



## Beetaloo JV

# 2016 HYDRAULIC STIMULATION AND WELL TESTING EP: AMUNGEE NW-1H, AND BEETALOO W-1 OR NUTWOOD DOWNS SW-1

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## 1. Introduction

### 1.1 Background

On 21 August 2014, a Farm-Out Agreement and Joint Operating Agreements were finalised between Falcon Oil and Gas Pty Ltd (Falcon), Origin Energy Resources Limited (Origin) and Sasol Limited (Sasol) for ongoing petroleum exploration activities within the Barkly region, Northern Territory, known as the Beetaloo Joint Venture (Beetaloo JV).

The exploration permits now cover 18,512 square kilometres (km<sup>2</sup>) of pastoral lease on the Sturt Plain, part of the Barkly Tableland, Northern Territory (Figure 1), and were originally granted by the NT Minister for Mines and Energy under previous version of the *Petroleum Act 2016*, as follows:

- 8 March 2001: EP76
- 4 February 2004: EP98 and EP99
- 14 March 2006: EP117.

On the 1 January 2014 the DME granted the permit areas to the Beetaloo Joint Venture (Beetaloo JV), with the exception of EP99 and small sections of the other permit areas being handed back.

Origin, as the operator of the permit areas for the Beetaloo JV, has lodged a 2016 Exploration Drilling Environmental Plan for its 2016 program with the Department of Mines and Energy (DME) and is now lodging a 2016 Hydraulic Stimulation and Well Testing Environmental Plan (Stimulation and Testing EP) to support its work program (refer Table 1).

Table 1 Work Program for EP76, 98 and 117

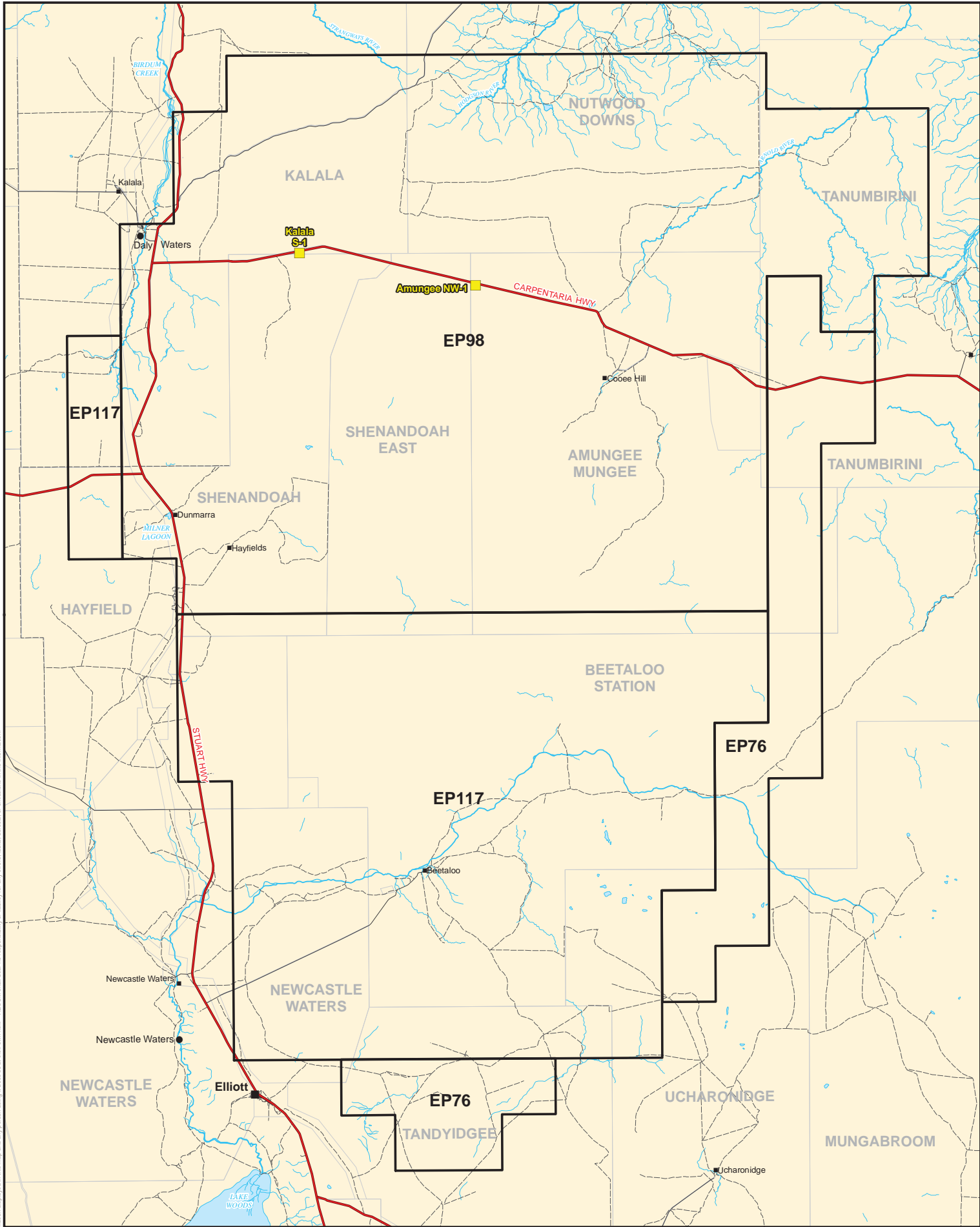
5 YEAR WORK PROGRAM					
EP	2014	2015	2016	2017	2018
<b>98</b>	Geological and geophysical studies	2 vertical wells, 1 horizontal well	1 HFS vertical well, 1 HFS horizontal well	Geological and geophysical studies, core studies	2 HFS horizontal wells Production testing Geological and geophysical studies
<b>117</b>	Geological and geophysical studies	Geological and geophysical studies	1 vertical well,	2 HFS horizontal wells Production testing Geological and geophysical studies	Geological and geophysical studies
<b>76</b>	Geological and geophysical studies	Geological and geophysical studies	Geological and geophysical studies	Geological and geophysical studies	Geological and geophysical studies

\*HFS  
Hydraulic Fracture Stimulation

This Stimulation and Testing EP addresses the proposed stimulation and testing of a number of wells during 2016 to fulfil work program commitments made to the NT government. The 2016 stimulation and testing program involves:

- Diagnostic fracture injection tests (DFITs)
- Hydraulic fracture stimulation (HFS)
- Well testing

Origin is seeking approval for the DFITs, HFS and testing operations of two wells (Amungee NW-1H and one of either Beetaloo W-1 or Nutwood Downs SW-1) targeting the Velkerri and Kyalla formations (refer to Figure 2 for the location of the sites within the Exploration Permits).



0 5 10 20  
Kilometers  
1:570,000 (when printed at A3)

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**LEGEND**

- Homestead
- Place Name
- Populated Place
- Existing Wells
- Highway
- Minor Road
- Tracks
- River
- Creek
- Cadastre
- Permit Areas

**LOCATION**

**ORIGIN ENERGY RESOURCES LIMITED  
2016 DRILLING ENVIRONMENTAL PLAN**

Location

PROJECT ID	60480548
CREATED BY	justin.dwyer
LAST MODIFIED	26-Feb-2016
VERSION	1

**Figure  
1**

## 1.2 Project Boundary

For the purpose of this Stimulation and Testing EP, the project boundaries are defined as the areas already disturbed in accordance with Origin's 2015 and 2016 Exploration Drilling EPs for the Amungee NW-1H, Beetaloo W-1 and Nutwood Downs SW-1 sites. No additional ground disturbance is required to undertake the stimulation and testing program.

**Table 2** Coordinates of Centroid of Stimulation and Testing Site

Exploration Permit	Well Name	Zone*	Easting	Northing
EP98	Amungee NW-1H	53	391676	8190013
EP98	Nutwood Downs NW-1	53	370771	8226069
EP117	Beetaloo W-1	53	368312	8106695

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

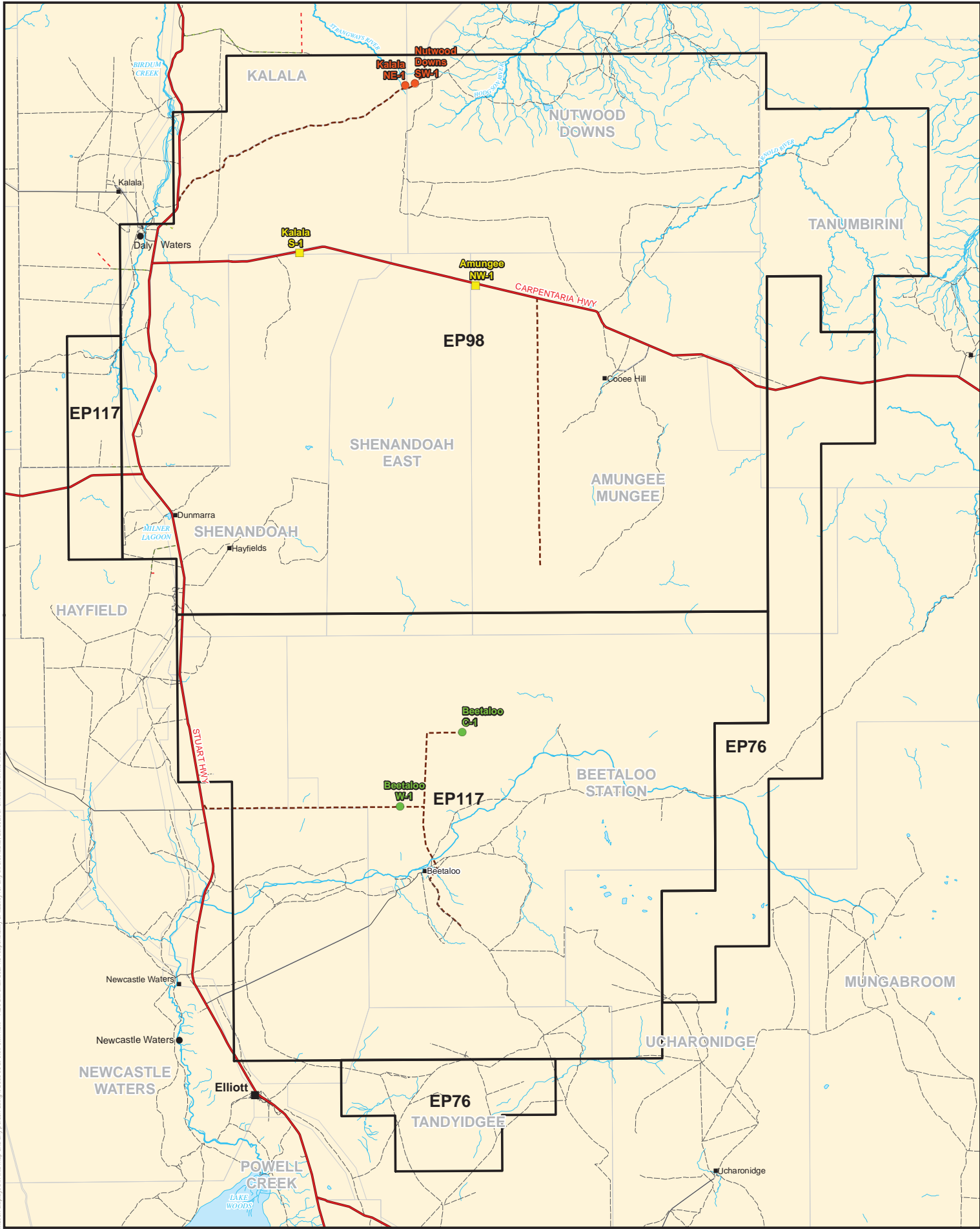
## 1.3 Objectives of the EP

Prior to commencing a stimulation and testing program Origin is required to provide a site-based EP for its proposed program to DME, the NLC and other relevant authorities (i.e. NT Environmental Protection Authority) for comment and approval. This Stimulation and Testing EP has been prepared with reference to clauses in the *Schedule of Onshore Petroleum Exploration and Production Requirements 2012*, Section 58 of the *NT Petroleum Act 2016* and the Exploration Agreement between Origin, local Aboriginal groups and the NLC.

The overall objective of the Stimulation and Testing EP is to ensure minimal environmental impact and minimise risk of any inadvertent adverse outcomes from Origin's activities in the Beetaloo Sub-basin.

Specifically, this Stimulation and Testing EP aims to:

- be a practical and usable document, with environmental management principles that are easily implemented and effective
- address regulatory requirements
- provide a description of site-specific aspects of the existing environment (physical, biological, social, cultural)
- provide site-specific impact management strategies to assist Origin in maintaining a positive position in the local community throughout its program
- provide site-specific plans for review, monitoring and rehabilitation.



0 5 10 20  
Kilometers

1:570,000 (when printed at A3)

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**LEGEND**

■ Homestead	--- Tracks
● Place Name	--- Access Routes
■ Populated Place	--- Existing Tracks
■ Existing 2016	--- Proposed New Tracks
● Proposed 2015	--- River
● Proposed 2016	--- Creek
* Other Drill Sites	--- Cadastre
--- Highway	■ Permit Areas
--- Minor Road	

**LOCATION**

**ORIGIN ENERGY RESOURCES LIMITED  
2016 DRILLING ENVIRONMENTAL PLAN**

**Location of Permit Areas, Proposed Test Wells and Access Tracks, 2016 Program**

PROJECT ID	60480548
CREATED BY	Justin Dwyer
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VERSION	1

**Figure  
2**



## 1.4 Regulatory Framework

In the NT, the granting of exploration permits and approval to commence petroleum exploration activities (which includes stimulation and well testing) rests with Department of Mines and Energy (DME), through its administration of the *Petroleum Act 2016* on behalf of the NT Minister for Mines and Energy.

Alongside the DME approval process, the Northern Territory Environment Protection Authority (NT EPA) administers the *Environmental Assessment Act 2013*; which allows for all proposals to be assessed as to the level of significance of potential impacts. The application to drill will be submitted to DME, and they will engage the relevant authorities for advice.

The NT EPA may also provide informal advice as to the need to refer a proposal to the Commonwealth Department of the Environment (DOTE), under the provisions of the *Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)*, as amended 2013.

In some instances, DOTE may require a formal environmental assessment, despite NT EPA not requiring the same under the *NT Environmental Assessment Act 2013*. This could occur, for example, if the proposal was to create a substantial impact on Commonwealth land, outside of the jurisdiction of the *NT Environmental Assessment Act*.

A summary of the environmental approvals process for petroleum exploration in the NT is provided below.

### 1.4.1 NT Department of Mines and Energy

An exploration permit or licence can be granted by DME in relation to any land within the NT and generally provides the holder with a conditional right of access to land specified in the permit to carry out exploration activities and sampling for a specified range of resources, as well as conditional access to land for supporting activities such as cultural heritage and environmental surveys.

