actively avoided.

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

Figure 21 2020 weed survey of the Amungee NW site

Table 24: High priority weeds to be managed or prevented within the Beetaloo exploration area

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

4.2.5 Fauna

Previous surveys and database searches indicate that the broader Beetaloo 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 of the region in the vicinity of the existing Amungee NW location provides 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 activity will have limited disturbances on these areas or species.

4.2.6 Significant fauna

The PMSR and searches of the NT NR Map fauna database, and records from the Atlas of Living Australia (ALA) of the Beetaloo exploration area 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 proposed lease areas (AECOM, 2018).

No core habitat for threatened fauna was identified surrounding the Amungee NW site. 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 suitable nesting habitat is located in close proximity to the site and it is unlikely this species breeds in close vicinity to the activity. 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 Amungee NW-1 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 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 Amungee NW-1 site and the Gouldian Finch is unlikely to be encountered throughout the year. This is confirmed by the fauna monitoring results, which have not thus far, detected the Gouldian Finch.

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.

4.2.7 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 and previous exploration activities, cattle grazing occurs regularly in the areas adjacent to the Amungee NW site. Based on records and observations from sites in the broader Beetaloo exploration area, many species such as dogs/dingo, pigs and cane toads will be present in the vicinity of the site. The disturbance from cattle varies depending on the season, with the level of disturbance at the proposed sites likely to have resulted in less than 5% damage.

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.

A fire event occurred during the operation of the Amungee NW appraisal well during late 2016. There was negligible evidence of the fire present during the 2018 survey, with the site recovering rapidly.

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

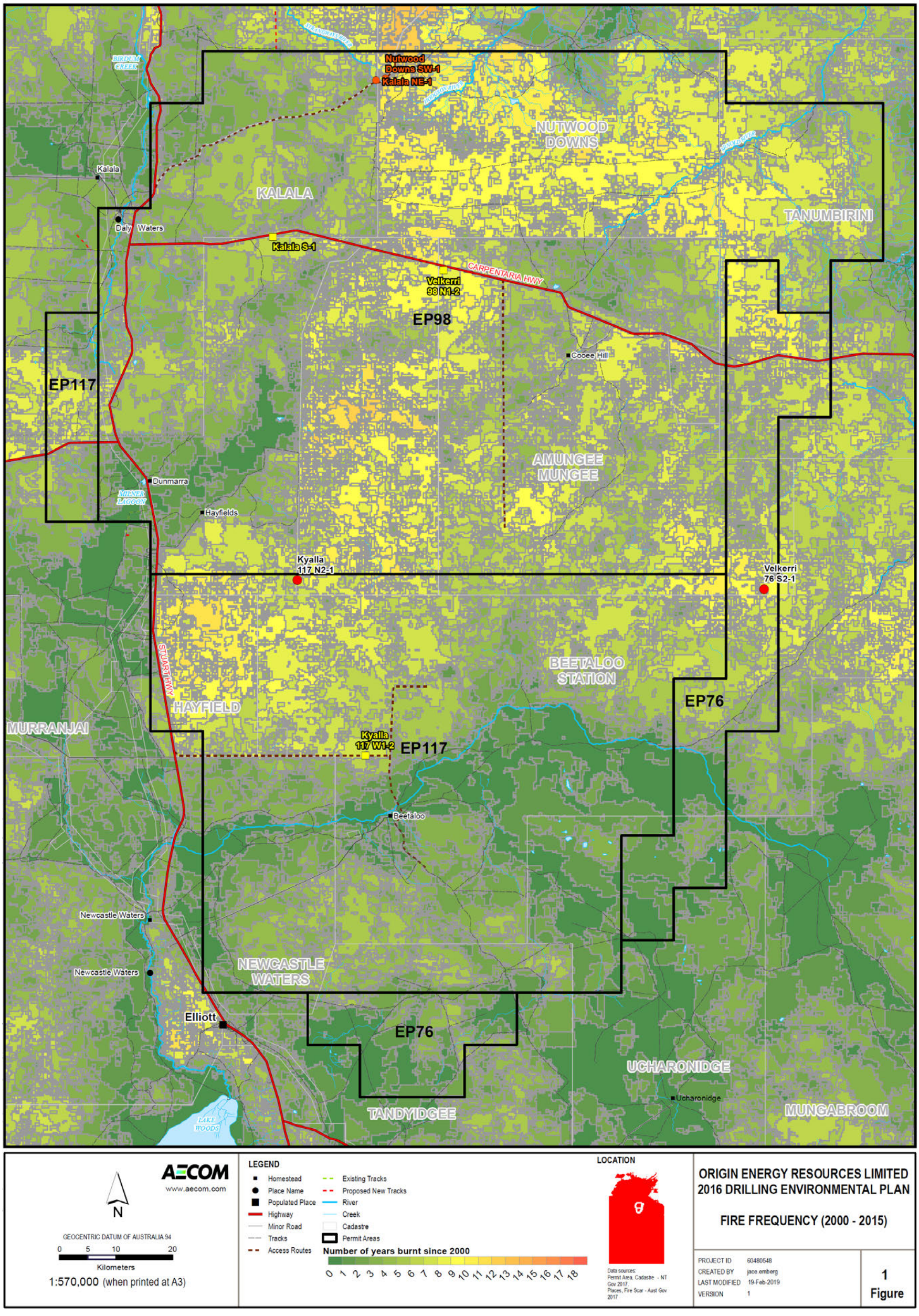

Figure 22: Fire frequency map of the Beetaloo Sub-Basin

4.4 Groundwater Dependent Ecosystems

A search of the National Groundwater Dependent Ecosystems (GDE) Atlas was conducted on 23/02/2021. 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.

A known aquatic GDE, the Strangways River (a tributary of the Roper River), was identified as occurring within 50km of the Amungee NW site. Eleven other locations were identified as having moderate aquatic GDE potential, including the Bull Creek, Hogdson River, Red Ochre Creek, Arnold River, Cow Creek and Crumby Creek river systems in the Roper River region.

The 50km buffer search identified one known terrestrial GDE, riparian vegetation *Melaleuca leucadendra, M.viridiflora* woodland in the Roper River region, and one moderate potential GDE, *Melaleuca citrolens, M. minutifolia* low woodland in the Victoria River–Wiso region.

All known and moderate potential GDE locations occurred at distances greater than 25km but less than 50km from the Amungee NW site. The impact on these units from Origin's total water extraction across the Beetaloo exploration area 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. A recent report on stygofauna within the Beetaloo Sub-basin by the Gas Industry Social and Environment Research Alliance (GISERA) program identified the presence stygofauna assemblages in the CLA units of the Beetaloo Sub-basin,[10]; including within the vicinity of the existing Amungee NW site (Rees *et al* 2020). The report found evidence of stygofauna being regionally extensive within the Beetaloo Sub-basin, with some species identified at locations separated by over 300km. This result logically confirms the continuity of the CLA and proves that stygofauna species are likely to be widespread across the basin. This reduces the potential risk of localised exploration activities on endemic stygofauna population, with the initial results indicating species are present regionally.

The report findings also highlights that any potential impacts on stygofauna from exploration activities are likely to be temporal, with stygofauna present within close proximity of the existing Amungee Nw-1H appraisal well. This confirms that drilling, stimulation and well testing activities (and associated water extraction) are unlikely to represent material risks to regional stygofauna communities.

Although Stygofauna are anticipated to be in the vicinity of the Amungee NW site, exploration activities are unlikely y to impact them based upon: Well design and construction to isolate aquifers

- The limit water extraction volumes proposed by this activity
- No drilling or stimulation proposed (noting that drilling and stimulation activities completed in 2016 do not appear to have affected the presence of stygofauna at this stie)
- The regional continuity of the CLA is likely to result in stygofauna being regionally abundant, with significant capacity to recolonise impact areas from adjacent area.

Based upon the above information, the potential impacts of the proposed extended production test and ongoing monitoring/ maintenance of the Amungee NW-1H well on stygofauna is consider remote.

[10] Further information is available on the GISERA website: https://gisera.csiro.au/wp-content/uploads/2021/03/GISERA-Project18-Stygofauna_final-report-20201208.pdf

4.5 Environmental and cultural sensitivities

4.5.1 Native Title

One Native Title claim has been determined over the Amungee Mungee Pastoral station as defined in Table 25.