An application for an exploration licence or permit in the NT must include a works program, outlining details of proposed exploration methods and expected expenditure, and inclusive of an Exploration Plan. In addition, the works program is to include:

- evidence of Sacred Site clearance and Authority Certificates from the Aboriginal Areas Protection Authority (AAPA)
- evidence of archaeological assessment and approval to proceed from the Heritage Branch
- evidence of agreement with land holders for the program to proceed.

This works program has to satisfy the Minister for Mines and Energy, who grants the licence and who may also impose title specific conditions. In addition, notice of the works program is advertised in the government gazette or a local newspaper.

DME also has a Security Assessment Board, which has authority to approve rehabilitation plans, and to which securities that rehabilitation will occur are provided.

### 1.4.2 Environment and Heritage Assessment Division of DLPE

Should this stimulation and testing EP be referred by the DME to the NT EPA, the NT EPA will review and provide advice to DME as to whether the proposal is required to be assessed under the *Environment Assessment Act 2013*. Should formal assessment be required, NT EPA will assess the extent, duration and significance of potential impacts, and make a recommendation on the level of assessment required by the proponent. The outcomes of such an assessment could result in any one of the following recommendations:

- approval of the EP
- requests for additional information
- preparation of a Public Environmental Report (PER), or
- preparation of a Draft Environmental Impact Statement (EIS) and Supplement.

If the proposal is to impact on a declared conservation or other reserve, approval to proceed cannot be issued prior to consideration of the opinion of the Minister administering the *Territory Parks and Wildlife Conservation Act 2013*.

### 1.4.3 Commonwealth DOTE

Should the proposal be required to be referred to the DOTE, a separate referral document is required to be prepared, following DOTE guidelines. The referral is assessed by DOTE, which can result in any of the following recommendations:

- not controlled action, where approval is not required if the action is taken in accordance with the referral
- not controlled action 'Particular Manner', where approval is not required if the action is taken in accordance with the manner specified, or
- controlled action, where the action is subject to the assessment and approval process under the *EPBC Act*.

Controlled Actions can be assessed under an accredited State/Territory process, such as that undertaken by NT EPA and DME. In this case, NT EPA would prepare the assessment report, which the Commonwealth Minister uses to make a decision to approve, approve with conditions or not approve the proposed action.

#### 1.4.4 Northern Land Council

Petroleum exploration in the Beetaloo Sub-basin is also subject to an Agreement between the proponent and the Northern Land Council (NLC), which has provisions under the *Native Title Act 1993* for (amongst others):

- opportunity to comment on the EP and provide approval to proceed
- Indigenous employment
- Sacred Site clearance.

#### 1.4.5 Legislation and Guidelines

A range of legislation and guidelines are relevant to the activities described in this Stimulation and Testing EP, as summarised in Table 3.

Table 3 Relevant Legislation, Guidelines and Agreements

NT Legislation	Administered By:
<b><i>Petroleum Act 2016 and associated Regulations and Schedule of Onshore Petroleum Exploration &amp; Production Requirements 2012</i></b> <ul style="list-style-type: none"> <li>- Provides a legal framework to undertake exploration for petroleum and to develop petroleum production so that the optimum value of the resource is returned to the NT.</li> <li>- Regulates the exploration for, and production of petroleum, including environmental protection measures which should be employed during exploration and production activities, including protection of parks and reserves and rehabilitation.</li> <li>- Provides legal framework within which persons are encouraged to undertake effective exploration for petroleum and to develop petroleum production so that the optimum value of the resource is returned to the Territory.</li> <li>- Most current petroleum permits and licences are governed by the <i>Petroleum Act</i> (Act).</li> <li>- Subject to section 82 of the Act, where a person is given the right to occupy land as a permittee or licensee, he shall have, for himself, his employees, agents and contractors, a right to construct a road or carry out other work to ensure access to the exploration permit or licence area by the shortest practicable route to a road, within the meaning of the <i>Control of Roads Act</i>, a railway line, the sea or a waterway.</li> <li>- In addition, the Act is supported by the <i>Petroleum Regulations</i> (Regulations) and the <i>Schedule of Onshore Petroleum Exploration and Production Requirements 2012</i> (Requirements).</li> <li>- The Act, Regulations and Requirements are administered by the Northern Territory Petroleum Registry (Registry) which forms part of the DME. The Minister for Mines and Energy (Minister) is the applicable Minister for the purposes of the Act.</li> </ul>	Department of Mines and Energy
<b><i>Petroleum (Prospecting &amp; Mining) Regulations 2001</i></b> <ul style="list-style-type: none"> <li>- These Regulations are made for the purposes of the <i>Petroleum (Prospecting and Mining) Act</i> that in accordance with section 119(2) of the Petroleum Act continues in force in respect of leases granted under Petroleum (Prospecting and Mining) Act (referred to as the repealed Act in section 119).</li> <li>- Relates to the rent increase to cover GST component from period after 30 June 2000.</li> </ul>	Department of Mines and Energy
<b><i>Aboriginal Land Act 2013</i></b> <ul style="list-style-type: none"> <li>- Provides for access to Aboriginal land, certain roads bordered by Aboriginal land and the seas adjacent to Aboriginal land.</li> <li>- Provides that a person shall not enter onto or remain on Aboriginal land or use a road unless he has been issued with a permit to do so in accordance with this Part II Entry onto Aboriginal land of the Act.</li> <li>- Land Council for the area in which Aboriginal land or a road is situated may issue a permit to a person to enter onto and remain on that Aboriginal land or use that road subject to such conditions as the Land Council thinks fit</li> </ul>	Land Council established by or under the Aboriginal Land Rights (Northern Territory) Act 1976 of the Commonwealth.
<b><i>Northern Territory Aboriginal Sacred Sites Act 2013 and associated Regulations</i></b>	Aboriginal Areas



<ul style="list-style-type: none"> <li>- Generally refers to land other than Aboriginal land.</li> <li>- Provides a practical balance between the recognized need to preserve and enhance Aboriginal cultural tradition.</li> <li>- Provides Aboriginal and all other peoples of the Territory for economic, cultural and social advancement.</li> <li>- Provides entry onto sacred sites and the conditions to which such entry is subject.</li> <li>- Provides for the protection and registration of sacred sites, through establishing: <ul style="list-style-type: none"> <li>• procedures for avoidance of such sites when developing and using land</li> <li>• procedures for the review of decisions of the Authority by the Minister, and for related purposes</li> <li>• an Authority for the purposes of the Act.</li> </ul> </li> </ul>	Protection Authority (AAPA)
<p><b>Heritage Act 2015 and associated Regulations</b></p> <ul style="list-style-type: none"> <li>- Protects both natural and cultural heritage.</li> <li>- Establishes the Heritage Council (consisting of eleven members).</li> <li>- Establishes the NT Heritage Register.</li> <li>- Sets the process by which places become heritage places.</li> <li>- Allows for interim protection of places.</li> <li>- Sets out the process for getting permission to do work to heritage places.</li> <li>- Allows for fines and imprisonment for offences against the Act.</li> <li>- Declares classes of places and objects of heritage significance to be protected.</li> <li>- Provides for heritage agreements to encourage the conservation, use and management of heritage places and objects.</li> <li>- Regulates work on heritage places and objects.</li> <li>- Establishes enforcement and offence provisions.</li> </ul>	Heritage Branch, Department of Lands, Planning and Environment
<p><b>Soil Conservation and Land Utilisation Act 2013</b></p> <ul style="list-style-type: none"> <li>- Provides for the prevention of soil erosion and for the conservation and reclamation of soil.</li> </ul>	Soil Branch, Department of Land Resource Management
<p><b>Biological Control Act 2016</b></p> <ul style="list-style-type: none"> <li>- Provides for the biological control of pests in the NT and related purposes.</li> </ul>	Department of Primary Industry and Fisheries
<p><b>Plant Health Act 2015</b></p> <ul style="list-style-type: none"> <li>- Provides the framework to ensure appropriate actions can be taken for the control of pests; and facilitates the production and trading of plants and plant products that are free from pests</li> </ul>	Department of Primary Industry and Fisheries
<p><b>Control of Roads Act 2015</b></p> <ul style="list-style-type: none"> <li>- Provides for the administration and control of roads, including the maintenance of roads, construction and opening and closing of roads.</li> </ul>	Department of Transport
<p><b>Energy Pipelines Act 2015</b></p> <ul style="list-style-type: none"> <li>- Provides for the construction, operation, maintenance and cessation of use or abandonment of pipelines for the conveyance of energy-producing hydro-carbons, and for related purposes.</li> <li>- Where a person desires to construct a pipeline, he may apply to the Minister for a permit to enter land for the purpose of determining the route of the proposed pipeline, the situation of proposed apparatus or works and the land, if any, to be used for the purpose of gaining access to the proposed pipeline and proposed apparatus or works.</li> </ul>	Department of Mines and Energy
<p><b>Environmental Assessment Act 2013 and associated Regulations</b></p> <ul style="list-style-type: none"> <li>- Provides for the assessment of the environmental effects of development proposals and for the protection of the environment.</li> <li>- Ensures to the greatest extent practicable that matter affecting the environment is fully examined and taken into account.</li> <li>- Defines environment as being "all aspects of the surroundings of man including the physical, biological, economic, cultural and social aspects".</li> </ul>	Northern Territory Environmental Protection Authority
<p><b>Environmental Offences and Penalties Act 2011</b></p> <ul style="list-style-type: none"> <li>- Establishes penalties for certain offences under prescribed Acts (such as an environmental offence) and for related purposes.</li> </ul>	Department of Lands, Planning and the Environment
<p><b>Public and Environment Health Act 2015 and associated Regulations</b></p> <ul style="list-style-type: none"> <li>- This Act provides a framework for regulations to be prescribed for all public health matters.</li> <li>- Protect and promote the health of individuals and communities from emerging environmental conditions, or public and environmental health issues, that may impact on their health and wellbeing.</li> </ul>	Department of Health

<ul style="list-style-type: none"> <li>- Protect individuals and communities who are at public health risk or facing particular health problems.</li> <li>- Improve public and environmental health outcomes in partnership with individuals and the community.</li> <li>- Provides for the monitoring, assessing and controlling of environmental conditions, factors and agents, facilities and equipment and activities, services and products that impact on or may impact on public and environmental health.</li> </ul>	
<b><i>Public Health (General Sanitation, Mosquito Prevention, Rat Exclusion and Prevention) Regulations 1988</i></b> <ul style="list-style-type: none"> <li>- Makes provision to protect and promote the health of individuals and communities in the Territory, and to monitor, assess and control environmental conditions, factors and factors and agents, facilities and equipment and activities, services and products that impact on or may impact on public and environmental health.</li> <li>- Relates to public health and is directed at preventing pollution of water-courses and water supplies in the Northern Territory. Wastewater treatment systems may be subject to requirements under the Public Health Act and Regulations. Sewerage Plants need to meet the NT Code of Practice for Small On-site Sewage and Sullage Treatment Systems and the Disposal or Reuse of Sewage Effluent</li> </ul>	Department of Health
<b><i>Bushfires Act 2014 and associated Regulations</i></b> <ul style="list-style-type: none"> <li>- Relates to the prevention and suppression of bushfires</li> <li>- Outlines regulations and established penalties for certain acts relating to lighting fires.</li> </ul>	Bushfires NT, Department of Land Resource Management
<b><i>Fire and Emergency Act 2015</i></b> <ul style="list-style-type: none"> <li>- Provides primarily for the establishment of the NT Fire and Rescue Service, the operational and emergency response activities of the Service, the protection of life, property and the environment against fires and other emergencies.</li> </ul>	Northern Territory Fire and Rescue Service
<b><i>Territory Parks and Wildlife Conservation Act 2014 (TPWC Act) and associated Regulations</i></b> <ul style="list-style-type: none"> <li>- Provides for the protection, conservation and sustainable utilisation of wildlife.</li> <li>- Provides protection of CEEVNT listed species.</li> </ul>	Flora and Fauna Division of the Department of Land Resource Management
<b><i>Waste Management and Pollution Control Act 2016 and associated Regulations</i></b> <ul style="list-style-type: none"> <li>- Protects and where practicable restores and enhances the quality of the NT environment</li> <li>- Encourages ecologically sustainable development and facilitates the implementation of National Environment Protection Measures established by the National Environment Protection Council.</li> <li>- Section 12 of the Act places obligation on a person to ensure they take all practicable measures to prevent or minimise pollution when undertaking an activity that could cause pollution and environmental harm.</li> </ul>	Northern Territory Environmental Protection Authority
<b><i>Work Health and Safety (National Uniform Legislation) Act 2014</i></b> <ul style="list-style-type: none"> <li>- Provides for a balanced and nationally consistent framework to secure the health and safety of workers and workplaces.</li> </ul>	NT WorkSafe
<b><i>Water Act 2013</i></b> <ul style="list-style-type: none"> <li>- Provides for the investigation, allocation, use, control, protection, management and administration of water resources, including extraction of groundwater, waste management and water pollution.</li> </ul>	Water Resources Division, Department of Land Resource Management
<b><i>Weeds Management Act 2013</i></b> <ul style="list-style-type: none"> <li>- Identifies declared weeds (those which must be controlled) and provides a framework for weed management.</li> <li>- Protects the Territory's economy, community, industry and environment from the adverse impact of weeds.</li> </ul>	Weed Management Branch, Department of Land Resource Management
<b><i>Dangerous Goods Act 2012 and Regulations</i></b> <ul style="list-style-type: none"> <li>- Provides for the safe storage, handling and transport of certain dangerous goods.</li> </ul>	NT WorkSafe
<b>Commonwealth Legislation</b>	<b>Administered By:</b>
<b><i>Aboriginal and Torres Strait Islander Heritage Protection Act 1984</i></b> <ul style="list-style-type: none"> <li>- Provides for the preservation and protection of places, areas and objects from injury or desecration of particular significance to Aboriginal people in accordance with Aboriginal tradition.</li> </ul>	Department of the Environment
<b><i>Environment Protection and Biodiversity Conservation Act 1999</i></b>	Department of the