Table 25: Native Title and IULA Agreements current for EP98

Type	Well site	Name	Summary	Contact details
Native Title	Amungee NW-1H	NTD17/2010 Amungee Mungee Pastoral Lease	Native Title exists in parts of the determination area and is held by the Karranjini Bamarrnganja primary estate groups	Refer the Northern Land Council who are the nominated point of contact for the Native Title holders reception@nlc.org.au 1800 645 299

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 avoidance and clearance surveys occurred prior to any on ground activities and AAPA Certification is held for the location and all proposed 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 of E&A sites within EP 117 and EP 98, including Amungee NW, was conducted by AECOM in August 2018. The assessment involved a desktop review of existing heritage data from the Australian Heritage Database, the NT Heritage Branch and the AAPA, as well as archaeological survey report, consultation with traditional owners of the study area and a field inspection. A field survey was conducted by AECOM in 2018 of sites within the wider Beetaloo exploration area. 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 location.

A search of the NT Heritage Register identified 41 Aboriginal archaeological sites within EP 98 and EP117, however no sites were located within 15km from the Amungee NW. A search of the Australia Heritage Database identified that no statutory listed heritage places were present within the EP 98. No culturally sensitive landforms or artefacts were identified during the 2014 field survey of Amungee NW, however sacred sites were subsequently listed on the AAPA certificate. The archaeological assessment is provided in Appendix D of the EP 98 Ground water bater bore EMP located at: https://depws.nt.gov.au/__data/assets/pdf_file/0004/611842/EMP-origin-water-monitoring-bore-drilling.pdf

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 been granted covering all activities covered under this EMP. A Restricted Work Area is located at a waterhole over 8km from Amungee NW and no access or works will be undertaken within 500m of the Sacred Site.

4.5.4 Natural resources

During the 2018 Sacred Site clearance and avoidance survey, representatives of the Traditional Owners identified a number of natural resources of importance to Aboriginal people in the Beetaloo exploration area Table 26.

Table 26: Natural resources of importance in the permit areas

Scientific name	Common name	Usage
Grewia retusifolia	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.
Marsdenia australis	Bush Banana/Gillibi	Bush 'fruit' eaten when young, as it matures 'fruit' seeds becomes feathery for dispersal in the wind and are not eaten
Pterocaulon sp.		Used for treating flu
Acacia sp.	Acacia	Leaves boiled and used to treat flu
Acacia holosericea	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 Murranji 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 EP 98. Frew Ponds, a reserve paying tribute to the building and joining of the Overland Telegraph Line is located 75km from the Amungee NW site.

4.5.7 Protected or conservation areas

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

The closest area is the Bullwaddy Conservation Reserve, which is located ~40km from the proposed activity area. The EPBC Listed Lake Woods is located ~160km from the site and is listed on the National Directory of Important Wetlands.

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

- As the proposed site is ~40km away from the Bullwaddy Conservation Reserve and 160km (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 Creek, which flows to Lake Woods via Newcastle Waters. Any spill would need to exceed the capacity of the site bund and travel over 160km to reach Lake Woods. A spill cannot impact the Bullwaddy Conservation Area as it is not in the overland flow path from the site.
- Groundwater direction is to the North West, which is not on the flow path of the Bullwaddy Conservation Reserve.
- All access tracks are to the east 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 EMP activities will occur within the Barkly Regional Council area, which covers 323,514 km^2. 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 (~70kms)
- Tennant Creek (~350kms)
- Elliott (~150kms)
- Daly Waters (~60kms)

- Newcastle Waters (~125kms)
- Neighbouring pastoral leases of Beetaloo Station, Tanumbirini Station and Hayfield Shenandoah Station.

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 is in ongoing consultations with the REDC.

4.6.2 Pastoral activity

The Amungee NW site is located on the Amungee Mungee Station which is used for pastoral activities. The 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 km^2 (Bubb, 2004), which is large by global standards.

4.6.3 Other land uses in the area

A range of other land uses exist in the Beetaloo exploration 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 Beetaloo exploration 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*.

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).

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 their representative, the Northern Land Council, as described in Exploration Agreements between the parties for EP98, EP117 and EP76 and further defined by the subsequence Native Title consent determinations; and
- **Host pastoralists** recognised as the landholders of the nine (9) Pastoral Lease Stations in Table 27 (With regard to this EMP for the Amungee NW location, the owners of the pastoral lease for Amungee Mungee 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 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.

Table 27: Pastoral properties in the permit area

Pastoral property	Permit areas			Contact details
	EP76	EP98	EP117	
Amungee Mungee		✓	✓	[redacted]
Kalala		✓	✓	NA
Tanumbirini	✓	✓		
Beetaloo	✓		✓	
Hayfield/Shenandoah		✓	✓	

Ucharonidge	✓		✓	
Tandyidgee	✓	✓		
Nutwood Downs		✓		
Newcastle Waters			✓	

5.3 Pastoralist stakeholder engagement

Origin has engaged with the representatives of the Amungee Mungee pastoral lease regarding the full range of exploration activities outlined in this revised EMP. As this is an existing approved site, the proposed ongoing works cover under this revised EMP are a variation to an existing land access agreement. The Stakeholder engagement completed for this revised EMP is focused on this continuation of activities and builds upon the existing stakeholder engagement completed with the pastoralist since negotiations on the Amungee NW site began in 2014. Key engagement efforts Origin has undertaken include:

- Historic engagement regarding the drilling, stimulation and well testing of the Amungee NW-1H well in 2014-2016
- Ongoing engagement with the Amungee Mungee lease regarding the status of the Amungee Mungee Nw-1H well
- Engaging in consultation for early works access to Amungee Mungee Station in preparation of low impact and small-scale exploration activities (Amungee NW 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
- Providing the landholder with draft copies of a Stakeholder Engagement Pack (SEP) covering the proposed exploration activities and providing opportunity for the landholder to comment (Appendix L Part B)

Origin is currently negotiating a variation to the existing Land Access Agreement with the Amungee Mungee Station, with the agreement expected to be finalised prior to the commencement of activities.

Appendix L Part A and B summarises Origin's engagement with the leaseholders of the Amungee Mungee Station as a relevant stakeholder and provide information in accordance with section 7(2)(a) of the *NT Petroleum (Environment) Regulations 2016*.

5.4 Host Traditional Owner(s) engagement

The Host Traditional Owners are provided in Table 25. 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
- 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.*
- Pursuant to 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*
- 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
- 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
- A second Sacred Site clearance and avoidance survey in October 2020.
- On country meetings with Traditional Owners, Origin and the NLC in March 2021 and early April 2021 to discuss Origin's work program for 2021, the outcomes of the Sacred Site clearance and avoidance surveys in September 2020 and address any questions about Origin's activities
- Ongoing communication between Origin and the Northern Land Council

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

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.

5.6 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 a 6 monthly time frame. With the engagement frequency agreed to with the pastoralist
  - Quarterly engagement with future host pastoralists for which activity is proposed within a 12-month 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
  - Ad hoc updates for the Northern Land Council when required, informing them of progress of exploration activities underway
  - Quarterly project status updates to the Northern Land Council informing them of progress of exploration activities underway
  - Site visits by Traditional Owners during exploration activity so that Traditional Owners can have first-hand observation of key activities
  - 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
  - Annual on country meetings with Native Title Holders to discuss current work program status and future exploration activities

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).

Risk management processes are 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 23. The toolkit considers the requirements of ISO 31000 and addresses risk identification, assessment and management.

Assessment of risk is completed using Origin's Risk Matrix (Figure 23) 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.

An "unmitigated" or "inherent" risk, in the context of this EMP, is considered a risk with only standard industry and pre code of practice controls applied (i.e. controls acceptable prior to the implementation of the Code of Practice). These risks are used to identify the risk controls that are of highest priority, however they do not represent a real world risk scenario as they do not include mandatory legislative requirements.

Origin risk management processes requires regular assessment of underlying (unmitigated[11]) risk from an activity, the residual risk once controls are applied, the effectiveness of controls (provided in Table 28) and the likelihood and consequence of a risk event. A risk is either accepted in accordance with strict delegations of authority or the activity does not proceed.

Table 28: 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.

[11] Unmitigated or inherent risk is calculated assuming the standard practices deployed before the Code of Practice was implemented. This may vary depending on operators, hence the unmitigated risk of one operator may differ from another, depending on their internal risk management standards.

Rating	Explanation
	• 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

Step A – describe the risk
Identify and describe the risk in terms of what could happen, its causes and potential effective/impact on Origin's objectives.

Step B – identify and assess controls
Identify and assess existing controls using the Control Assessment Ratings. Consider any related significant incidents, near miss events and assurance activities when assessing controls.

Step C – assess the level of consequence
Decide on the level of consequence that best represents the risk. Determine the highest credible consequence level in all relevant consequence categories in the Risk Matrix, taking into account current control assessment.

Step D – assess the likelihood
Determine the likelihood level in the Risk Matrix that represents the chance of the risk occurring at each consequence level identified, taking into account current control assessments.