<ul style="list-style-type: none"> <li>- Provides for the protection of the environment and conservation of biodiversity, particularly species and places of national significance.</li> <li>- Invoked only if a development is likely to have environmental impacts of national significance.</li> </ul>	Environment
<b>Aboriginal Land Rights (Northern Territory) Act 1976</b> <ul style="list-style-type: none"> <li>- Provides for the granting of Traditional Aboriginal Land in the Northern Territory for the benefit of Aboriginals, and for other purposes.</li> </ul>	Department of Prime Minister and Cabinet
<b>Native Title Act 1993</b> <ul style="list-style-type: none"> <li>- Provides for the recognition and protection of native title for Indigenous peoples.</li> <li>- Establishes ways in which future dealings affecting native title may proceed and to set standards for those dealings.</li> <li>- Establishes a mechanism for determining claims to native title.</li> <li>- Provides for the validation of past acts, and intermediate period acts, that have been invalidated because of the existence of native title.</li> </ul>	Native Title Tribunal
<b>Australian Heritage Council Act 2003</b> <ul style="list-style-type: none"> <li>- Establishes the Australian Heritage Council which is the principal adviser to the Australian Government on heritage matters.</li> <li>- The Council's major role is to assess the heritage values of places nominated for the National Heritage List and the Commonwealth Heritage List, and to advise the Minister on promotion, research, education, policies, grants, conservation and other matters</li> <li>- The Council also makes assessments under the <i>EPBC Act</i>, and performs any other functions conferred on the Council by the <i>EPBC Act</i></li> </ul>	Department of the Environment
<b>National Environment Protection Council Act 1994</b> <ul style="list-style-type: none"> <li>- The object of this Act is to ensure that, by means of the establishment and operation of the National Environment Protection Council               <ul style="list-style-type: none"> <li>a) people enjoy the benefit of equivalent protection from air, water or soil pollution and from noise, wherever they live in Australia; and</li> <li>b) decisions of the business community are not distorted, and markets are not fragmented, by variations between participating jurisdictions in relation to the adoption or implementation of major environment protection measures.</li> </ul> </li> <li>- Provides national standards for ambient air quality, movement of controlled wastes, and contaminated sites.</li> <li>- The Commonwealth, the States, the Australian Capital Territory, the Northern Territory and the Australian Local Government Association have entered into an Agreement known as the Intergovernmental Agreement on the Environment setting out certain responsibilities of each party in relation to the environment.</li> </ul>	Department of the Environment
<b>Agreements</b>	<b>Administered By:</b>
<b>Native Title Agreement between NLC and Origin</b> <ul style="list-style-type: none"> <li>- Details the environmental and cultural protection measures to be included in the Exploration EP.</li> </ul>	Northern Land Council
<b>Exploration Permits</b> <ul style="list-style-type: none"> <li>- Details the environmental protection measures to be included in the Exploration EP.</li> </ul>	Department of Mines and Energy
<b>Guidelines</b>	
<b>AS 1940: The storage and handling of flammable and combustible liquids, 2004</b> <ul style="list-style-type: none"> <li>- Provides guidance for the operation and handling of flammable and combustible liquids.</li> </ul>	
<b>Codes of Practice of the Australian Petroleum Producing Exploration Association</b> <ul style="list-style-type: none"> <li>- Provides guidance for environmental management during petroleum exploration and production activities.</li> </ul>	
<b>Environmental Health Program Directorate Code of Practice for Small On-site Sewage and Sullage Treatment Systems and the Disposal or Reuse of Sewage Effluent, 2014</b> <ul style="list-style-type: none"> <li>- Provides guidance of the management of effluent.</li> </ul> <p>It is noted that Territory Health Services will issue any amendments to the above Code on an annual basis.</p>	
<b>ISO 19011: Guidelines for quality and/or environmental management systems auditing, 2002</b> <ul style="list-style-type: none"> <li>- Provides guidance on environmental auditing to a certifiable standard.</li> </ul>	
<b>The Northern Territory Dangerous Goods Regulations and Australian Standard 1985 (as amended 2014)</b> <ul style="list-style-type: none"> <li>- Provides regulation and guidance on appropriate storage requirements for on-site fuel tanks.</li> </ul>	
<b>Northern Territory Pastoral Land Clearing Guidelines (NT Pastoral Land Board, 2010)</b> <p>Although clearing for roads or tracks is a significant cause of erosion on pastoral leases, there is no requirement to obtain formal approval from the Pastoral Land Board. Instead, clearing must be carried out in accordance with Land Clearing Guidelines (NRETAS, 2010).</p>	

**Integrated Natural Resource Management Plan for NT (NT Government, 2011)**

- Describes the current condition, use and threats, and provides possible management solutions for the Territory's natural resources and environments
- Includes guidance for improved management of pastoral land, through control of weeds, responsible clearing, prevention of overstocking and reduction in wildfire occurrence.

**Best Practice Erosion and Sediment Control (International Erosion Control Association, 2008)**

- Facilitates the identification of those issues that should be considered when formulating and evaluating strategies for best practice erosion and sediment control
- Facilitates best practice stormwater management
- Facilitates active avoidance or minimisation of soil erosion resulting construction activities
- Facilitate best practice soil and sediment control management on sites.

**Australian Best Practice Guidelines including:**

- Best Practice Environmental Management in Mining (1998) - Dust Control
- Best Practice Environmental Management in Mining - Environmental Impact Assessment (1995)
- Best Practice Environmental Management in Mining - Hazardous Materials Management, Storage and Disposal (1997)
- Best Practice Environmental Management in Mining - Noise, Vibration and Airblast Control (1998)
- Best Practice Environmental Management in Mining - Onshore Minerals and Petroleum Exploration (1996)

## 1.5 Structure of EP

This Stimulation and Testing EP is structured as follows:

- Section 1 – provides background information to the program
- Section 2 – provides a detailed description of the proposed program
- Section 3 – describes the existing environment in detail, including the site location, site history and the physical, natural and social environment of the permit areas
- Section 4 – provides detail on stakeholder consultation
- Section 5 – describes the potential impacts and risks associated with the program, how these can be managed or mitigated, responsibilities for management and monitoring and performance measurement
- Section 6 – provides the implementation strategy
- Section 7 – provides a rehabilitation strategy for the proposed exploration program
- Appendices – ancillary information in support of the EP.

## 1.6 Corporate Environmental Policy

A copy of Origin's Health, Safety and Environment Policy is contained in Appendix A.

## 2.0 Description of Program

### 2.1 Proposed timetable

Origin Energy is the operator for the Beetaloo Basin Joint Venture (Origin Energy 35%, Sasol 35% and Falcon Oil and Gas 30%). The overall Project is made up of three stages of exploration which will take place over a five year permit term. This term is granted by the Department of Mines and Energy (DME) on behalf of the Northern Territory Government (NTG). Origin will be the operator of the permits on behalf of their joint venture partners.

This Stimulation and Testing EP identifies the current plan to stimulate one horizontal exploration well and one vertical exploration well in EP98 and EP117, Amungee NW-1H (horizontal) and Beetaloo W-1 or Nutwood Downs SW-1 (vertical). The selection of the vertical stimulation well will be finalised after the wells have been drilled and analysed.

The data acquired from the 2016 stimulation and testing program will be used to shape decisions for subsequent years of the exploration program.

### 2.2 Proposed Stimulation and Testing Activities

The stimulation and testing activities for the 2016 program consist of:

- Conducting a DFIT of each well. The DFIT is a leak off test designed to understand key reservoir and HFS parameters including stresses, pore pressure, and permeability. The DFIT consists of injecting a small volume of fluid (1-5 m<sup>3</sup>) without proppant into the formation. The pressure falloff is then monitored to estimate the reservoir and HFS parameters.
- The fluid used in the DFIT will either be the drilling suspension fluid if the DFIT is executed prior to the first HFS stage or the HFS fluid if the DFIT is executed after the first HFS stage.
- Hydraulic Fracture operations of the nominated well sites including:
  - construction of water storage facilities on existing well leases
  - stimulation of up to 10-12 stages in Amungee NW-1H horizontal well in the Velkerri Shale formation
  - stimulation of 1-4 stages in the vertical (Beetaloo W-1 or Nutwood Downs SW-1) well targeting the Velkerri and Kyalla formations
  - coiled tubing intervention
  - wireline intervention
  - construction of an on-site office and living accommodation for 24 hour operations and activities.
- Completion operations of nominated well sites including:
  - Service rig intervention to install production tubing
- Well testing operations of nominated well sites including:
  - 30 to 90 day production test at Amungee NW-1H
  - 30 day production test at Beetaloo W-1 or Nutwood Downs SW-1.

Upon completion of the stimulation and well test program, the wells will be suspended. Origin will seek approval from the DME for each well suspension. Origin understands that no future activities are approved through this application and further activities would be subject to a separate application to the DME.

#### 2.2.1 Stimulation / Well Test Schedule

It is proposed that stimulation activities will commence during the dry season of 2016 for the two wells. The proposed order of the sites and estimated durations are provided below:

1. Amungee NW-1H: 40 days DFIT/stimulation/completion operations and 30 to 90 day well test
2. Beetaloo W-1 or Nutwood Downs SW-1: 21 days DFIT/stimulation/completion operations and 30 days well test

This order is subject to change, dependent on drilling operations and source water availability.

### 2.2.2 Stimulation and Well Test Crew and Equipment

Preliminary estimates of the crew and equipment associated with the stimulation and well test program are described in Table 4.

**Table 4** Stimulation and well test crew and equipment (estimate)

Task	Crew List	Equipment and Machinery
DFIT	1 x Origin Supervisor 1 x Cement Pumping Supervisor 2 x Cement Pump Operators 1 x Engineer	- Cement pumping unit x 1 - Surface iron/manifold package
Fracture Stimulation	2 x Origin Supervisors 2 x Origin Engineers 1 x Frac Supervisor 10 x Pump operator 2 x Mechanic/E-tech 1 x Frac engineer	- Pumping units x 9 - Hydration unit x 1 - Sand chief x 2 - Blender x 2 - Frac tanks x 2 - Pump Manifold x1 - Chemical trailer x 1 - Water storage facilities
Service Rig	1 x Rig manager 2 x Driller 2 x Floor hand 2 x Derrick man 2 x Lease hand 2 x motor man	- Service Rig and associated equipment
Coiled Tubing	2 x Coil Supervisor 4 x Coil/Pump operator/ Dogman 2 x N2 operator 2 x Crane operator	- Coiled tubing unit and associated equipment - Crane
Accommodation	2 x Cooks 2 x Camp Staff	- Camp
Wireline	4 x Wireline operations 2 x Wireline engineers	- Wireline unit and associated equipment
Flowback	4 x Flowback operators	- Flowback tanks and manifold equipment
Well test	4 x Well test operators	- Test separator - Flare stack - Manifold system

### 2.2.3 Proposed Stimulation Fluid Additives

HFS fluid mixtures typically comprise 99% water, sand and guar gum (if required) by volume with the remaining 1% made up of salts and fluid additives. Fluid additives used in HFS are commonly found in food and other household domestic products.

All chemicals used in Australia must be approved for use by the Federal Government, Department of Health and listed on the Australian Inventory of Chemical Substances (AICS) which is maintained under the National Industrial Chemicals Notification and Assessment Scheme (NICNAS). No HFS fluids or additives that are used in the process contain BTEX (benzene, toluene, ethylbenzene and xylene).

Origin is currently investigating two fluid systems that may be utilised during the 2016 program. The likely chemical compositions of the two fluid systems (Slickwater and Crosslinked Gel) are outlined in Table 5 and Table 6 respectively. Fluid and proppant volumes will vary dependent on stimulation fluid type. For a slickwater application the preliminary design is for 1000-1500 m<sup>3</sup> of fluid and 75-150 tonnes of sand (proppant) per stage. A crosslinked gelled system would comprise 500-1000 m<sup>3</sup> of fluid and 75-150 tonnes of sand per stage. Prior to commencing HFS activities, Origin will disclose the final composition of fluids and additives to the DME, including chemical abstracts service (CAS) number and material safety data sheet (MSDS) information.

Table 5 Slickwater Stimulation Fluid

Contains: Water, Surfactant, Hydrochloric Acid, Friction Reducer, Iron Control Agent, Scale Inhibitor, Clay Control Agent, Bactericide, Propping Agent Sand, Chelating Agent					
CAS #	Chemical Name	Mass Fraction (%)	Mass (Kg)	Volume (L)	Volume Fraction (%)
-	Water	~ 95	~ 14,500,000	~ 14,500,000	~ 97
57-13-6	Urea	< 0.001	< 1,000	< 1,000	< 0.01
64-02-8	Tetrasodium ethylenediaminetetraacetate	< 0.001	< 1,000	< 1,000	< 0.01
67-48-1	2-hydroxy-N,N,N-trimethylethanaminium	< 1	~ 160,000	~ 160,000	< 1
67-63-0	Propan-2-ol	< 0.001	< 1,000	< 1,000	< 0.01
79-06-1	2-Propenamid (impurity)	< 0.0001	< 100	< 100	< 0.001
107-21-1	Ethylene glycol	< 0.1	~ 16,000	~ 16,000	< 1
111-46-6	2,2"-oxydiethanol (impurity)	< 0.001	< 1,000	< 1,000	< 0.001
139-33-3	Disodium Ethylene Diamine Tetra Acetate (impurity)	< 0.0001	< 100	< 100	< 0.001
150-38-9	Trisodium Ethylenediaminetetraacetate (impurity)	< 0.0001	< 100	< 100	< 0.001
540-97-6	Dodecamethylcyclhexasiloxane	< 0.00001	< 10	< 10	< 0.00001
541-02-6	Decamethyl cyclopentasiloxane	< 0.00001	< 10	< 10	< 0.00001
556-67-2	Octamethylcyclotetrasiloxane	< 0.00001	< 10	< 10	< 0.00001
1310-73-2	Sodium hydroxide (impurity)	< 0.0001	< 100	< 100	< 0.0001
2682-20-4	2-methyl-2h-isothiazol-3-one	< 0.001	< 1,000	< 1,000	< 0.01
2836-32-0	Sodium Glycolate (impurity)	< 0.0001	< 100	< 100	< 0.001
5064-31-3	Trisodium nitrilotriacetate (impurity)	< 0.00001	< 10	< 10	< 0.0001
6381-77-7	Sodium erythorbate	< 0.0001	< 100	< 100	< 0.001
7447-40-7	Potassium chloride (impurity)	< 0.0001	< 100	< 100	< 0.0001
7631-86-9	Silicon Dioxide	< 0.0001	< 100	< 100	< 0.0001
7647-01-0	Hydrochloric acid	< 0.1	~ 16,000	~ 16,000	< 0.1
7647-14-5	Sodium chloride	< 0.01	< 10,000	< 10,000	< 0.01
7757-82-6	Sodium sulfate	< 0.0001	< 100	< 100	< 0.0001
7758-98-7	Copper(II) sulfate	< 0.00001	< 10	< 10	< 0.00001
7783-20-2	Ammonium sulfate	< 0.01	< 10,000	< 10,000	< 0.1
7786-30-3	Magnesium chloride	< 0.001	< 1,000	< 1,000	< 0.001
10043-52-4	Calcium Chloride	< 0.01	< 10,000	< 10,000	< 0.1
10377-60-3	Magnesium nitrate	< 0.001	< 1,000	< 1,000	< 0.01
14464-46-1	Cristobalite	< 0.0001	< 100	< 100	< 0.0001
14808-60-7	Quartz, Crystalline silica	< 5	~ 670,000	~ 260,000	< 2
26172-55-4	5-chloro-2-methyl-2h-isothiazolol-3-one	< 0.001	< 1,000	< 1,000	< 0.01
31726-34-8	Polyethylene glycol monohexyl ether	< 0.1	~ 16,000	~ 16,000	< 0.1
38193-60-1	Acrylamide, 2-acrylamido-2-methylpropanesulfonic acid, sodium salt polymer	< 0.01	< 10,000	< 10,000	< 0.1
61789-77-3	Dicoco dimethyl quaternary ammonium chloride	< 0.001	< 1,000	< 1,000	< 0.01
63148-62-9	Dimethyl siloxanes and silicones	< 0.00001	< 10	< 10	< 0.0001
67762-90-7	Siloxanes and silicones, dimethyl, reaction products with silica	< 0.00001	< 10	< 10	< 0.0001
91053-39-3	Diatomaceous earth, calcined	< 0.01	< 10,000	< 10,000	< 0.1



**Contains: Water, Surfactant, Hydrochloric Acid, Friction Reducer, Iron Control Agent, Scale Inhibitor, Clay Control Agent, Bactericide, Propping Agent Sand, Chelating Agent**

CAS #	Chemical Name	Mass Fraction (%)	Mass (Kg)	Volume (L)	Volume Fraction (%)
129898-01-7	2-Propenoic acid, polymer with sodium phosphinate	< 0.1	~ 16,000	~ 16,000	< 0.1
136793-29-8	Polymer of 2-acrylamido-2-ethylpropanesulfonic acid sodium salt and methyl acrylate	< 0.001	< 1,000	< 1,000	< 0.001

**Table 6 Crosslinked Gel Stimulation Fluid**

**Contains: Water, Surfactant, Hydrochloric Acid, Breakers, Gelling Agent, Crosslinker, Iron Control Agent, Scale Inhibitor, Clay Control Agent, Bactericide, Propping Agent Sand, Activator, Chelating Agent**

CAS #	Chemical Name	Mass Fraction (%)	Mass (Kg)	Volume (L)	Volume Fraction (%)
-	Water	~ 85	~ 4,450,000	~ 4,450,000	~ 89
64-02-8	Tetrasodium ethylenediaminetetraacetate	< 0.001	< 100	< 100	< 0.01
67-48-1	2-hydroxy-N,N,N-trimethylethanaminium chloride	< 1	~ 56,000	~ 51,000	< 1
67-63-0	Propan-2-ol	< 0.001	< 100	< 100	< 0.01
107-21-1	Ethylene Glycol	< 0.1	< 10,000	< 10,000	< 1
110-17-8	Fumaric acid	< 0.01	< 1,000	< 1,000	< 0.1
111-46-6	2,2"-oxydiethanol (impurity)	< 0.001	< 100	< 100	< 0.01
139-33-3	Disodium Ethylene Diamine Tetra Acetate (impurity)	< 0.0001	< 10	< 10	< 0.001
150-38-9	Trisodium Ethylenediaminetetraacetate (impurity)	< 0.0001	< 10	< 10	< 0.001
1310-73-2	Sodium hydroxide (impurity)	< 0.1	< 10,000	< 10,000	< 1
1319-33-1	Boronatocalcite	< 0.1	< 10,000	< 10,000	< 1
1330-43-4	Sodium tetraborate	< 0.01	< 1,000	< 1,000	< 0.1
2682-20-4	2-methyl-2h-isothiazol-3-one	< 0.001	< 100	< 100	< 0.01
2836-32-0	Sodium Glycolate (impurity)	< 0.0001	< 10	< 10	< 0.001
5064-31-3	Trisodium nitrilotriacetate (impurity)	< 0.0001	< 10	< 10	< 0.001
6381-77-7	Sodium erythorbate	< 0.001	< 100	< 100	< 0.01
7447-40-7	Potassium chloride (impurity)	< 0.0001	< 10	< 10	< 0.001
7631-86-9	Non-crystalline silica (impurity)	< 0.01	< 1,000	< 1,000	< 0.1
7647-01-0	Hydrochloric acid	< 0.1	< 10,000	< 10,000	< 1
7647-14-5	Sodium chloride	< 0.01	< 1,000	< 1,000	< 0.1
7704-73-6	Monosodium fumarate	< 0.01	< 1,000	< 1,000	< 0.1
7727-54-0	Diammonium peroxodisulphate	< 0.1	< 10,000	< 10,000	< 1
7786-30-3	Magnesium chloride	< 0.001	< 100	< 100	< 0.01
7789-38-0	Sodium bromate	< 0.1	< 10,000	< 10,000	< 1
9000-30-0	Guar gum	< 3	~ 170,000	~ 240,000	< 5
10043-35-3	Boric acid	< 0.01	< 1,000	< 1,000	< 0.1
10043-52-4	Calcium Chloride	< 0.01	< 1,000	< 1,000	< 0.1
10377-60-3	Magnesium nitrate	< 0.001	< 100	< 100	< 0.01
14464-46-1	Cristobalite	< 0.0001	< 10	< 10	< 0.001
14807-96-6	Magnesium silicate hydrate (talc)	< 0.0001	< 10	< 10	< 0.001
14808-60-7	Quartz, Crystalline silica	< 12	~ 670,000	~ 260,000	< 5
25038-72-6	Vinylidene chloride/methylacrylate copolymer	< 0.01	< 1,000	< 1,000	< 0.1
26172-55-4	5-chloro-2-methyl-2h-isothiazolol-3-one	< 0.001	< 100	< 100	< 0.01
31726-34-8	Polyethylene glycol monohexyl ether	< 0.1	< 10,000	< 10,000	< 1



Contains: Water, Surfactant, Hydrochloric Acid, Breakers, Gelling Agent, Crosslinker, Iron Control Agent, Scale Inhibitor, Clay Control Agent, Bactericide, Propping Agent Sand, Activator, Chelating Agent

CAS #	Chemical Name	Mass Fraction (%)	Mass (Kg)	Volume (L)	Volume Fraction (%)
61789-77-3	Dicoco dimethyl quaternary ammonium chloride	< 0.001	< 100	< 100	< 0.01
91053-39-3	Diatomaceous earth, calcined	< 0.01	< 1,000	< 10,000	< 1
125005-87-0	Diutan gum	< 0.001	< 100	< 100	< 0.01
129898-01-7	2-Propenoic acid, polymer with sodium phosphinate	< 0.01	< 1,000	< 1,000	< 0.1

#### 2.2.4 Water and Flowback Management

All HFS flowback will be stored on location in lined, above ground flexipond(s) (refer Figure 2-1, Figure 2-2 and Figure 2-3) to allow Origin to assess the quality and chemistry of the flowback fluid to accurately determine the appropriate management of that fluid. Above ground contained storage also prevents access to the fluid by livestock and other ground dwelling fauna.

For this campaign, water will be sourced from aquifers within the Gum Ridge Formation utilising nearby water bores that were drilled under Origin's 2015 and 2016 Exploration Drilling EP with the exception of the Amungee NW-1H site where an additional water bore will be drilled – the location of this additional water bore will be located at the Amungee camp site (Easting: 380863, Northing: 8192820, zone 53K). It is anticipated that up to 10,000-15,000m<sup>3</sup> of water may be utilised per well for stimulation activity.

Flexiponds, provided by a third party company (Grizzly Energy Services), which are engineered and certified to meet Australian standards, have been selected as the best water storage option for this project. Each modular above ground storage pond will have both geotextile and polyethylene linings (i.e. multiple barriers) in addition to monitoring to detect any leakage through the primary barrier. The flexiponds provide a storage capacity of 17,300m<sup>3</sup>, which will all be available at Amungee NW-1H where four flexiponds will be installed. However, as per Table 7 the total storage capacity for flowback fluid post HFS is 12,975m<sup>3</sup>, which assumes a 0.5m freeboard is maintained (this allows for a 72 hour, 1 in 100 year average recurrence intensity rainfall event of 370.8mm, which is calculated from BOM Daly Waters historical rainfall Intensity-Frequency-Duration data). All flowback water will be evaporated or removed from site(s) prior to the wet season.



Figure 2-1 Flexipond example during HFS operations in Queensland

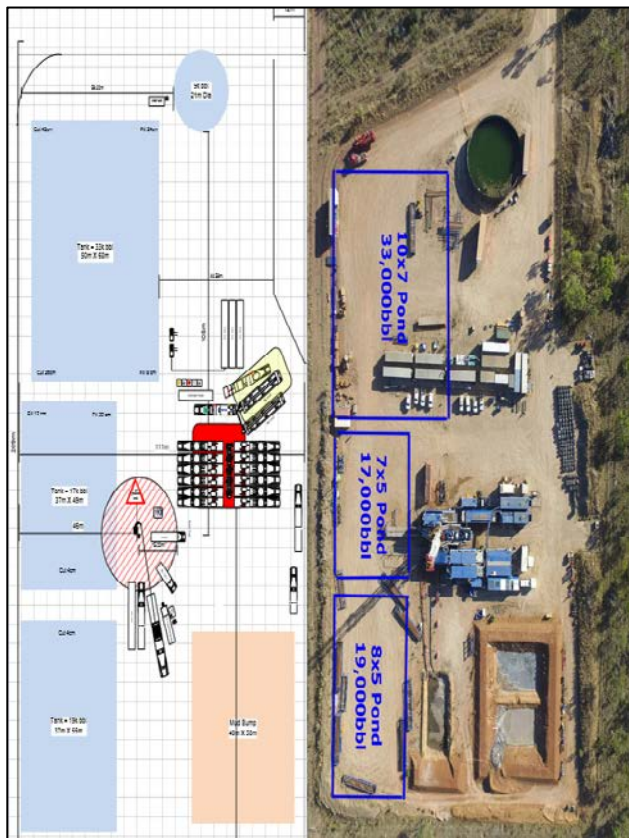
Table 7. Water and flowback fluid storage summary.

Site	Number of Flexiponds	Additional Storage Infrastructure	Total Storage Capacity (potable water)	Total Storage Capacity with 0.5m freeboard (flowback fluid)
Amungee NW-1H	4	1 21m diameter ring tank	17,300m <sup>3</sup>	12,975m <sup>3</sup>
Beetaloo W-1 or Nutwood Downs SW-1	1	1 21m diameter ring tank	6,677m <sup>3</sup>	5,008m <sup>3</sup>

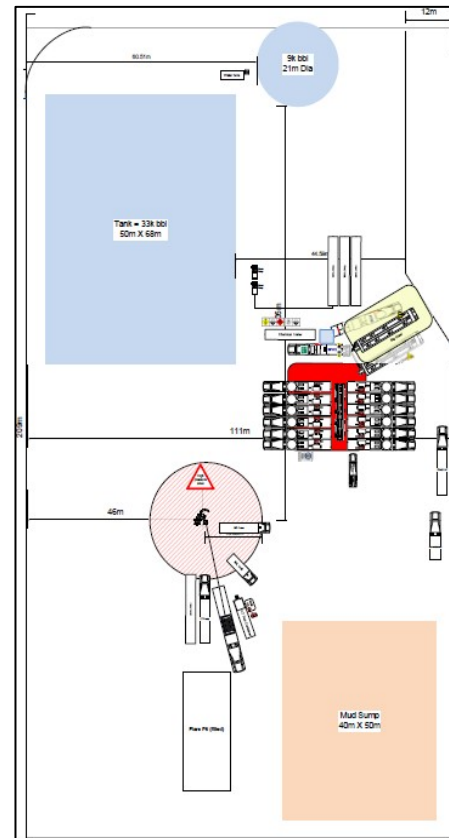
The initial flowback will predominantly be HFS fluid and sand utilised in the stimulation process. As observed in other shale reservoirs around the world, Origin anticipates 20-60% of injected stimulation fluid volume to be recovered during the flowback process. For the 10-12 stage horizontal application at Amungee NW-1H, this would equate to approximately 2-9 ML of fluid to be stored in the above ground flexiponds (noting that prior to storage, sand/proppant will be filtered out and stored in the mud sumps). During initial flowback, fluid will be directed to the water storage ponds and as the well begins to produce gas, the flow will be diverted through the test equipment to separate and measure water, sand and gas volumes. It is anticipated that the well will produce a dry gas (i.e. methane with limited ethane and other hydrocarbons) which will be flared (burned) as part of the well testing process. Origin will collect fluid samples regularly (defined by the approved HFS Activity Authorisation from the DME) during the flowback and production test for ALS Darwin to analyse and report fluid composition.

The proposed water storage configuration for Amungee NW-1H provides approximately 10,472m<sup>2</sup> of surface area (consisting of 1 x 3,400m<sup>2</sup> flexipond, 1 x 1,813m<sup>2</sup> flexipond, 1 x 2035m<sup>2</sup> flexipond, 1 x 2,844m<sup>2</sup> flexipond and 1 x 380m<sup>2</sup> ring pond). For a 10-12 stage horizontal application, based on a 50% HFS fluid recovery and the above surface area, evaporation and rainfall rates in Table 5, and flowback commencing on 1 September 2016, approximately 1ML of fluid will remain as at 30 November 2016.

For the proposed vertical well HFS operation, and assuming a 20-60% recovery rate of HFS fluid and a four stage vertical application, approximately 0.8-2.4ML of fluid will require storage in a single above ground flexipond (noting that prior to storage in the pond, solids will be filtered out and stored in the mud sumps as per the above explanation). This above ground flexipond will provide a surface area of 3,400m<sup>2</sup> and using the evaporation and rainfall rates in Table 5, and flowback commencing on 1 October 2016 there will be a relatively minimal quantity of flowback fluid requiring transport prior to the wet season. The flexipond and ring tank at the vertical well location provide a storage capacity of 6,677m<sup>3</sup> for potable water. However, as per Table 7 the total storage capacity for flowback fluid post HFS is 5,008m<sup>3</sup>, which assumes a 0.5m freeboard is maintained (this allows for a 72 hour, 1 in 100 year average recurrence intensity rainfall event of 370.8mm, which is calculated from BOM Daly Waters historical rainfall Intensity-Frequency-Duration data). All flowback water will be evaporated or removed from site(s) prior to the wet season.



**Figure 2-2 Proposed site layout and flexipond configuration at Amungee NW-1H and a smaller pond will be located at the camp pad (note that drilling rig will not be present during HFS)**



**Figure 2-3 Proposed layout of flexiponds for HFS at Beetaloo W-1 / Nutwood Downs SW-1**

Table 8 Average rainfall and evaporation at Daly Waters

Month	Mean Monthly Rainfall (mm)			Mean Daily Evaporation (mm)		
	DW	NW	E	DW	NW	E
January	165.4	125.5	133.1	7.1	8.2	7.9
February	165.4	130.9	164.0	6.0	7.0	7.3
March	120.1	93.7	85.9	5.9	6.3	7.3
April	23.6	24.6	23.0	6.2	6.4	7.5
May	5.0	9.3	7.2	5.9	5.1	6.5
June	5.6	5.3	4.6	5.5	4.4	5.6
July	1.5	3.4	2.8	5.6	4.6	5.7
August	1.7	1.0	1.1	6.6	6.2	6.7
September	4.9	5.4	5.9	8.4	8.2	8.4
October	22.5	20.9	22.4	8.8	9.1	9.4
November	59.4	35.7	49.0	8.5	9.2	9.5
December	110.0	77.3	95.7	8.1	9.1	8.7
Annual	680.5	535.4	608.2			
Minimum	1.5	1.0	1.1	5.5	4.4	5.6
Maximum	165.4	130.9	164.0	8.8	9.2	9.5
Average	57.1	44.4	49.56	6.9	7.0	7.5

When the flexiponds are decommissioned the associated residual solids, brines and liners are removed and disposed of at an appropriately licensed waste disposal facility. Any remaining flowback fluid will be transported, by road, to a disposal facility within Queensland that is licensed to accept such waste under Queensland legislation. The material will be transported by an NT EPA approved contractor and in accordance with the NT's Waste Management and Pollution Control Act (whilst in the NT), the subsequent transport through Queensland and disposal in Queensland will be completed in accordance with Queensland's Environmental Protection Act. The transportation of wastes fluids across state/territory borders will be done in accordance to the National Environmental Protection Measure (NEPM) guidelines.