Step E – determine the level of residual risk
Use the Risk Matrix to determine the level of risk

Step F – determine the priority for risk treatment and approval
Using the Risk Treatment and Acceptance Criteria, determine the risk treatment required and who can approve/accept the risk at its current level.

Step G – assess the potential maximum consequence
Estimate the potential maximum consequence (plausible worse case level assuming all current controls fail) using the consequence categories.

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

Risk Matrix

CONSEQUENCE	IMPACT ON ORIGIN OPERATIONS – Conduct Business with Due Care: People	Environment and Community	IMPACT ON ORIGIN OPERATIONS – Create Value: EBIT	Cash flow	NPV	EXTERNAL RESPONSE – Decisions are Subject to Scrutiny: Stakeholder Perceptions	Laws, regulation and civil actions
6 CATASTROPHIC	Multiple fatalities ≥4 or life threatening illness or total permanent disability to a large exposed group (10 or more people)	Extensive permanent damage to endangered species, habitats, ecosystems or area/s of cultural significance Extensive irreversible loss of community livelihood. Long-term social unrest and outrage	>$200m	>$1b	>$1.5b	Multiple stakeholder groups confirming coordinated action, as reflected in media channels with significant reach and influence (eg. scheduled blockade or boycott covered in media for more than 1 week).	Criminal charges against any director or senior executive involving jail or loss of right to manage the company. Public inquiry – requiring considerable resources and Executive Management time. Loss of licence to operate an asset
5 CRITICAL	1 – 3 fatalities or life threatening illness or total permanent disability to a small exposed group (<10 people)	Extensive long term partially reversible damage to vulnerable species, unique habitats, ecosystems or area/s of cultural significance Extensive reversible loss of community livelihood. Prolonged community outrage.	>$50m - $200m	>$250m - $1b	>$375m - $1.5b	Multiple stakeholder groups mobilising and encouraging others to take action, as reflected in media channels with significant reach and influence (eg. social media campaign calling for protest, escalating over several days).	Criminal charges against any director, senior executive or senior manager not involving jail or loss of right to manage the company. Prolonged major litigation – exposure to significant damages / fines / costs. Suspension / restriction to operate an asset.
4 MAJOR	Injury or illness to one or more persons, resulting in permanent partial disability	Long term reversible impacts to listed species, habitats, ecosystems or area of cultural significance Significant impacts to community cost of living, business viability or social wellbeing. High levels of community tension.	>$20m - $50m	>$100m - $250m	>$150m - $375m	More than one stakeholder group's opinion or view influencing other stakeholders, reported through media channels with some reach and influence (eg. government comments in national media or in Parliament).	Criminal charges against any employee (not described above) Major litigation – exposure to damages / fines / costs.
3 SERIOUS	Injury or illness to one or more persons resulting in hospitalisation, 5 or more days lost time or alternative / restricted duties for 1 month or more	Serious medium term reversible impacts to low risk species, habitats, ecosystems or area/s of cultural significance Moderate impacts to community cost of living, business viability or social wellbeing. Moderate levels of community tension.	>$5m - $20m	>$25m - $100m	>$37.5m - $150m	More than one stakeholder group offering an opinion or view, reported through media channels with some reach and influence (eg. state based commentary lasting one 24 hour media cycle across internet, print, television, radio).	Non-compliance with conditions of licence to operate an asset or to conduct an activity. Litigation – exposure to damages / fines / costs.
2 MODERATE	Injury or illness to 1 or more persons resulting in medical treatment, up to 5 days lost time or alternative / restricted duties for up to 1 month	Moderate short term impacts to common regional species, habitats, ecosystems or area of cultural significance Small scale impacts to cost of living, business viability or social wellbeing. Isolated examples of community tension.	>$1m - $5m	>$500k - $25m	>$750k - $37.5m	A single stakeholder group drawing attention to an incident, issue or approach, conveyed though media channels with potential reach and influence (eg. some social media complaints or local media reports).	Moderate non-compliance with external mandatory obligations or breach of contractual or other legal obligations (not described above). Litigation possible.
1 MINOR	Injury or illness requiring first aid to 1 or more persons, or no treatment (record only)	Minor environmental or community impact - readily dealt with	>$100k - $1m	<$500k	<$750k	A person or organisation within stakeholder group signaling an interest in an incident, event or approach, using channels with limited reach or influence (eg. letter of complaint/commendation).	Minor non-compliance with external mandatory obligations or breach of contractual or other legal obligations.

CONSEQUENCE	LIKELIHOOD – 1 REMOTE: <1% chance of occurring within the next year. Only occurs as a '100 year event' or less frequent.	2 HIGHLY UNLIKELY: <10% chance of occurring within the next year. Could occur within decades.	3 UNLIKELY: <30% chance of occurring within the next year. Could occur within the next few years.	4 POSSIBLE: <60% chance of occurring within the next year. Could occur within months to years.	5 LIKELY: <90% chance of occurring within the next year. Could occur within weeks to months.	6 HIGHLY LIKELY: Likely to happen multiple times a year
6 CATASTROPHIC	HIGH	HIGH	VERY HIGH	VERY HIGH	VERY HIGH	VERY HIGH
5 CRITICAL	MEDIUM	MEDIUM	HIGH	VERY HIGH	VERY HIGH	VERY HIGH
4 MAJOR	MEDIUM	MEDIUM	MEDIUM	HIGH	VERY HIGH	VERY HIGH
3 SERIOUS	LOW	MEDIUM	MEDIUM	MEDIUM	HIGH	HIGH
2 MODERATE	LOW	LOW	MEDIUM	MEDIUM	MEDIUM	MEDIUM
1 MINOR	LOW	LOW	LOW	MEDIUM	MEDIUM	MEDIUM

* Cash Flow - change from expectation over the life of the exposure. EBIT change from expectation over 12 – 18 month period.

Figure 24: Origin's Risk Matrix

6.2 ALARP

Origin's risk management process requires risks to be managed 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 29 to determine the acceptability of a residual risk. Each residual risk event outlined in Appendix I 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 I.

Table 29: 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

#	Criteria	Origin's acceptance threshold
		annually with the intent to reduce the risk severity lower. **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.

Scientific certainty is qualitatively assessed using a generic means of ranking the data available in accordance with Table 30. Considerations of uncertainty have been included in the risk assessment discussed in Section 6.5.

Table 30: 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.
- 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 52 risk sources which may potentially result in a risk occurring. Of the 52 risk sources, six (6) were ranked as 'Moderate' with the remaining ranked as 'Low'. The medium residual risks sources identified through the risk assessment include:

1. Impact to fauna habitats and threatened flora and fauna though the introduction and spread of weeds in the area
2. Impact to fauna habitats and threatened flora and fauna through accidental ignition of fire from exploration activities (flaring, general access)
3. 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
4. Reduction in agriculture productivity through the introduction and spread of weeds in the area
5. Reduction in agriculture productivity through bushfire from accidental ignition by site activities or site personnel
6. 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 and ignition of bushfires from the proposed activities. The reduced risk profile associated with proposed 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 (2016).

Table 31 provides a count of the post-treatment environmental risks associated with this EMP. A copy of the risk assessment is provided in Appendix I.

Table 31: Count of Residual Environmental Risks for the Amungee NW-1H program

	Residual Environmental Risk Level			
	Low	Medium	High	Very High
Total 58	52	6	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 I. Tables 33 to 39 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 32: 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 Amungee NW as a result of Origin's exploration activities	S-1	No releases of contaminants (chemicals, hydrocarbon 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 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	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 12) • Soil erosion from cleared areas (access tracks, lease pads and camp pads) (Risk ID 13) • Spills/leaks from the on-site storing and handling of fuels, chemicals and flowback (Risk ID 14) • Flowback tank overtopping (Risk ID 15) • Chemical and waste transportation accident (Risk ID 16) • Failure of a flowback tank (Risk ID 17) • Wastewater evaporation mist transported off-site during wastewater treatment (Risk ID 18) • Greywater and sewerage disposal (camps) (Risk ID 19)			

6.6.2 Surface water

Table 33: 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 12	Discharge monitoring results retained for each stormwater release
	SW-3	No reportable spill, 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 Amungee NW-1 site	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
Risk sources	• Failure of flowback storage tank (Risk ID 6) • Overtopping of flowback tanks (including wet season operations) (Risk ID 7) • Transportation accident releasing chemical or flowback (Risk ID 8) • Storage and handling of bulk fuels and minor chemical storages (Risk ID 9) • Release of stormwater from activities to surface water (Risk ID 10) • Runoff from sewage treatment irrigation areas (Risk ID 11)			

6.6.3 Groundwater

Table 34: 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 value (quality and quantity) of the underlying groundwater resources	GW-2	No failure of wastewater tank secondary liner or tank structure	All leak detection or level (high and low) alarms or structural issues on wastewater tanks investigated within 24hour, with no incidents of secondary liner or tank failure	Records of alarms investigations retained on site Incidents of secondary liner or tank failure documented in OCIS and reported to regulator.
	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	• Cross flow of formation through inappropriate well barrier design and construction (Risk ID 1) • Leakage of either flowback, produced water, or hydrocarbons (liquid and gaseous) from suspended or abandoned wells (Risk ID 2) • Over extraction of groundwater for well testing activities (Risk ID 3) • Surface spills from the storage, handling and transportation of flowback water (Risk ID 4) • Failure of flowback storage tank (Risk ID 5) • Surface spills from the overtopping of flowback tanks (including during wet season) (Risk ID 15)			

	• Surface spills from the failure of flowback storage tank (Risk ID 17) • Cumulative impact from regional groundwater take exceeds the natural recharge rate of the Basin (Risk ID 54)

6.6.4 Ecology—flora, fauna and habitats

Table 35: 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 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	Weekly 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	Weekly 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 20) • Structural failure and overtopping of flowback storage tanks (Risk ID 21) • Introduction and spread of weeds in the area (Risk ID 22) • Accidental ignition of fire from exploration activities (flaring and general access) (Risk ID 23) • Poor rehabilitation of the site reduces regional habitat and promotes weed invasions (Risk ID 24) • Trapping and drowning of fauna in storage tanks (Risk ID 25) • Contaminants in water and soil pass through the food chain and bioaccumulate in fauna causing detrimental impacts to local species and communities (Risk ID 26) • Vehicle collisions with fauna/fauna mortality results in a localised decline in species abundance (Risk ID 27) • Encouragement of feral animals and other pest species increases leading to competition with native species. This includes the introduction of cane toads (Risk ID 28)			

6.6.5 Air Quality and Greenhouse Gas emissions

Table 36: 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	• Bushfire from accidental ignition by site activities (civil work, flaring, grinding) or personnel (Risk ID 40) • Dust emissions from civil works and truck movements (Risk ID 47) • Emissions from the combustion of diesel (Risk ID 49) • Air emissions from flaring (Risk ID 50) • Uncontrolled release of gas encountered during well testing from operator error or vehicle collision (Risk ID 51) • Uncontrolled release of gas from well due to sabotage (Risk ID 52) • Leak of gas from wells (Risk ID 53) • Cumulative impact of exploration activities on amenity through additional dust generation (Risk ID 56) • Cumulative impact of exploration activities on NT and Australian greenhouse gas emissions (Risk ID 58)			

6.6.6 Community

Table 37: 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 to be from NT businesses i.e. 60% of services or material that can be provided by NT businesses are provided by NT business.	Project expenditure data confirms the NT business spend on the Beetaloo exploration project exceeds >60% of addressable[1] spend of the project	Data on NT business spend retained
Risk sources	• Industrialisation of landscape (Risk ID 33) • Increased traffic (Risk ID 34) • Light emissions impact on sensitive receptor (such as pastoralist) (Risk ID 35) • Influx of workers to region (Risk ID 36) • Noise emissions from activities (Risk ID 37) • Introduction and spread of weeds in the area (Risk ID 38) • Over extraction of groundwater (Risk ID 39) • Bushfire from accidental ignition by site activities (civil works, drilling, flaring grinding) or personnel (Risk ID 40) • Poor rehabilitation of exploration infrastructure (Risk ID 41) • Disruption of agricultural operations due to ongoing access, traffic and helicopter movements (Risk ID 42)			

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

	• Increased risk of vehicle accident (Risk ID 43) • Exploration activities compete with agricultural industry for resources (Risk ID 44) • Emissions from the combustion of diesel (Risk ID 45) • Air emissions from flaring (Risk ID 46) • Dust emissions from civil works and truck movements (Risk ID 47) • Cumulative impacts on amenity (Risk ID 56) • Cumulative impacts on surface water quality (Risk ID 57)

6.6.7 Cultural heritage

Table 38: Environmental outcomes, performance standards and measurement criteria—Cultural heritage

Environmental performance measures: Cultural heritage				
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 29) • Accidental ignition by site activities (civil works, well testing, grinding) or site personnel (Risk ID 30) • Flowback tank structural failure (Risk ID 31) • Personnel unauthorised access to sacred site (Risk ID 32)			

7 Management Plans

The following section provides a high-level summary of the various management plans required to be implemented in accordance with the Code of Practice.

7.1 Wastewater management plan

A wastewater management plan (WWMP) has been developed to satisfy the requirements of the code of Practice. The WWMP describes how Origin will store wastewater to minimise the risk to the environment.

A copy of the WWMP is provided in Appendix D.

7.2 Spill management plan

The use of secondary containment to prevent spills during EPT 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 (SPMP) has been developed covering Origin's proposed exploration activities. This SPMP is provided in Appendix F.

An example of bunding used for drilling and stimulation activities is provided in Figure 25.

Figure 25: Example of spill mats used to contain potential wastewater transfer spills

7.3 Methane emission management plan

A methane emission management plan (MEMP) is required to be developed to demonstrate how methane emissions will be managed. The MEMP describes how Origin:

- Mitigates the generation of methane emissions, such as the minimisation of venting and use of reduced emission completions
- Outlines the required leak detection and repair programs

- Summarises the leak reporting requirements,

A copy of the MEMP is provided in Appendix E.

7.4 Erosion and sediment control plan

An erosion and sediment control plan has been developed to outline how the site will be operated to minimise the risk of erosion and sediment releases to the surrounding environment. The ESCP is provided in Appendix H

7.5 Rehabilitation plan

Once a determination has been made to decommission the Amungee NW site, the Amungee NW-1H well will be plugged and decommissioned, with the lease pad and associated infrastructure rehabilitated. 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, freshwater 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 K.

7.6 Weed management plan

Exploration activities are undertaken in accordance with Origin's Beetaloo Weed Management Plan (NT-2050-PLN-019 Appendix G. 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.

7.7 Bushfire management plan

A bushfire management plan (BMP) has been developed to outline the controls to prevent, detect and respond to fires associated with Origin's activities. Controls implemented include:

- Implementation and maintenance of firebreaks
- Monitoring during periods of high fire danger
- Flaring controls, including separation distances and cessation of flaring during total fire bans
- Fire response and reporting

A copy of the BMP is provided in Appendix C.

7.8 Well Operations Management Plan

A well operations management plan (WOMP) must be developed and submitted to the Minister for Industry, Tourism and Trade (DITT) for approval prior to the commencement of activities. The WOMP is a separate approval from the EMP and provides an operational description of how Origin plans to operate, suspend and decommission the Amungee NW-1H E&A well in a manner that ensures all risk to the environment are reduced to As Low As Reasonably Practicable (ALARP).

8 Implementation strategy

8.1 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 27) 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"*.

8.2 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 26.