Investigations are still underway to determine if there is a suitable disposal facility within the NT to accept this fluid. If a suitable facility is located within the NT the transport of the fluid will be done in accordance with the NT's Waste Management and Pollution Control Act.

### 2.2.5 Stimulation overview

The proposed HFS will determine the nature, quality and quantity of petroleum products within exploration permits held by the Beetaloo Joint Venture (JV). This two phase program will incorporate a HFS/completion phase followed by a well testing phase.

HFS activity is planned to take place during 12 hour, day-time operations. Auxiliary activities such as wireline and coiled tubing operations may occur outside of these operating hours to support the HFS activities. During the well test phase, the majority of the HFS equipment will be demobilised leaving a minimal footprint of equipment.

The process of HFS is executed by injecting a pressurised fluid mixture down the well and into the reservoir target formation through a set of perforations in the casing. The formation rock is physically fractured and propped open to create a conductive pathway for hydrocarbons to flow into the wellbore. This completion technique will be conducted in accordance to industry standards and best practices issued by the American Petroleum Institute (API) and comply with relevant NT and Federal Government legislation and regulations.

- API Guidance Document –HF1, Hydraulic Fracturing Operations – Well Construction and Integrity Guidelines
- API Guidance Document –HF2, Water Management Associated with Hydraulic Fracturing
- API Guidance Document –HF3, Practices for Mitigating Surface Impacts Associated with Hydraulic Fracturing
- API Standard 65-2, Isolating Potential Flow Zones During Well Construction
- NT DME – Schedule of Onshore Petroleum Exploration and Production Requirements 2012
- Northern Territory Petroleum Act 1 May 2016
- NT Environmental Regulations

Prior to HFS activities, wellbore integrity is confirmed via a cement bond log (CBL). A casing pressure test is also conducted to the maximum anticipated stimulation pressure. The CBL is conducted in the vertical section of the wellbore to ensure isolation between aquifers and hydrocarbon bearing zones along the wellbore.

After the wellbore integrity has been tested, validated and confirmed, the reservoir can be accessed via perforations using wireline perforation guns. Perforation spacing and total number of perforation shots per stage will be engineered to optimize stimulation efficiency. 10,000 psi rated bridge plugs will be utilised to provide zonal isolation between stages.

### 2.2.6 Stimulation Camps

The stimulation camp would be a temporary, mobile camp that would house up to 46 people. The area for the camp will be the same area used during the drilling activities.

The stimulation camps will be constructed to house approximately 46 people composed of two crews that will work 12-24 hour shifts, plus the camp staff, supervisory staff and service company personnel on as required basis. The camp includes:

- accommodation
- ablutions and septic(s) waste treatment
- recreation room

- kitchen and mess
- freezer unit
- site office
- generator and diesel storage
- water tank.

As for the drilling camp, stimulation camp infrastructure is temporary and portable and powered by diesel generators. The potable water supply for the camps is to be sourced from groundwater bores established for drilling activities and treated to the appropriate drinking water standards. It is likely the domestic solid waste generated by camp activities will be removed by a waste contractor, or where practicable using local waste disposal arrangements in accordance with the NT waste guidelines. Wastewater, sewage and sullage generated by the domestic camp activities will be managed by an approved sewage treatment system. If there is to be any release to the environment, the siting and design of these will be determined by a hydraulic engineer in accordance with the *Code of Practice for Small On-site Sewage and Sullage Treatment Systems and the Disposal or Reuse of Sewage Effluent*, issued by the NT Department of Health. Under the same code of practice any septic systems releasing to the environment will not be within the minimum separation distance of a potable groundwater supply bore.

An oil-water separator/interceptor trap for kitchen wastewater will be used to enable efficient working of the septic system. Any opportunities for recycling of waste materials such as aluminium cans, cooking oil, etc. will be investigated and used where practicable.

Camps will be managed in compliance with the *NT Environmental Health Fact Sheet No 700, Requirements for mining and construction projects*.

### 2.2.7 Contractor Details

Schlumberger Australia Pty Ltd (ABN 74 002 459 225) has been appointed as the principal contractor for this stimulation and well testing scope. The following services will be provided:

#### Primary

- Stimulation
- Coiled tubing
- Wireline
- Well testing
- Camp

#### Third Partied through Schlumberger

- Wellhead equipment
- Water storage
- Trucking and water haulage

#### Additional Service Providers

- Halliburton Australia Pty Ltd – DFIT services
- Savanna Energy Services Pty Ltd – Completion Rig Services



### 3.0 Existing Environment

#### 3.1 Site Land Use

##### 3.1.1 Pastoral Activity

The current land use in the project area is pastoral with varying stocking rates and varying management practices. Within the permit area there are nine pastoral properties, as shown in Figure 3 and Table 8. All of the land within the permit area is Leasehold Land. There are no areas of Aboriginal Freehold land.

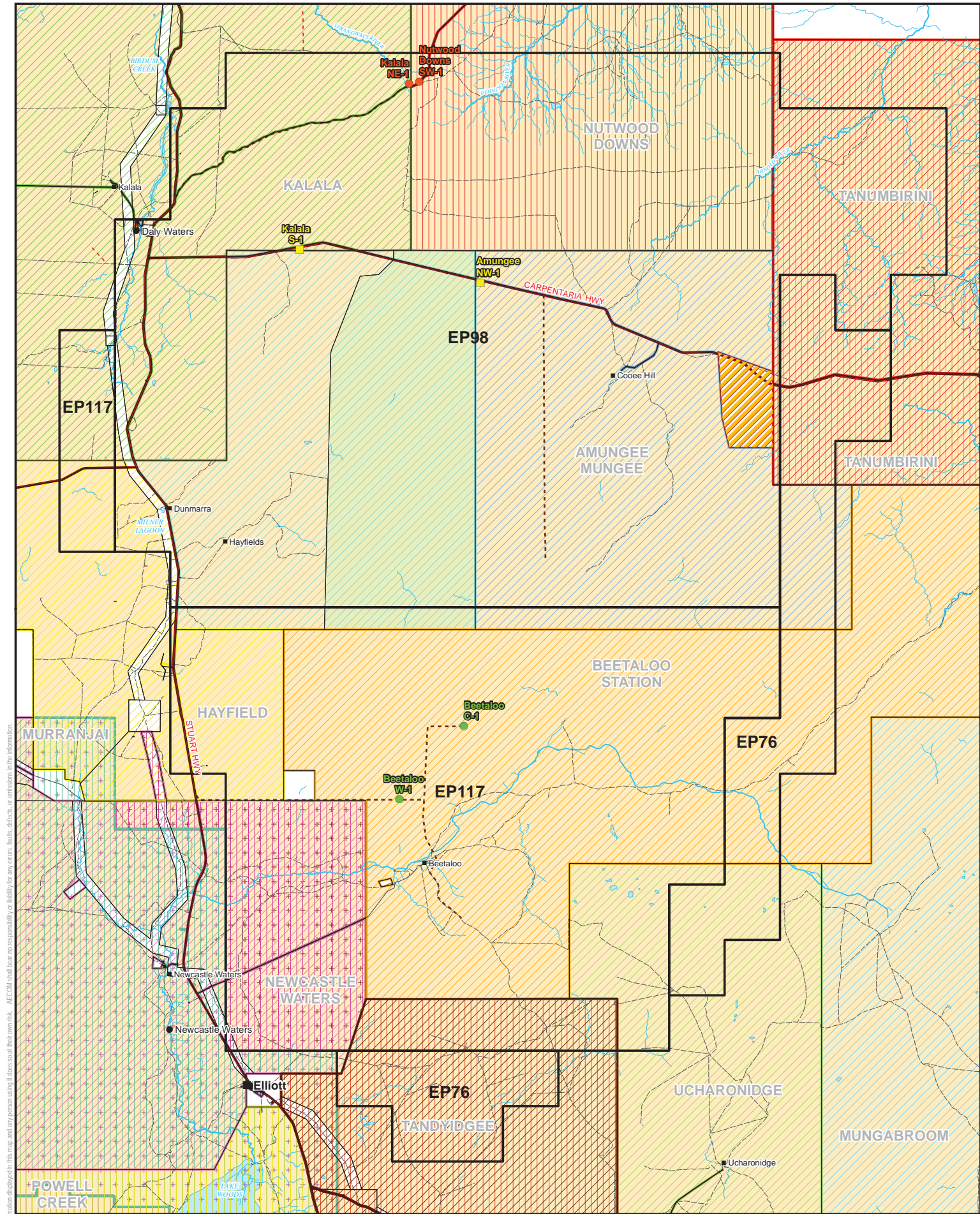
Table 9 Pastoral properties in the Permit Area

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

The project area has been subject to pastoral activities for over 100 years (Randall, 1967). The average size of a Station in the Barkly Region is 8,186 km<sup>2</sup> (Bubb, 2004), which is very large by global standards.

The 2016 stimulation and testing sites are located within following stations:

- Amungee NW-1H – located on Amungee Mungee Station
- Beetaloo W-1 – located on Beetaloo Station
- Nutwood Downs SW-1 – located on Nutwood Downs Station



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**LEGEND**

**Test Wells**

- Existing 2016
- Proposed 2015
- Proposed 2016

**Place Name**

- Homestead
- Populated Place

**Access Routes**

- Existing Tracks
- Proposed New Tracks
- Tracks

**Land Tenure**

- Pastoral Lease
- Perpetual Pastoral Lease

**NTDA Register 2015**

- DC2001/008
- DC2001/045
- DC2002/032
- DC2004/001

**NTDA Schedule 2015**

- DC2001/008
- DC2001/037
- DC2001/045
- DC2002/032
- DC2004/001
- DC2011/032
- DC2012/003
- DC2013/003
- DC2013/004

**NTD 2015**

- DCD2007/002
- DCD2009/001
- DCD2012/003
- DCD2012/006
- DCD2012/007
- DCD2012/008
- DCD2012/009
- DCD2012/011
- DCD2012/012
- DCD2012/013
- DCD2013/019
- DCD2014/007

**LOCATION**

Data sources:  
Permit Area, Cadastre, Native Title - NT Gov 2014  
Places - Aust Gov 2014  
Highways, Roads, Drainage - StreetPro 2014

**ORIGIN ENERGY RESOURCES LIMITED**

**2016 DRILLING ENVIRONMENTAL PLAN**

**Property Boundaries and Land Tenure**

PROJECT ID: 60480548

CREATED BY: justin.dwyer

LAST MODIFIED: 08-Mar-2016

VERSION: 1

**Figure**

**3**

### 3.1.2 Native Title Claims

There are no new native title claims over the permit areas. There are five Native Title determinations that have been finalised and one Indigenous Land Use Agreement. In addition, there is one Native Title determination that was not accepted for registration but has been resubmitted. Details for the Native Title Claims are provided as follows:

- NTD21/2010 Shenandoah Pastoral Lease – Native Title exists in parts of the determination area and is held by the Kinbinningu and Bamarrnganja groups
- NTD27/2010 Beetaloo Pastoral Lease – Native Title exists in parts of the determination area and is held by the Karranjini group; the Bamarrnganja group; the Warranangku group; the Pinda (OT Downs) group; and the Lija/Muwartpi group
- NTD17/2010 Amungee Mungee Pastoral Lease - Native title exists in parts of the determination area and is held by The Karranjini group; the Bamarrnganja group
- DCD2012/009 Kalala Pastoral Lease – Native Title Exists in parts of the determination area and is held by the Badpa group; the Murrunggun Kunakingka group; the Guyal Bardi Bardi group.
- NTD26/2010 Hayfield Pastoral Lease – Native title exists in parts of the determination area and are held by the Kinbinningu group, the Warranangku group and the Marlinja group
- D12004/014 Jingaloo CLA ILUA registered for Community Living Area and Tenure resolution.
- DC2013/004 Nutwoods Downs Pastoral Lease – Native Title Claim was not accepted for registration. The Native Title Applicants, which include Mambali Amaling-gan, Murungun Igalumba, Murungun Milgawirri, Budal Yuwaran and Guyal Bardi Bardi Dumbyun-Ngatanyana Estate Groups, resubmitted on 11 December 2013, with consent expected to occur within the second half of 2016.

Figure 3 shows the boundaries of the areas of Native Title in relation to pastoral properties, the permit areas and the 2016 stimulation and testing sites.