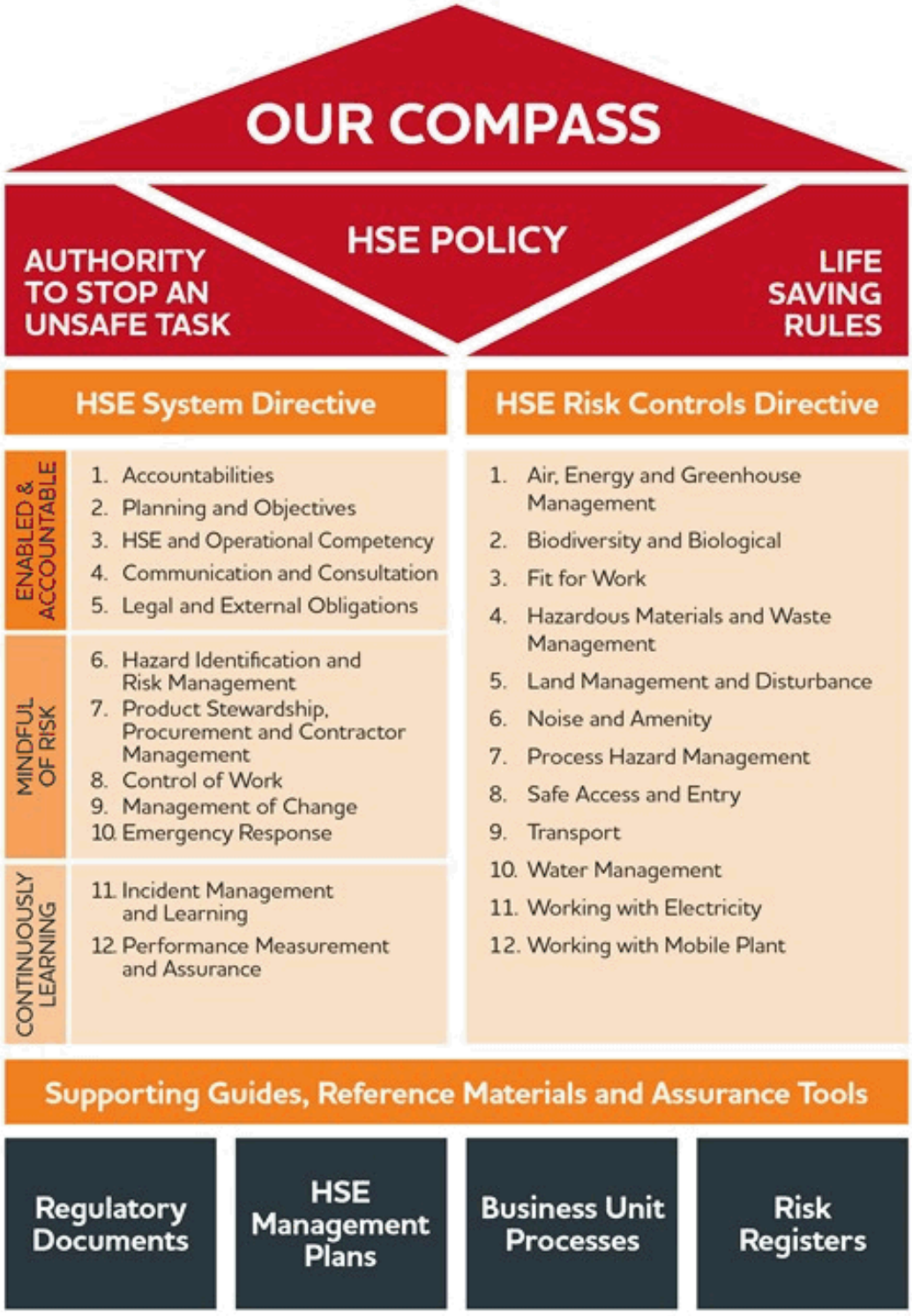

Figure 26: Origin's HSEMS structure

OUR HEALTH, SAFETY AND ENVIRONMENT POLICY

origin

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.

Frank Calabria
CEO
Origin Energy

ORG-HSE-POL-001 November 2016

Figure 27: Origin's Health, Safety and Environment (HSE) Policy

8.3 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 28. 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 Onshore Petroleum Weed Management Officer.
  - 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 well testing activities are designed and implemented in accordance with the NT legislation and Code of Practice.
  - Ensures all well testing 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 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 well testing 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 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 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 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 (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.

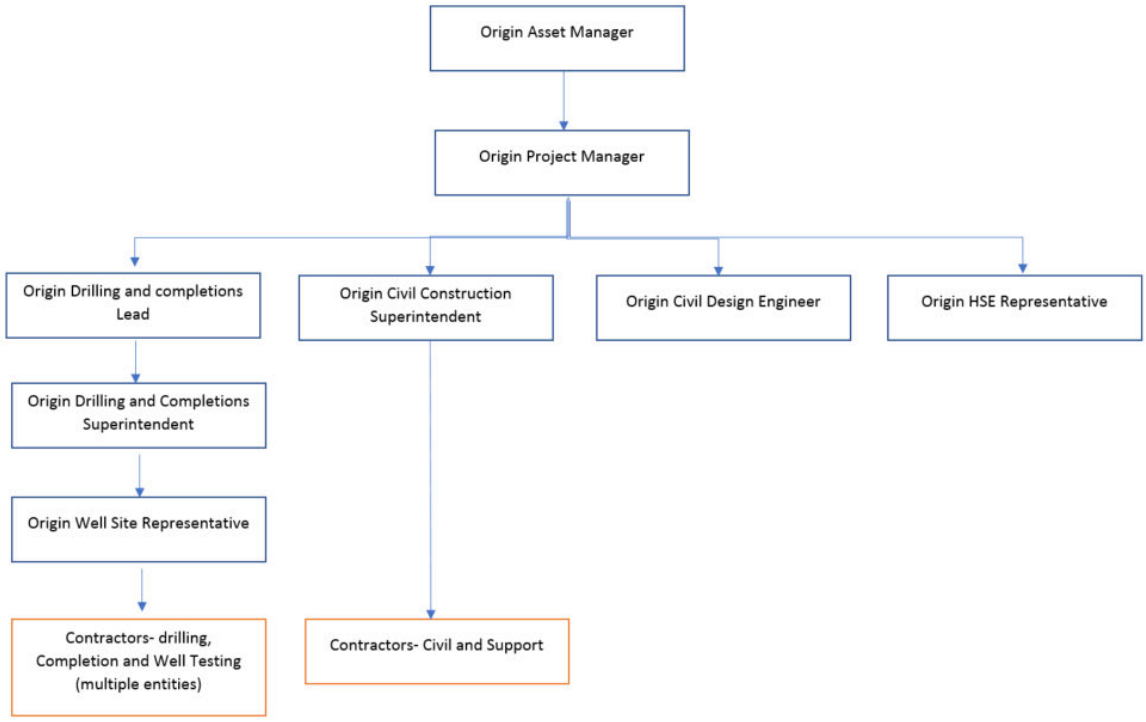

Figure 28: Beetaloo Project Organisation Chart

8.4 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

8.5 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 M are sourced from the risk assessment (Appendix I) and environmental outcomes, performance standards and measurement criteria tables (Tables 33–39). The implementation and compliance against these risk controls will be assessed as part of the annual environmental report (refer in Section 8.10).

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.

8.6 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 29.

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.

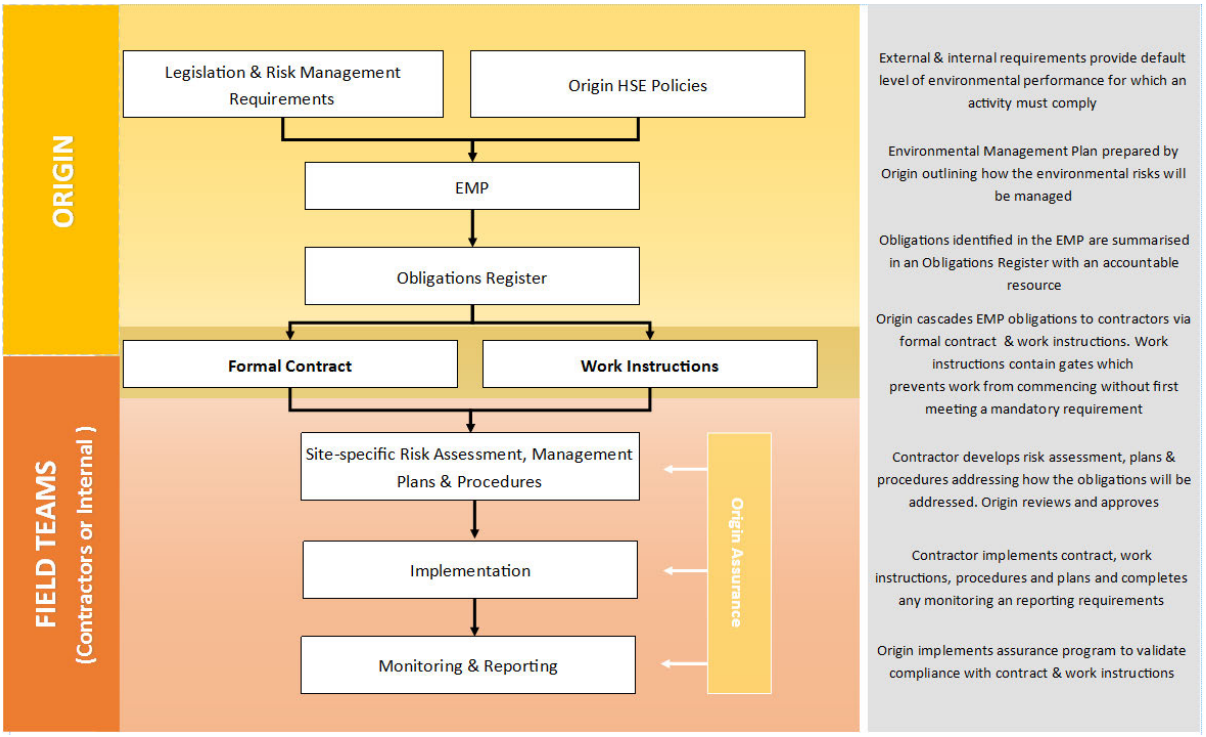

Figure 29: EMP implementation overview flowchart

8.7 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.

8.7.1 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 the *Petroleum Act*. This also includes any potential or actual damage to a sacred site.

'Material environmental harm' is defined in section 117AAB(1) of the *Petroleum Act* to mean environmental harm that:

(a) is not trivial or negligible in nature

(b) consists of an environmental nuisance of a high impact or on a wide scale

(c) results, or is likely to result, in not more than $50,000 or the prescribed amount (whichever is greater) being spent in taking appropriate action to prevent or minimise the environmental harm or rehabilitate the environment; or

(d) results in actual or potential loss or damage to the value of not more than $50,000 or the prescribed amount (whichever is greater).

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.* An initial report about a reportable incident must be given as soon as practicable, but not later than three days after the incident occurs, and must include comprehensive details about the following:

1. The results of any assessment or investigation of the conditions or circumstances that caused or contributed to the incident
2. The nature and extent of the material environmental harm or serious environmental harm that the incident caused or had the potential to cause
3. Any actions taken, or proposed to be taken, to clean up or rehabilitate an area affected by the incident
4. Any actions taken, or proposed to be taken, to prevent a recurrence of a similar incident.

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.

8.7.2 Recordable incidents

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

1. Has resulted in an environmental impact or environmental risk not specified in the current plan for the activity; or
2. Has resulted in a contravention of an environmental performance standard specified in the current plan for the activity; or
3. Is inconsistent with an environmental outcome specified in the current plan for the activity; and
4. 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).

8.7.3 *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.

8.7.4 Gas Leak reporting

Each gas leak shall be classified, repaired and reported in accordance with Table 39.

Table 39: 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	In the case of an emergency situation, DPIR 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	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
	or The leak is too large or not safe to measure.	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 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.	

8.8 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 40: 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

8.9 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 Amungee NW 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 N.

8.10 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 41: 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 • 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	Origin management DEPWS

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
Report about flowback fluid	A report regarding flowback is required within 6 months of the flowback commencing, in accordance with section 37A of the *NT Petroleum (Environment) Regulations 2016*	a) The Minister for Environment

8.11 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.

8.12 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 risk (including risk level) or impact is introduced, then a revision of the EMP is required under the PER's.

8.13 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.

9 Bibliography

Adams, M.D., Donato, D.B., Schulz, R.S., Smith, G.B., Gibbons, T., Davies, S and Hillier D., 2013. Hypersaline-Induced Reduction in Cyanide Ecotoxicity at Gold Operations, thereby Obviating Detoxification Plants. Conference Paper, World Gold Conference, Australia, Brisbane.

Adams, M.D., Donato, D.B., Schulz, R.S., Smith, G.B., 2008. Influences of hypersaline tailings on wildlife cyanide toxicosis: MERIWA project M398 (Phase II) cyanide ecotoxicity at hypersaline gold operations. Final Report Volume 2—Definitive Investigation. Minerals and Energy Research Institute of Western Australia, Perth.

AECOM. 2011. *Archaeological Assessment – Drill Sites and Access Roads*, unpublished for Falcon Oil and Gas Australia.

AECOM. 2012a. *EP99 Archaeological Survey, Beetaloo Basin*, unpublished report for Falcon Oil and Gas Australia.

AECOM. 2012b. *Interim Report Archaeological Surveys 2011*, unpublished report for Hess Australia (Beetaloo) Pty Limited

AECOM. 2013. *Environmental Closeout Survey, Sweetpea Seismic Survey 2006*, Prepared by AECOM for submission to DME, Darwin, NT.

AECOM. 2018 Appendix C- Land Condition Assessment: Velkerri 76 S2 and Kyalla 117 N2 Exploration Program, Prepared for Origin Energy, Available at https://depws.nt.gov.au/__data/assets/pdf_file/0006/706155/ep117-origin-betaloo-basin-kyalla-emp.pdf

Aldrick JM and Wilson PL. 1990. Land systems of the Southern Gulf Region, Northern Territory, Technical Report No. 42, Conservation Commission of the Northern Territory, Palmerston, NT.

Aumann, T. and Baker-Gabb D. 1991. RAOU Report 75. *A Management Plan for the Red Goshawk*. RAOU. Royal Australasian Ornithologists Union, Melbourne.

Australian Natural Resources Atlas (ANRA), 2008. *Rangelands 2008 Taking the Pulse- Stuart Plateau Bioregion.*

Australian Radiation Protection and Nuclear Safety Agency (ARPANSA),2019 Radon exposure and health, website access 06/09/2019,

https://www.arpansa.gov.au/understanding-radiation/radiation-sources/more-radiation-sources/radon

Australian Petroleum Production and Exploration Association Limited (APPEA). 2008. *Code of Environmental Practice*, Canberra, ACT.

AustRoads 2019, Guide To Traffic Management Part 12: Traffic Impacts of Developments

AustRoads 2017 Guide to Traffic Management Part 3: Traffic Studies and Analysis

Barkly Regional Council, 2018, *The Region*, website accessed 18 September 2018, https://www.barkly.nt.gov.au/region/demographics

Barrett, G., Silcocks, A., Barry, S., Cunningham, R., and Poulter, R. 2003. *The New Atlas of Australian Birds*. Royal Australasian Ornithologists Union, Melbourne.

Barkly Regional Council, 2018, *The Region*, website accessed 18 September 2018, https://www.barkly.nt.gov.au/region/demographics

Bubb, A. (2004). 'Pastoral industry survey 2004. Tennant Creek'. (Northern Territory Government: Darwin).

Cassman, EA., Griffin WM,. And Mitchell,AL. 2016. Lung Cancer risk from Radon in the Marcellus Shale Gas in Northeast US Home s, Society for Risk Analysis, Volume 36 (11), 2105-2119.

Commonwealth of Australia. 2001. Australian Native Vegetation Assessment 2001, Land and Water Australia, Canberra.

Christian CS, Noakes LC, Perry RA, Slatyer RO, Stewart GA and Traves DM. 1951. *Survey of the Barkly Region, Northern Territory and Queensland, 1947-48,* Land Research Series No. *3*, CSIRO, Melbourne, SA.

Churchill, S. 2008. *Australian Bats*. Second edition. Jacana Books, Crow's Nest.

Cogger, H.G. (2000). *Reptiles and Amphibians of Australia - 6th edition*. Sydney, NSW: Reed New Holland.

Cole, J. and Woinarski, J. 2002. *Field Guide to the Rodents and Dasyurids of the Northern Territory*. Surrey Beatty and Sons, Chipping Norton, NSW.

Cooney, S.J.N. (2009). *Ecological associations of the hooded parrot (Psephotus dissimilis)*. Ph.D. Thesis, Australian National University.

Curtis, Lee K., A. J. Dennis, K. R. McDonald, P. M. Kyne, and Debus S.J.S., Eds. (2012). *Queensland's Threatened Animals*. CSIRO Publishing, Collingswood.

Davie, R., Foulger, G., Bindley, A., and Styles,P. 2013. Induced seismicity and Hydraulic Fracturing for the recovery of hydrocarbons. Marine and petroleum geology, V45. Pp171-1785

Debus, S. (2012). *Birds of prey of Australia*, 2nd edition. CSIRO Publishing, Collingwood.

Department of the Environment (2014). *Tyto novaehollandiae kimberli in Species Profile and Threats Database*, Department of the Environment, Canberra. Available from: http://www.environment.gov.au/sprat. Accessed Wed, 10 Sep 2014.

Department of the Environment (2014). *Dasyurus hallucatus in Species Profile and Threats Database*, Department of the Environment, Canberra. Available from: http://www.environment.gov.au/sprat. Accessed Wed, 10 Sep 2014.

Department of Environment and Energy, State and Territory Greenhouse Gas Inventories 2016, published February 2018

Department of the Environment and Energy. 2018. Key threatening processes under the EPBC Act. http://www.environment.gov.au/biodiversity/threatened/key-threatening-processes, accessed14 September 2018.

Department of Environment and Natural Resource. 2018. *Daly Roper Beetaloo Water Control District*, Northern Territory Government, Darwin, NT.

Department of Natural Resources, Environment, The Arts and Sport (NRETAS) 2019. Land Clearing Guidelines. Northern Territory Government.

Department of Environment, Parks and Water Security (DEPWS). 2018a. Listing of "Threatened Animals", "Plants" and "Weeds", accessed August and September 2018. https://nt.gov.au/environment/animals/threatened-animals,

Department of Environment, Parks and Water Security (DEPWS). 2018b. *Northern Territory Stream Order*, *Strahler stream orders over the Northern Territory, topographic scale data 250k*, Spatial Data and Mapping Branch, Water Resources Division, Northern Territory Government, Darwin, NT.