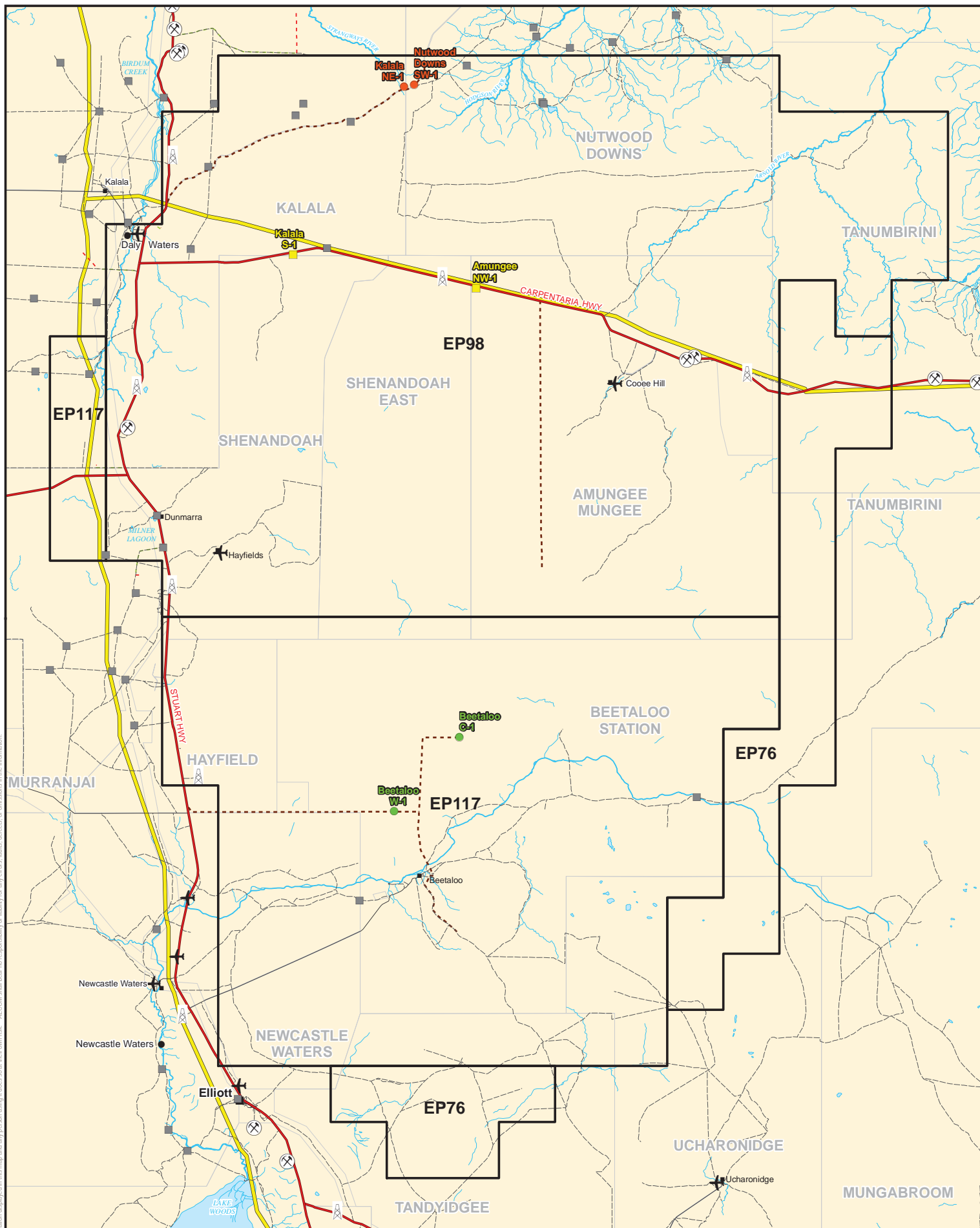
### 3.1.3 Other Land Uses in the Area

A range of other land-uses exists in the permit area or in the larger region, including a range of public utilities and facilities (Figure 4). These include the following:

- Roads 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 – the recently installed 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 township of Daly Waters and Dunmarra lie within EP98.
- 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 heritage sites within the exploration permit area. There are also number of heritage areas of importance to regional tourism are located in the broader region, including Elliott, Newcastle Waters and other heritage listed homesteads. These sites have been identified as part of the environmental assessment, and the proposed 2016 exploration sites will not impact on these.
- 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 25 registered Sacred Sites. The stimulation and testing sites were assessed in August 2014 and April 2016 and it was identified as part of the environmental assessment that the stimulation and testing sites will not impact on these areas.



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#### LEGEND

##### Test Wells

- Existing 2016
- Proposed 2015
- Proposed 2016
- Aircraft Facility
- Tower
- Mine
- Yard
- Homestead
- Place Name
- Populated Place
- Highway
- Minor Road
- Tracks
- Access Routes
- Existing Tracks
- Proposed New Tracks
- Pipeline

- River
- Creek
- Cadastral
- Permit Areas

#### LOCATION



Data sources:  
Permit Area, Cadastral - NT Gov  
2014;  
Places - Aust Gov 2014  
Highways, Roads, Drainage -  
StreetPro 2014

#### ORIGIN ENERGY RESOURCES LIMITED 2016 DRILLING ENVIRONMENTAL PLAN

##### Public Utilities and Facilities

PROJECT ID: 60480548  
CREATED BY: Justin Dwyer  
LAST MODIFIED: 07-Mar-2016  
VERSION: 1

Figure  
4

## 3.2 Physical Environment

### 3.2.1 Climate

The climate of the permit areas can be described as arid to semi-arid, with rainfall decreasing in frequency and quantity from north to south. The climate is monsoon influenced, with a distinctive wet and dry season experienced through the year. The area experiences a wet season during the summer months between October and March, which is dominated by hot and wet conditions. During the winter months, known as the Dry Season, from May to August, mild days and cool nights are experienced (Holt and Bertram, 1981). September and April are transitional months, with occasional rainfall. The average annual rainfall in the north of the permit area is listed at 680 mm at Daly Waters. The southern portion of the permit area records an average annual rainfall of 535 mm at Newcastle Waters and 608 mm listed at Elliott. Approximately 90% of the rainfall occurs during the Wet Season, and annual totals show moderate variability from year to year. Table 9 presents the climate averages for Daly Waters, Newcastle Waters and Elliot.

The maximum rainfall for the permit area occurs during January and February. Daly Waters experience the highest rainfall in the region at this time, with 165 mm during each month, followed by Elliott (133-164 mm during each month) and Newcastle Waters (125-130 mm during each month). July and August experience the least amount of rainfall and are the driest months across all three weather monitoring sites, ranging from one to four mm of rainfall. The annual rainfall pattern within the area is highly variable, and becomes increasingly unpredictable with distance from the coast. Drought conditions are known to occur in the region once every ten years (Holt and Bertram, 1981).

The maximum temperature in the permit area exceeds 30°C from August to May. November is usually the hottest month with the temperature reaching up to 40°C (Table 9). Minimum monthly temperatures range from 11 to 24°C, with July being the coldest month.

Relative humidity and evaporation are highest during the summer months. The 9am maximum average for relative humidity ranges from 68% to 73% and occurs during February across all three monitoring sites. The maximum mean daily evaporation level is 8.8 mm at Daly Waters, 9.6 mm at Newcastle Waters and 9.8 mm at Elliott. The evaporation rate is high because of the high temperatures, moderate humidity, wind and (indirectly) the high number of sunshine hours that are experienced in the area (Holt and Bertram, 1981).

The prevailing wind in the permit area is from the south east; with winds blowing velocities of at 6 to 9 km/hr. Daly Waters is the only weather station to experience a change in wind direction from October to December, with winds blowing from the north east and commonly up to 6 to 7 km/hr (BOM, 2014).

A weather impact study was carried out in early 2015 to provide a better understanding of the likely timing of the onset and contraction of the monsoon season in order to optimise planning of operations. The study aimed to assist in identifying the timing associated with undertaking activities with respect to NT weather patterns, as well as the susceptibility of the drill sites and access to flooding and soil integrity deterioration under moist conditions. Although the weather impact study focused on 2015 there were some findings that are still of relevance to the program and have therefore been included below.

The following findings from the study are of general relevance to the project:

- The climate of Northern Australia is dominated by the dry and wet or monsoon seasons. Conducting activities during the wet seasons can be difficult if not impossible at times as a result of flooding and generally wet ground conditions that result from poor natural drainage throughout much of Northern Australia. Therefore, for transport operators, the timing of the onset of the monsoon can be critical for planning operations.
- Seasonal rainfall variation and variation in the onset date of the monsoon in the Beetaloo region was assessed. The long term average monsoon onset date was found to be 25 November, based on the commonly applied criteria. The influence of ENSO on the monsoon onset was investigated, and a general trend of early monsoon onset during La Niña episodes and late monsoon onset during El Niño episodes was observed. During La Niña the monsoon tends to start during early October to late November, whereas during El Niño the monsoon tends to start from late November to early January.
- The proposed southern well site (Beetaloo W-1) is likely to become inaccessible earlier in the monsoon than the northern well sites. This is due to their access road potentially crossing clayey soil, which has a high susceptibility to soil deterioration when moist.
- The soil integrity at Amungee NW-1 is likely to deteriorate earlier in the monsoon than other sites due to the higher fines content in the soil at Amungee NW-1.

- The northern well site of Nutwood Downs SW-1 is located off the NTG maintained Nutwood Downs Road. This road is generally inaccessible following the onset of the monsoon.
- Sustained rainfall of the monsoons, the soils may become saturated and result in significant soil integrity deterioration at all sites.
- The well site and the short access road for Amungee NW-1H is not likely to be impacted by flooding of adjacent major flow paths and creeks. The long access track for the Beetaloo W-1 site crosses several major flow paths and it likely to be impacted significantly by flooding during the monsoon season.

Table 10 Average Climate at Daly Waters, Newcastle Waters and Elliott

Month	Daily Maximum Temperature (°C)			Daily Minimum Temperature (°C)			Mean Monthly Rainfall (mm)			Relative Humidity (%) <sup>#</sup>			Mean Daily Evaporation (mm)			Wind Speed (km/hr) <sup>#</sup>			Wind Direction <sup>#</sup>		
	DW	NW	E	DW	NW	E	DW	NW	E	DW	NW	E	DW	NW	E	DW	NW	E	DW	NW	E
January	36.6	37.3	37.6	24.0	24.1	24.1	165.4	125.5	133.1	69	63	65	7.1	8.2	7.9	5.9	8.8	5.5	NW	NW	NW
February	35.5	35.6	36.6	23.4	23.7	23.7	165.4	130.9	164.0	73	68	70	6.0	7.0	7.3	4.8	9.4	5.8	NW	E,SE	W
March	34.6	34.7	35.6	22.4	22.6	22.2	120.1	93.7	85.9	70	62	64	5.9	6.3	7.3	4.5	11.0	6.9	SE	E,SE	E
April	33.7	33.3	34.4	19.3	19.4	19.6	23.6	24.6	23.0	53	54	50	6.2	6.4	7.5	6.7	14.0	9.2	SE	E,SE	SE
May	31.4	30.0	31.3	15.8	16.1	15.9	5.0	9.3	7.2	50	51	47	5.9	5.1	6.5	7.8	16.7	10.4	SE	E,SE	SE
June	28.7	27.7	28.4	12.9	12.7	12.4	5.6	5.3	4.6	50	51	46	5.5	4.4	5.6	7.5	15.2	11.6	SE	E,SE	E
July	28.9	27.5	28.3	11.8	11.3	11.2	1.5	3.4	2.8	47	47	42	5.6	4.6	5.7	7.8	15.0	10.8	SE	E,SE	SE
August	31.9	30.8	31.3	13.5	13.7	13.2	1.7	1.0	1.1	44	42	37	6.6	6.2	6.7	6.6	15.3	11.2	SE	E,SE	SE
September	35.0	34.1	35.4	17.2	17.4	17.4	4.9	5.4	5.9	43	41	36	8.4	8.2	8.4	7.8	14.2	11.4	SE	E,SE	E
October	37.7	37.1	38.0	21.1	21.2	20.9	22.5	20.9	22.4	45	42	41	8.8	9.1	9.4	7.8	14.5	11.2	SE	N	N
November	38.4	38.4	39.1	23.5	23.3	23.3	59.4	35.7	49.0	52	43	45	8.5	9.2	9.5	6.7	12.5	8.6	NW	N	NW
December	38.2	38.5	38.6	24.0	24.1	24.4	110.0	77.3	95.7	59	51	56	8.1	9.1	8.7	5.5	10.1	6.5	NW	N	N
Annual							680.5	535.4	608.2												
Minimum	28.7	27.5	28.3	11.8	11.3	11.2	1.5	1.0	1.1	43	41	36	5.5	4.4	5.6	4.5	8.8	5.5			
Maximum	38.4	38.5	39.1	24.0	24.1	24.4	165.4	130.9	164.0	73	68	70	8.8	9.2	9.5	7.8	16.7	11.6			
Average	34.2	33.8	34.6	19.1	19.1	19.0	57.1	44.4	49.56	54	51	50	6.9	7.0	7.5	6.6	13.1	9.1			

DW – Daly Waters, NW – Newcastle Waters, E – Elliott, # data recorded at 9am daily, - No data recorded.  
 Data sourced from Bureau of Meteorology, *Climate Averages and Wind Frequency Analysis for Station 014618 Daly Waters recorded from 1873-2013, 015089 Newcastle Waters recorded from 1941-1980 and 015131 Elliott recorded from 1949-2014.*

### 3.2.2 Topography

The permit area is located within three main topographic zones. These are primarily made up of black soil plains in the south, laterite plains in the north and small sections of bedrock hills in the south west and north east of the permit areas (Tickell, 2003). Figure 5 shows the topographic contours for the permit areas.

The black soil plains are primarily located within the Barkly Tablelands, which covers EP76 and a small section of EP98. The Barkly Tablelands are dominated by a gently undulating to flat landscape with relatively low relief. The lowest area, Lake Woods, lies outside of the south west limit of the permit area near Newcastle Waters, at approximately 200 m above sea level. Away from Lake Woods the plains gently increase to between 220 m and 250 m above sea level.

The laterite plains, which were formed by laterite capping on Cretaceous aged sedimentary rocks, are located within EP98 (Tickell, 2003). A small section of laterite plains extends from Beetaloo to Mungabroom and is separated from the northern laterite plains by a 6 to 8 km line of black soil plains. The northern laterite plains are approximately 250 m to 280 m above sea level and located along the drainage divide that separates inland drainage from the north flowing streams (Nutwood Downs), which lead into the Gulf of Carpentaria. From there, the land gently slopes towards the south and south west (Tickell, 2003).

The bedrock hills occur adjacent to Amungee Mungee in the eastern border of EP98, near the Carpentaria Highway. The maximum elevation in this area is slightly higher than 300 m above sea level and drains north into the Arnold River (Tickell, 2003).

The elevation of the 2016 stimulation and well test locations can be described as:

- Amungee NW-1 – approximately 263 mAHD
- Beetaloo W-1 – approximately 234 mAHD
- Nutwood Downs SW-1 – approximately 240 mAHD.

### 3.2.3 Land Systems

Land systems are defined because of their distinct differences from the surrounding areas and by the recurring pattern of geology, topography, soils and vegetation. Land system information for the permit areas is described in Table 10 and shown in Figure 6.

Land system mapping for the permit area developed is a compilation of the Northern Land Systems (scale 1:250 000) and the Southern Land Systems (scale 1:1 000 000) (Department of Land Resource Management 2013).

The data set is made up of the following:

- *Land Systems of the Northern Part of the Northern Territory* is an amalgamation of 16 existing Land System surveys with modifications to some of the original interpretations. This land system dataset is the Northern Territory contribution to Australian Soil Resource Information System (ASRIS) national soils database at scale 1:250,000.
- *Land Systems of the Southern Part of the NT* is a compilation of three existing land system surveys and the Atlas of Australian Soils (scale 1:2,000,000). It covers the southern part (approx. 70%) of the Northern Territory. Published maps were made digital and edited to accommodate overlaps, gaps and mismatching boundaries. Where possible, the land system descriptions have been extrapolated into areas covered by the broader scale Atlas mapping.

Using the available information, there are 23 different land systems located within the exploration permit areas.

The Amungee NW-1H and Beetaloo W-1 sites occur in the Beetaloo Land System which is characterised by:

- gently undulating lateritic plains and rises
- lateritic red earths and lateritic podzolic soils
- *Acacia shirleyi* (Lancewood) forest.

The Nutwood SW-1 site occurs in the Sturt Land System which is characterised by:

- almost level to gently undulating plains on the plateau surface, lacking contemporary surface drainage except where traversed by local tributaries
- variable depth red earth soils with or without gravel
- mixed Eucalyptus woodlands over perennial grasses.

However, the Nutwood SW-1 site is very close and will most likely also intersect the Beetaloo Land System.

Table 10 identifies the Beetaloo and Sturt Land Systems as having a low to slight erosion potential.

It is noted that the Beetaloo W-1 access track crosses into Joanundah Land System which can be described as very gently undulating northern heavy grey pedocals, also known as the black cracking clays. These have a moderate erosion potential.