Department of Land Resource Management. 2015. *Barkly Regional Weed Management Plan 2015 - 2020.*

Department of Land Resource Management and Charles Darwin University. 2018, *Guidelines for the Management of the Weeds of Beetaloo 2018.*

Department of Industry, Tourism and Trade (DITT). 2016. *Partheneum found in the NT.* https://dpir.nt.gov.au/news/2016/december/parthenium-found-in-the-nt accessed 14 September 2018.

Department of Natural Resources and Environment. 2018. *Weed Management Planning Guide - Onshore Shale Gas Development Projects.*

Dickman C.R. 2009. *House cats as predators in the Australian environment: impacts and management*. Human-Wildlife Conflicts 3:41-48.

Dickman, C. R. 1996. *Impact of exotic generalist predators on the native fauna of Australia*. Wildlife Biology 2(3):185-195.

Doody TM, Hancock PJ, Pritchard JL 2019. Information Guidelines explanatory note: Assessing groundwater-dependent ecosystems. Report prepared for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development through the Department of the Environment and Energy, Commonwealth of Australia 2018.

Dostine, P.L., and Franklin, D.C. 2002. *A comparison of the diet of three finch species in the Yinberrie Hills area, Northern Territory*. *Emu* 102:159-164.

Environment Australia. 1998. *Best Practice Environmental Management in Mining - Dust Control*, Canberra, ACT.

Environment Protection Agency. 1995. *Best Practice Environmental Management in Mining - Environmental Impact Assessment,* Canberra, ACT.

Environment Australia. 1997. *Best Practice Environmental Management in Mining - Hazardous Materials Management, Storage and Disposal*, Canberra, ACT.

Environment Australia. 1998. *Best Practice Environmental Management in Mining - Landform Design for Rehabilitation*, Canberra, ACT.

Environment Australia. 1998. *Best Practice Environmental Management in Mining - Noise, Vibration and Airblast Control*, Canberra, ACT.

Environment Protection Agency. 1996. *Best Practice Environmental Management in Mining - Onshore Minerals and Petroleum Exploration*, Canberra, ACT.

Faulks JJ, 2001. *Roper River Catchment - An Assessment of the Physical and Ecological Condition of the Roper River and its Major Tributaries, Technical Report No. 36/2001*. Natural Resources Division, Department of Lands, Planning and Environment, Katherine, NT.

Fisher, A. and Woinarski, J. 1994. *Golden Bandicoot*. *Australian Natural History* 26, 20-21.

Fisher A. 2001. *Biogeography and Conservation of Mitchell Grasslands in Northern Australia*, PhD Thesis, Faculty of Science, Information Technology and Education, Northern Territory University, Darwin, NT.

Fisher, A., Baker, B., Woinarski, J. 2002 *Biodiversity Audit – Bioregional Summaries*, Compilation of individual summaries for the National Land and Water Audit, Parks and Wildlife Service, NT.

Fitzsimons, P., Bond, M., and Webber, S. 2010. Creating a participatory adaptive capacity index for climate change adaptation - Report of engagement process in the South-West of Victoria. Department of Primary Industries Victoria (in press)

Fleming MR, Johnson KA, Latz PK and McKean JR. 1983. *A Biological Survey of Junction Stock Reserve and Newcastle Waters Pastoral Lease on The Barkly Tablelands*, Wildlife Research Section, Conservation Commission of the NT.

Fulton, S. and Knapton, A. (2015) *Beetaloo Basin Hydrogeological Assessment*. Prepared by CloudGMS

Garnett, S., J. Szabo & G. Dutson. 2011. *The Action Plan for Australian Birds 2010*. CSIRO Publishing.

GHD 2013, Vista Gold Australia Pty Ltd Mt Todd Gold Project Traffic and Transport Impact Assessment June, available at https://ntepa.nt.gov.au/__data/assets/pdf_file/0005/289625/appendixV_traffic_transport.pdf

Gibbons, R.D., Bhaumik, D.K. and Aryal S. (2009) Statistical Methods for Groundwater

Monitoring, Second Edition, Wiley374pp.

Gillespie, G. R., Brennan, K., Gentles, T., Hill, B., Low Choy, J., Mahney, T., Stevens, A., and Stokeld, D. (2015). A guide for the use of remote cameras for wildlife survey in northern Australia. Darwin: Charles Darwin University

Griffiths SR, Smith GB, Donato DB, Gillespie CG 2009a. Factors influencing the risk of wildlife cyanide poisoning on a tailing storage facility in the Eastern Goldfields of Western Australia. Ecotoxicology and Environmental Safety 72 (2009) 1579-1586

Griffiths SR, Smith GB, Donato DB, Lumsden LF, Coulson G., 2009b. Hypersalinity reduces the risk of cyanide toxicosis to insectivorous bats interacting with wastewater impoundments at gold mines. Ecotoxicology and Environmental Safety 99 (2014) 28-34

Groves RH and Williams OB. 1981. *Natural grasslands*. In Groves RH, (*ed*.) *Australian Vegetation,* pp. 293-316. Cambridge University Press, Melbourne.

Heinz Schandl, Tim Baynes, Nawshad Haque, Damian Barrett and Arne Geschke (2019). Final Report for Final Report for GISERA Project G2 - Whole of Life Greenhouse Gas Emissions Assessment of a Coal Seam Gas to Liquefied Natural Gas Project in the Surat Basin, Queensland, Australia. CSIRO, Australia

Heritage Surveys. 1999. *Additional archaeological assessments, Daly Waters to McArthur River Gas Pipeline, Northern Territory*, unpublished report to Northern Territory Power and Water Authority.

Hermes, M. 1986. *Amadeus Basin to Darwin Natural Gas Pipeline – Spread 2: Internal report on archaeological findings*, unpublished report to Museums and Art Galleries of the Northern Territory.

Higgins, P.J. & S.J.J.F. Davies, eds. 1996. *Handbook of Australian, New Zealand and Antarctic Birds. Volume Three - Snipe to Pigeons*. Melbourne, Victoria: Oxford University Press.

Hirano, T., M. Kiyota, et al. 1995. "*Physical effects of dust on leaf physiology of cucumber and kidney bean plants*." Environmental Pollution. vol. 89, no. 3, pp. 255-261.

HLA-Envirosciences Pty Ltd (HLA), 2005. *Environmental Management Plan: Onshore Petroleum Exploration Beetaloo Basin, NT.* Report prepared for Sweetpea Petroleum Pty Ltd.

HLA, 2006a. *An Analysis of Available Water Quality Data and Gap Analysis for Beetaloo Basin, Northern Territory.* Report prepared for Sweetpea Petroleum Pty Ltd.

HLA, 2006b. *Surface Water Quality Investigation, Beetaloo Basin, Northern Territory.* Report prepared for Sweetpea Petroleum Pty Ltd.

HLA, 2006c. *Sweetpea Petroleum Environmental Program 2006: Baseline Vegetation Assessment.* Report prepared for Sweetpea Petroleum Pty Ltd.

HLA, 2006d. *Archaeological Assessment 2006 for the Sweetpea Petroleum Seismic Program, Beetaloo Basin, NT, 2006.* Report prepared for Sweetpea Petroleum Pty Ltd.

HLA, 2006e. *Beetaloo Basin: Cooee Hill and 80 Metre Tower Archaeological Assessment*. Report prepared for Sweetpea Petroleum Pty Ltd.

HLA. 2006f. *Beetaloo Basin: Yaroo, South Martyr's Tree and Dunmarra Archaeological Assessment*, unpublished report for Sweetpea Petroleum.

HLA, 2007a. *Supplementary Environmental Management Plan, Drilling Program 2007, Beetaloo Basin, NT.* Report prepared for Sweetpea Petroleum Pty Ltd.

HLA, 2007b. *2007 Environmental Works Progress Report 1 (March to May 2007).* Letter to Sweetpea Petroleum dated 28 May 2007.

HLA, 2007c. *Groundwater Monitoring Program, Sweetpea Petroleum Exploration Program, Beetaloo Basin, NT.* Report prepared for Sweetpea Petroleum Pty Ltd.

HLA, 2007d. *Archaeological Assessment Newcastle Waters Proposed Drilling Site for the Sweetpea Petroleum Seismic Program, Beetaloo Basin, NT*, 2006. Report prepared for Sweetpea Petroleum Pty Ltd.

Hose GC, J Sreekanth, Barron O, Pollino C (2015) *Stygofauna in Australian Groundwater Systems: Extent of knowledge*. CSIRO, Australia.

Land and Water Australia, 2004. Australian Water Resources Assessment. In: *National Land and Water Resource Audit*, 2004. Canberra, ACT.

De León, L.F. & Castillo, A. 2015. RHINELLA MARINA (Cane Toad). SALINITY TOLERANCE. Herpetological Review 46(2):237-238.

Kerle, J.A., Foulkes, J.N., Kimber, R.G., and Papenfus, D. 1992. *The decline of the brushtail possum*, *Trichosurus vulpecula* (Kerr 1798), in arid Australia. Rangelands Journal 14, 107-127.

Land and Water Australia, 2004. Australian Water Resources Assessment. In: *National Land and Water Resource Audit*, 2004. Canberra, ACT.

Lloyd P., M. Sanders, T. Reis and A. Abbott. 2013. Targeted trapping surveys shed new light on the distribution and habitat characteristics of the Carpentarian pseudantechinus (*Pseudantechinus mimulus*), a threatened dasyurid marsupial. *Australian Mammalogy*. 35:220-223.

Mayes, P. J. 2006. The ecology and behaviour of *Varanus mertensi* (Reptilia: Varanidae). PhD Thesis. Edith Cowan University. Retrieved from http://ro.ecu.edu.au/theses/42.

McCue, K. 2013 Historical earthquakes in the northern Territory, Australian Earthquake Engineering Society, https://aees.org.au/wp-content/uploads/2013/11/McCue_NT_EQs.pdf. Accessed 21 January 2019.

Menkhorst, P. and Knight F. 2011. *A Field Guide to the Mammals of Australia*. Oxford University Press, Sydney.

Morcombe, M. 2000. *Field guide to Australian birds.* Steve Parish Publishing.

Noakes LC and Traves DM. 1951. *Outline of the Geology of the Barkly Region*. In: *Survey of the Barkly Region, Northern Territory and Queensland, 1947-48*. CSIRO Land Research Series No. 3.

North Australia Fire Information (NAFI), 2018. *Fire Maps*. http://www.firenorth.org.au Accessed 16 September 2018.

Northern Territory Government. 2015. *NT Weed Management Handbook*.

Northern Territory of Australia. 2017. *Northern Territory Weed ID Deck*.

Northern Territory Government. 2018. *A – Z List of Weeds in the Northern Territory*. https://nt.gov.au/environment/weeds/weeds-in-the-nt/A-Z-list-of-weeds-in-the-NT accessed 13 September 2018.

Northern Territory Government. 2005. *Integrated Natural Resource Management Plan for the Northern Territory*, Northern Territory Government.

Orr, DM. and Holmes, WE. 1984 *'Mitchell Grasslands*.' In G.N. Harrington, A.D. Wilson and M.D. Young (eds) *Management of Australia's Rangelands*, Australia, CSIRO: 241-254.

Palmer, C., Woinarski J., and Ward S. 2012. *Threatened Species of the Northern Territory: Gouldian Finch Erythrura gouldiae*. Department of Land Resource Management, Northern Territory Government.

Parks and Wildlife Commission of the NT. 2005. *Bullwaddy Conservation Reserve Plan of Management*, Parks and Wildlife Commission of the NT, Darwin.

Pavey, C. 2006. *National Recovery Plan for the Greater Bilby Macrotis lagotis*. Northern Territory Department of Natural Resources, Environment and the Arts.

Pizzey, G., Knight, F. and Pizzey, S. 2012. *The Field Guide to Australian Birds*. HarperCollins Publishers, Sydney.

Quaternary Archaeological Surveys. 1998. *Archaeological survey of the Stuart Highway to Mataranka Homestead Optic Fibre Cable Corridor, Northern Territory*, unpublished report for Telstra.

Randal MA. 1967. *Groundwater in the Barkly Tableland, NT*, Bulletin 91, Bureau of Mineral Resources, Geology and Geophysics, Canberra, ACT.

Rees GN, Oberprieler S, Nielsen D, Watson G, Shackleton M, Davis JA (2020) Characterisation of the stygofauna and microbial assemblages of the Beetaloo Sub-basin, Northern Territory. CSIRO,

Australia Ryder Scott Company (Ryder Scott), 2010. Evaluation of the Unconventional Oil Resource Potential Pertaining to Certain Acreage Interests in the Beetaloo Basin, Northern Territory, Australia. Report prepared for Falcon Oil and Gas Australia Pty Ltd.

Seismology Research Centre (SRC) 2017, Earthquakes in Australia, https://www.src.com.au/earthquakes/seismology-101/earthquakes-in-australia/ Accessed January 21 2019.

Southgate, R. I. & Paltridge, R. 1998. *Recovery of the Greater Bilby Macrotis lagotis*. Final Report for Project Number 185, Nature Australia, Biodiversity Group, Endangered Species Program and Feral Pests Program.

Smith, J.G., and Phillips, B.L. 2006.*Toxic tucker: the potential impact of cane toads on Australian reptiles*. Pacific Conservation Biology 12:40-49.

Smith, M.A. 1986. An investigation of possible Pleistocene occupation at Lake Woods, Northern Territory, *Australian Archaeology*, 22:60-72.

Tennant Creek Regional Economic Development Committee, 2014, Tennant Creek and Barkly Region Strategic & Action Plan 2014-2016, endorsed 28 October 2014, Northern Territory Government, https://nt.gov.au/ data/assets/pdf file/0007/198340/tennant-creek-and-barkly-region-strategic-and-action-plan.pdf

Tickell S.J. 2003. *Water Resource Mapping Barkly Tablelands*, Unpublished draft report prepared by the Department of Infrastructure Planning and Environment, Darwin, NT.

Trainor, C.R. 2005. *Distribution and Natural History of the Cryptic Dragon Chelosonia Brunnea: A Review of Records*. *Northern Territory Naturalist* 18:24-44.

United States Geological Survey (USGS) 2017 Induced Earthquakes, myths and misconceptions, https://earthquake.usgs.gov/research/induced/myths.php Accessed January 21 2019.

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). U.S. Environment Protection Agency, Washington, DC, EPA/600/R-16/236F, 2016.

Ward, S.J. 2008. Habitat-use, foraging and breeding ecology of the northern shrike-tit *Falcunculus frontatus whitei*. Report to NHT (Department of Natural Resources, Environment, the Arts and Sport, Darwin).

Ward, S.J., Berghout, M. and Baker, B. 2009. Notes on the form and habitat of nests of the northern shrike-tit. *Northern Territory Naturalist* 21:54-60.

Wilson, S. And Swan, G. 2010. *A Complete Guide to the Reptiles of Australia*. 2010. New Holland,Sydney.

Woinarski, J.C.Z. 2004a. *National Multi-species Recovery Plan for the Partridge Pigeon Geophaps smithii smithii, Crested Shrike-tit, Falcunculus frontatus whitei, Masked Owl Tyto novaehollandiae kimberli and Masked Owl Tiwi Islands Tyto novaehollandiae melvillensis 2004-2009*. Northern Territory Department of Infrastructure Planning and Environment. Available http://www.environment.gov.au/biodiversity/threatened/publications/recovery/smithii-whitei-kimberli-melvillensis/index.html.

Woinarski, J.C.Z. 2004b. National Multi-species Recovery Plan for the Carpentarian Antechinus *Pseudantechinus mimulus*, Butler's Dunnart *Sminthopsis butleri* and Northern Hopping-mouse *Notomys aquilo*, 2004 - 2009. . Northern Territory Department of Infrastructure Planning and Environment.

Woinarski J.C.Z., Pavey C., Kerrigan R., Cowie I. & Ward S. 2007. *Lost from our Landscape: Threatened Species of the Northern Territory*. Palmerston: Department of Natural Resources, Environment and the Arts.

Woinarski, J.C.Z. and Tidemann, S.C., 1991. *The bird fauna of a deciduous woodland in the wet-dry tropics of northern Australia*. *Wildlife Research* 18: 479-500.

Woinarski, J.C.Z and Ward, S. 2012. Threatened Species of the Northern Territory: Crested Shrike-tit *Falcunculus (frontatus) whitei*. Department of Land Resource Management, Northern Territory Government.

10 Acronyms and 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) (Cmwlth))
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

Acronym	Meaning
EP	Exploration Permit (e.g. EP76, EP98 and EP117)
EPA	Environment Protection Authority (NT)
EPBC	Environment Protection and Biodiversity Conservation Act
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
Ml	Local Magnitude

Acronym	Meaning
Mm	millimetre
mMDRT	Meters measured depth below rotary table
MNES	Matters of National Environmental Significance
SDS	Safety Data Sheet
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
TPWC Act	*Territory Parks and Wildlife Conservation Act*
TRH	Total Recoverable Hydrocarbons
TSS	Total Suspended Solids
VOCs	Volatile Organic Compounds
WBIV	Well barrier integrity verification

Acronym	Meaning
WEL	Water Extraction Licence
WIMP	Well Integrity Management Plan
WMP	Weed management Plan
WOMP	Well Operations Management Plan
WoNS	Weed of National Significance
WWMP	Wastewater Management Plan