The Nutwood Downs Road, that will be used to access either Nutwood SW-1 site, traverses through five Land Systems, including:

- Larrimah Land System – Relict gilgai floodplains. Olive brown, brown and grey clays.
- Bulwaddy Land System – Gently undulating terrain comprising frequent rises and associate slopes, almost level residual plains and closed clay depressions.
- Sturt Land System – Almost level to gently undulating plains on the plateau surface, lacking contemporary surface drainage except where traversed by local tributaries. Variable depth red earth soils with or without gravel.
- Keckwick Land System - Low rises and crests along margins of Sturt Plateau. Gravelly Red, Brown and Yellow Kandosols.
- McGorrery Land System – Eroded upper catchments. Soils highly variable, mainly gravelly brown earths.

Table 11 Description of Land Systems

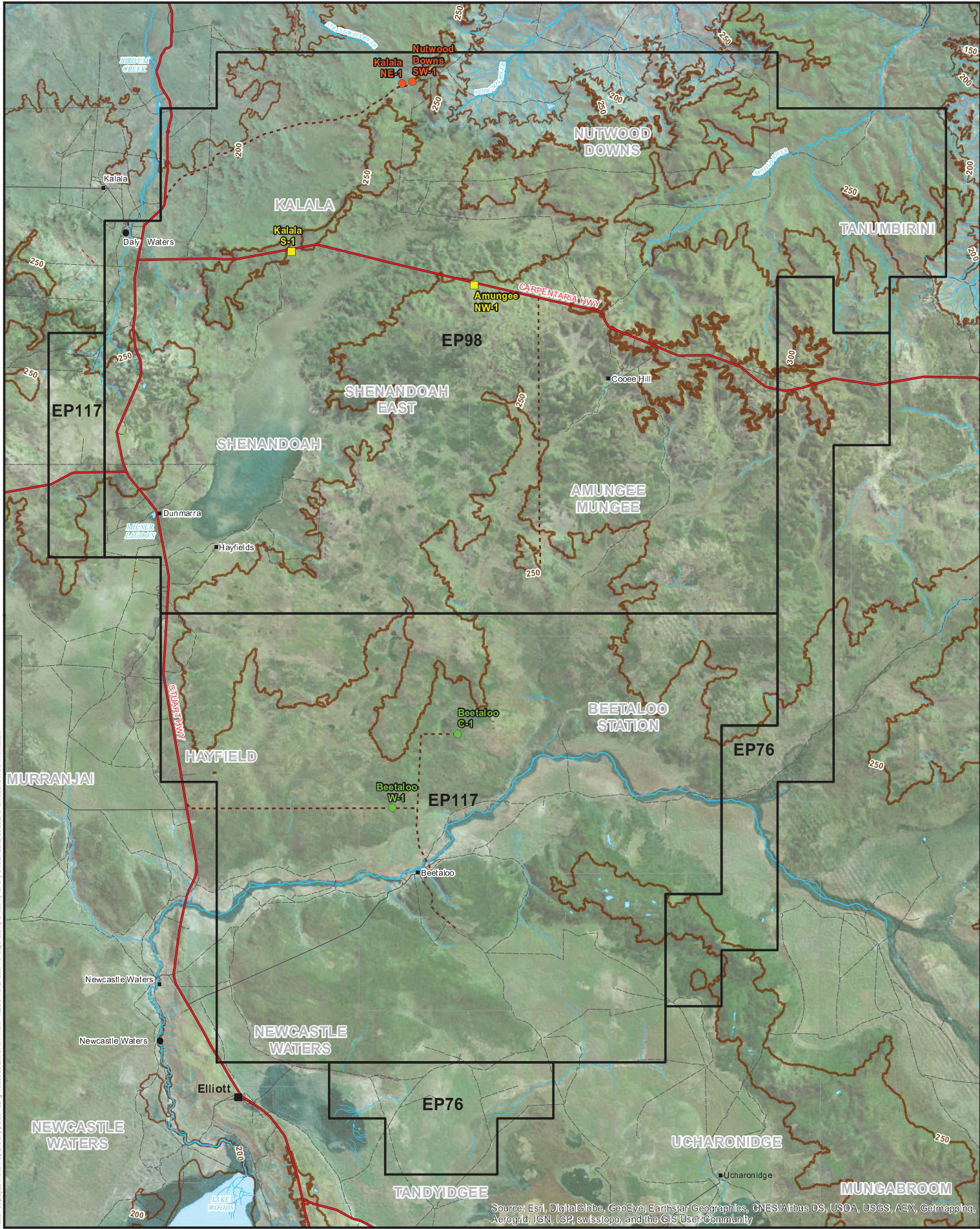
Map Unit	Name	Description	Permit Area	Erosion Susceptibility	Reference
Ald	Downs	Mainly fine-grained sandstones, sandy yellow earths and siliceous sands. Mixed woodlands of <i>Melaleuca</i> , <i>Pandanus</i> and <i>Eucalyptus</i> .	EP98	Moderate	Aldrick and Wilson, 1990
Be	Beetaloo	Gently undulating. Lateritic red earths and lateritic podzolic soils. <i>Acacia shirleyi</i> (Lancewood) forest.	EP76, EP98, EP117	None/Slight	Christian <i>et al.</i> , 1951
Bj	Banjo	Gently undulating to almost level plains. Predominantly loamy red earths with gravelly red and yellow earths and lithosols. Mixed <i>Eucalyptus dichromophloia</i> woodland over perennial grasses.	EP98	Moderate	Day <i>et al.</i> , 1985
By	Bullwaddy	Gently undulating terrain comprising frequent rises and associate slopes, almost level residual plains and closed clay depressions. Variable soils with lithosols, gravelly earths and deep loamy red earths. Vegetation variable, dense <i>Macropteranthes keckwickii</i> (Bullwaddy) shrublands to <i>Eucalyptus</i> woodlands.	EP98	Moderate	Day <i>et al.</i> , 1985
C	Cresswell	Very gently undulating. Northern heavy grey pedocals. <i>Eulalia fulva</i> / <i>Dichanthium fecundum</i> grassland.	EP76, EP98	Moderate	Christian <i>et al.</i> , 1951
Ey	Eley	Gently undulating to almost level plains, slightly lower than surrounding land systems, characterised by a considerable proportion of large closed depressions. Variable depth, sandy and loamy red earths. Mixed <i>Eucalyptus</i> woodlands, extremely variable vegetation and soils in closed depressions.	EP98	Moderate	Day <i>et al.</i> , 1985
Ibn	Nutwood	Plains and low rises on basalt and basic igneous rocks. Brown, grey and red clays and brown and red earths. Mixed woodland of <i>Lysiphyllum cunninghamii</i> and <i>Eucalyptus</i> spp..	EP98	None/Slight	Aldrick and Wilson, 1992
J	Joanundah	Very gently undulating. Northern heavy grey pedocals. <i>Eucalyptus microtheca</i> / <i>Eulalia fulva</i> / <i>Dichanthium fecundum</i> woodland.	EP76	Moderate	Christian <i>et al.</i> , 1951
K	Keckwick	Low rises and crests along margins of Sturt Plateau. Gravelly Red, Brown and Yellow Kandosols. Mid-high open forest ( <i>Macropteranthes keckwickii</i> , <i>Acacia shirleyi</i> and <i>E. leucophloia</i> over <i>Enneapogon polyphyllus</i> , <i>Cymbopogon bombycinus</i> , <i>Chrysopogon latifolius</i> )	EP	Moderate	
La	Larrimah	Relict gilgai floodplains. Olive brown, brown and grey clays. <i>Eucalyptus</i> woodlands and mixed shrublands.	EP98	None/Slight	Day <i>et al.</i> , 1985

Map Unit	Name	Description	Permit Area	Erosion Susceptibility	Reference
Ld	Lancewood	Crenulate escarpments, rugged low hills and gently undulating lower slopes on actively eroding claystone and laterite sediments. Grey and brown clays and lithosols. Mid-high open woodlands of <i>Eucalyptus pruinosa</i> with areas of grasslands and <i>Acacia shirleyi</i> (Lancewood) on cliffs and slopes.	EP98	High	Day <i>et al.</i> , 1985
Lwi	Inacumba	Gently undulating rises and undulating plains to low hills. Laterite and weathered sandstones, lithosols. Mixed <i>Eucalyptus</i> and <i>Acacia shirleyi</i> (Lancewood) woodlands.	EP76, EP98	Moderate	Aldrick and Wilson, 1990
Lwl	Kilgour	Steeplly to gently undulating. Mostly podzolic truncated lateritic solis and kilgour heavy grey pedocals. <i>Eucalyptus brevifolia</i> woodland and <i>Astrelba pectinata</i> grassland respectively.	EP98	Moderate	Christian <i>et al.</i> , 1951
Mg	Mering	Undulating low gravelly crests and slopes with isolated ridges. Mainly shallow gravelly earths and sands on slopes and extremely variable soils in drainage depressions. Vegetation very variable, mixed <i>Eucalyptus</i> woodlands, <i>Acacia shirleyi</i> (Lancewood) and <i>Melaleuca</i> woodlands.	EP98	Moderate	Day <i>et al.</i> , 1985
My	McGorrery	Eroded upper catchments. Soils highly variable, mainly gravelly brown earths. Vegetation also variable, mixed <i>Eucalyptus</i> woodlands and grasslands.	EP98	High	Day <i>et al.</i> , 1985
Py	Pollyarra	Gently undulating. Lateritic red earths and lateritic podzolic soils. <i>Eucalyptus dichromophloia</i> woodland and <i>E. brevifolia</i> woodland.	EP76	High	Christian <i>et al.</i> , 1951
S	Sylvester	Bluebush swamps. Distributary heavy grey pedocals. <i>Chenopodium auricomum</i> shrubland.	EP76	None/Slight	Christian <i>et al.</i> , 1951
St	Sturt	Almost level to gently undulating plains on the plateau surface, lacking contemporary surface drainage except where traversed by local tributaries. Variable depth red earth soils with or without gravel. Mixed <i>Eucalyptus</i> woodlands over perennial grasses.	EP98	None/Slight	Day <i>et al.</i> , 1985
Tac	Balbarini	Very gently undulating "black soil" plains. Northern heavy grey pedocals. <i>Eulalia fulva</i> / <i>Dichanthium fecundum</i> grassland.	EP98	None/Slight	Christian <i>et al.</i> , 1951
Tam	McArthur	Broad or narrow fluvial corridors conducting regional drainage towards the coast. Grey and brown clays and siliceous sands. Mixed <i>Eucalyptus</i> and <i>Melaleuca</i> woodlands.	EP98	Moderate	Aldrick and Wilson, 1990
Tcd	Daglese	Pediaplain, pediments and plains on detritus left by retreat of the Sturt Plateau. Sedentary claystones which underlie the original laterite, brown and yellow earths and brown clays. <i>Eucalyptus</i> woodlands.	EP76, EP98	Moderate	Aldrick and Wilson, 1992
Tct	Tanumbirini	Gently sloping pediplains, isolated from lateritic escarpments.	EP98	None/Slight	Aldrick and Wilson, 1990



Map Unit	Name	Description	Permit Area	Erosion Susceptibility	Reference
		Lateritic yellow earths and brown clays. <i>Eucalyptus</i> woodland.			
Wn	Western	Active floodplains of present streams. Olive brown and grey clays. <i>Eucalyptus</i> woodlands and grasslands.	EP98	Moderate	Christian <i>et al.</i> , 1951





Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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**LEGEND**

<b>Test Wells</b>	<b>Access Routes</b>	<b>Contours (m AHD)</b>
Existing 2016	Existing Tracks	150m Interval
Proposed 2015	Proposed New Tracks	200m Interval
Proposed 2016	River	250m Interval
Homestead	Creek	300m Interval
Place Name	Cadastre	
Populated Place	Permit Areas	
Highway		
Minor Road		
Tracks		

**LOCATION**

**ORIGIN ENERGY RESOURCES LIMITED  
2016 DRILLING ENVIRONMENTAL PLAN**

**Topography**

PROJECT ID: 60480548  
CREATED BY: justin.dwyer  
LAST MODIFIED: 07-Mar-2016  
VERSION: 1

Figure  
**5**





### 3.2.4 Geology

The geology within and surrounding the permit areas (Figure 7) was primarily formed over three main periods – the Precambrian (> 550 million years ago), the Cambrian (500 million years ago) and the Cretaceous (100 million years ago).

Pre-Cambrian rock formations, known as the Roper Group, are located at depth across the permit areas, beneath the younger formations, and are exposed only in the bedrock hills located to the north east of EP98 (Tickell, 2003).

Cambrian formations are expressed only in the south west region of the study area. They predominantly fall outside of the identified permit areas, and comprise of limestone, siltstone and sandstone. The rock formation is near flat, rarely cut by faults and forms distinct layers. The Cambrian sediments contain the sub-artesian water storage, pedocalcic soils, Cambrian dolomite, limestone, and tertiary alluvium (Tickell, 2003).

The majority of the permit area is located within the McArthur Basin, which was formed during the Mesoproterozoic period, over 1,000 million years ago. Soft clays and sandstone are the primary rock formation in the basin and overlie the older Pre-Cambrian and Cambrian rocks. Small and patchy occurrences of freshwater limestone accumulations, formed during the Miocene Period (15 million years ago) when erosion and the gradual sinking of some areas produce isolated fresh-water lakes.

Following the deposition of Cretaceous sediments, a period of geomorphic activity occurred during the Tertiary period. This resulted in the area, being gently folded and warped, which exposed it to a long period of erosional forces (Christian *et al.*, 1951). These forces resulted in the area being dominated by undulating plains that contain extensive swampland and lakes.

Following a period of lateritization during the end of the Tertiary period, rivers were at grade and erosion was reduced to a state that allowed deep stable soil profiles to be established and be preserved (Christian *et al.*, 1951), resulting in the 'black' soil clay plains and the lateritic and non-lateritic rises that are in the region today (Randal, 1967). With the onset of a more arid climate during the post-Miocene period, lakes and swamps dried up, resulting in high concentrations of lime and silica deposits that were leached from the lateritic soils into the ground and surface waters, which in turn formed a number of Tertiary limestone outcrops within the permit area. During the Quaternary period, which occurred less than 2 million years ago, the minor alluvial and lake deposits throughout the permit area were formed.

The field wide geology is similar across the three permits, although there is substantially less control over the southernmost well (Beetaloo W-1). Nutwood Downs SW-1 is located reasonably close to existing offset wells; Altree-2, Walton-2 and McManus-1. The proximity of these offsets wells significantly increases the stratigraphic control.

The geology to be drilled can be split into two groups, the top hole above the Chambers River Formation and the shales and sandstones, including the zones of interest, from the Chambers River down.

The following tables (Table 11 to Table 20) provides the depths of the Formations as shown in Plate 1 for the southernmost well, Beetaloo W-1 and northernmost well Nutwood Downs SW-1.

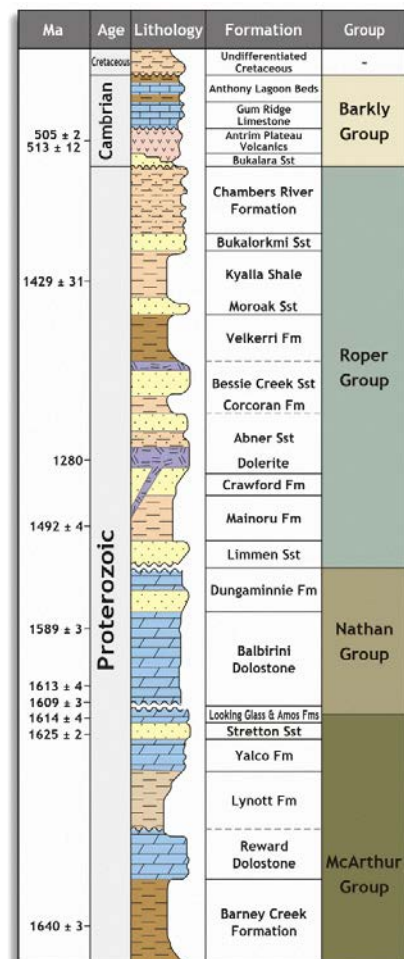


Plate 1 Beetaloo Sub-Basin Stratigraphic Column



**Undifferentiated (Cretaceous)**

Cretaceous claystone located near the surface in the Beetaloo Basin can be extremely unstable and may be very wet under the surface, retaining water from the previous wet season. The formation poses a risk to the spudding of the well due to its propensity to slough into the hole and wash out.

Table 12 Undifferentiated (Cretaceous)

Well	Beetaloo W-1	Nutwood Down SW-1	Amungee NW-1H
Top (mTVD)	Surface	Surface	Surface
Bottom (mTVD)	85	56	78
Thickness (m)	85	56	78

**Anthony Lagoon Beds**

The Anthony Lagoon Beds are made up of dolomitic siltstones and limestones. They pose no specific drilling risk. The formation is not expected to be encountered in the northern well, Nutwood Downs SW-1 or Amungee NW-1H.

Table 13 Anthony Lagoon Beds

Well	Beetaloo W-1	Nutwood Downs SW-1	Amungee NW-1H
Top (mTVD)	85	N/A	N/A
Bottom (mTVD)	238	N/A	N/A
Thickness (m)	153	N/A	N/A

**Gum Ridge Formation**

The Gum Ridge formation is described as a cavernous limestone. It is the regional aquifer for local domestic and commercial use and is therefore extremely important to isolate from any potential cross-flow contamination. Given its description as a cavernous limestone, it is highly likely that total losses would be taken during drilling.

Table 14 Gum Ridge Formation

Well	Beetaloo W-1	Nutwood Downs SW-1	Amungee NW-1H
Top (mTVD)	238	56	78
Bottom (mTVD)	447	120	200
Thickness (m)	209	64	122

**Antrim Volcanics**

The Antrim Volcanics are a volcanic extrusion within the Beetaloo Basin; however, the field extent is unknown. In offset wells, it has been used as a casing point, allowing the thief zone and aquifer above the Gum Ridge formation, to be effectively isolated.

During the drilling of Ronald-1, it was noted that a gas flow was coming from the base of the Antrim Volcanics, later discovered to be a zone of weathered and permeable basalt. The flow was extremely low and the zone was able to be air drilled without any problems. The Basis of Well Design includes an offset study that has been conducted and no further gas flows have been observed. The research also states that encountering gas in the upper section of the Antrim is highly unlikely as shallow hydrocarbons are likely to have escaped into the permeable Gum Ridge Formation above; it is also relevant to note the well will be drilled off-structure, further reducing the likelihood of trapped gas being encountered.

Table 15 Antrim Volcanics

Well	Beetaloo W-1	Nutwood Downs SW-1	Amungee NW-1H
Top (mTVD)	447	120	200
Bottom (mTVD)	495	343	457
Thickness (m)	48	223	257

The Antrim Volcanics are a volcanic extrusion within the Beetaloo Basin, however the field extent is unknown. In offset wells, it has been used as a casing point, allowing the thief zone and aquifer above the Gum Ridge formation, to be effectively isolated.

During the drilling of Ronald-1, it was noted that a gas flow was coming from the base of the Antrim Volcanics, later discovered to be a zone of weathered and permeable basalt. The flow was extremely low and the zone was able to be air drilled without any problems. The Basis of Well Design includes an offset study that has been conducted and no further gas flows have been observed. The research also states that encountering gas in the upper section of the Antrim is highly unlikely as shallow hydrocarbons are likely to have escaped into the permeable Gum Ridge Formation above; it is also relevant to note the well will be drilled off-structure, further reducing the likelihood of trapped gas being encountered.

#### Bukalara Sandstone

The Bukalara Sandstone has been identified as a highly permeable sandstone aquifer with enhanced yield due to jointing. The formation consists of red to white quartz sandstone with minor interbedded shale. In the north of Nutwood Downs Station and on Hodgson River Station, this aquifer is targeted by a number of water bores. Successful bores typically yield between 1.0 to 5.0 L/s when airlifted.

Offset information indicates that it does not pose any significant drilling challenges, however due to its propensity to produce water it is unlikely that the section could be air/hammer drilled.

Table 16 Bukalara Sandstone

Well	Beetaloo W-1	Nutwood Downs SW-1	Amungee NW-1H
Top (mTVD)	495	343	457
Bottom (mTVD)	520	343	495
Thickness (m)	25	0	38

#### Chambers River Formation

The Chambers River formation consists primarily of mudstone with a thin sandstone layer between the upper and lower units. This formation is very hard with offset wells drilled very slow. In some historical wells, this formation has been used to set casing shoes. Note: during the 2015 drilling campaign, this formation was drilled overbalanced (9.0ppg mud) with PDC bits achieving good ROP; KS-1 = 21m/hr.

Table 17 Chambers River Formation

Well	Beetaloo W-1	Nutwood Downs SW-1	Amungee NW-1H
Top (mTVD)	520	343	495
Bottom (mTVD)	790	690	981
Thickness (m)	270	347	486

#### Bukalorkmi Sandstone

The Bukalorkmi sandstone has been the target of petroleum exploration in the region and although it has had hydrocarbon shows there is no evidence of overpressure or moveable hydrocarbons in offset wells. In fact, it has been used as a casing point (Elliot-1). No drilling hazards are anticipated from the Bukalorkmi.

Table 18 Bukalorkmi Sandstone

Well	Beetaloo W-1	Nutwood Downs SW-1	Amungee NW-1H
Top (mTVD)	720	690	981
Bottom (mTVD)	900	762	1054
Thickness (m)	110	72	73



**Kyalla Formation**

The Kyalla formation is a thick shale section with a thin sandstone layer. The bottom section of the Kyalla is potentially organic rich and is the secondary target for the well. During the drilling of Shenandoah-1A, background gas increased steadily drilling through this section. Overpressure is possible (estimated maximum 0.6psi/ft or 11.6ppge) although unlikely.

Table 19 Kyalla Formation

Well	Beetaloo W-1	Nutwood Downs SW-1	Amungee NW-1H
Top (mTVD)	900	762	1054
Bottom (mTVD)	1700	958	1497
Thickness (m)	800	196	443

**Moroak Sandstone**

The Moroak sandstone lies between the Kyalla and Velkerri formations. The formation ranges between relatively clean sandstone to silty sandstone. It has been the target of exploration drilling in the region, although no commercial discoveries have been made. During the drilling of Shenandoah-1A, there were some poor shows in the sandstone. Some slight overpressure is anticipated in the formation with an estimated pore pressure between 9.4-10.6ppge. Given the presence of hydrocarbons in an over pressured sandstone, this formation poses the biggest risk of moveable hydrocarbons.

This section is extremely hard and a prolific producer of brackish water. During the 2015 Drilling Campaign, a number of attempts were made to air/hammer drill the Moroak with excessive water production ultimately hampering efforts. Mud logs and wireline logs indicated the upper 100-150 m portion of the Moroak to be clean highly permeable well-cemented sandstone. The lower portion appears to consist of interbedded sands, silts and clays.

Table 20 Moroak Sandstone

Well	Beetaloo W-1	Nutwood Downs SW-1	Amungee NW-1H
Top (mTVD)	1700	958	1497
Bottom (mTVD)	2285	1258	1866
Thickness (m)	585	300	369

**Velkerri Formation**

The Velkerri formation is a shale with rich organic content and the primary target for these exploration wells. Drilling this formation produces high gas shows through the mid-Velkerri section. The Rate of Penetration (ROP) is again very slow through this formation due to the high unconfined compressive strength (UCS). The benefit of the high UCS is that the wellbore integrity should be high.

Table 21 Velkerri Formation

Well	Beetaloo W-1	Nutwood Downs SW-1	Amungee NW-1H
Top (mTVD)	2285	1258	1866
Bottom (mTVD)	3280	2088	2856
Thickness (m)	995	830	990

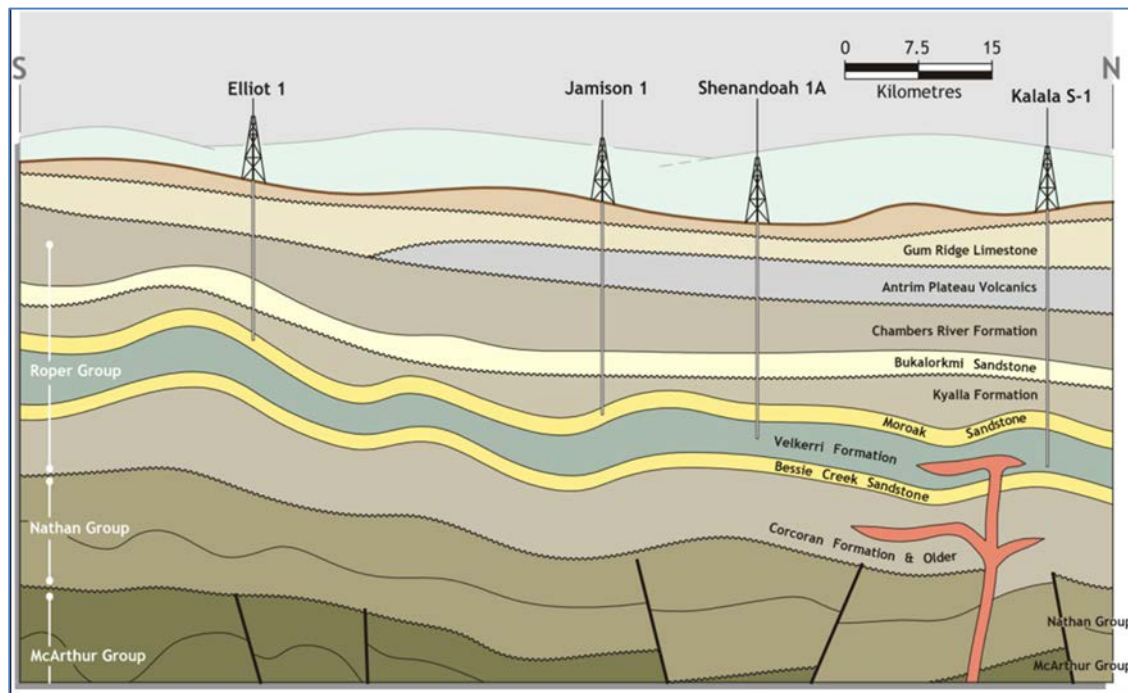


Plate 2 Beetaloo Basin Stratigraphy

### 3.2.5 Soils

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

The soils within the Sturt Plateau have been derived from ancient rock formations and ancestral soils that were formed during earlier weathering cycles. The soils have been deeply weathered, leached and are relatively infertile because they have not been enriched by any recent geological events (Orr and Holmes, 1984). The distribution and diversity of soils in the plateau have been influenced by:

- the past wetter conditions of the region that formed relict Tertiary plains which comprise of highly leached and generally lateritic soils
- extensive areas of Post-Tertiary Alluvia on which a variety of mature soils formed
- the dissected hilly country which is dominated by skeletal soils or rocky outcrops
- the range of parent materials of residual soils, ranging from basic volcanic and highly calcareous rocks to granitoid rocks and sandstones (Christian *et al*, 1951).

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

The lateritic plains, located within EP98 and the northern part of EP117, are classed as very strongly leached soils of the Tertiary land surface. Three main soil types are located within this area, including:

- Tertiary Lateritic Red Earths, which occur on the gently undulating topography
- 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
- 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 and the Gulf Falls.

The Black Soil Plains, located within the Barkly Tablelands, covers EP76, the southern part of EP117 and a small section of EP98. The soils in the Black Soil Plains are described as moderately to weakly weathered leached soils with carbonate horizons. Black soils are uniform, fine-textured soils (vertisols) that are typically grey, brown or red clay. The soils usually crack widely in the upper profile upon drying and have a loose, self-mulching surface. The soils are neutral to alkaline, calcareous and commonly have depths to one metre (Fisher, 2001). The cracking clay soils occur mostly on flat or gently undulating plains ('downs') and are associated with the exposure and weathering of sedimentary or basic volcanic rocks. The Black soils also occur on the more recent depositional landscapes in the form of alluvial clays associated with drainage lines and major river systems. The main soil types within this area include:

- Heavy Grey Pedocals, located on the gently undulating to nearly flat topography on a variety of fine-textured calcareous parent materials
- Northern Heavy Grey Pedocals, soils with poorer structure in the surface and fine manganiferous concretions throughout the profile. They occur in high rainfall areas or poorly drained areas.

Heavy Grey Pedocal soils can have a number of variants, including the Tertiary Swamp soils and limestones with light chert gravel on the surface. The residual soils on the Tertiary Lake Limestone generally have pebbles of silicified material scattered on the surface.

#### 3.2.5.1 Susceptibility to Erosion

Soil erosion susceptibility varies throughout the permit area, dependent upon the soil types, slope and extent of ground disturbance. Apart from the erosive impact of climatic conditions, soil erosion is influenced mainly by the inherent properties of the soils and the processes which occurred during the formation of landscapes (Aldrick and Wilson, 1992). Erosion will occur if the land is used beyond its capacity, as is seen if land is overstocked, for example.

The location of proposed drill sites have been examined on the ground, to determine the risk of erosion occurring. Factors considered include the following.

- Soil type – soils with higher clay content are prone to generation of bulldust and are easily eroded by wind and water. Gravelly soils tend to be more robust to disturbance on the scale expected during the exploration program.
- Slope – the slope of the site will determine the risk of erosion during rainfall events, with steeply inclined areas a higher risk than small undulations in the landform.
- Aspect – the position of the access track and drill pads in relation to the direction of the contour should be considered and creation of tracks across (as opposed to parallel with) the contour should be avoided.
- Rainfall – Table 21 and Table 22 present 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 (Nutwood Downs SW-1, Amungee NW-1H) and Newcastle Waters (Beetaloo W-1 site). It is noted that stimulation and testing activities will commence during the dry season, which the overall risk of erosion from rainfall is considered very low (April to October).

**Table 22** 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

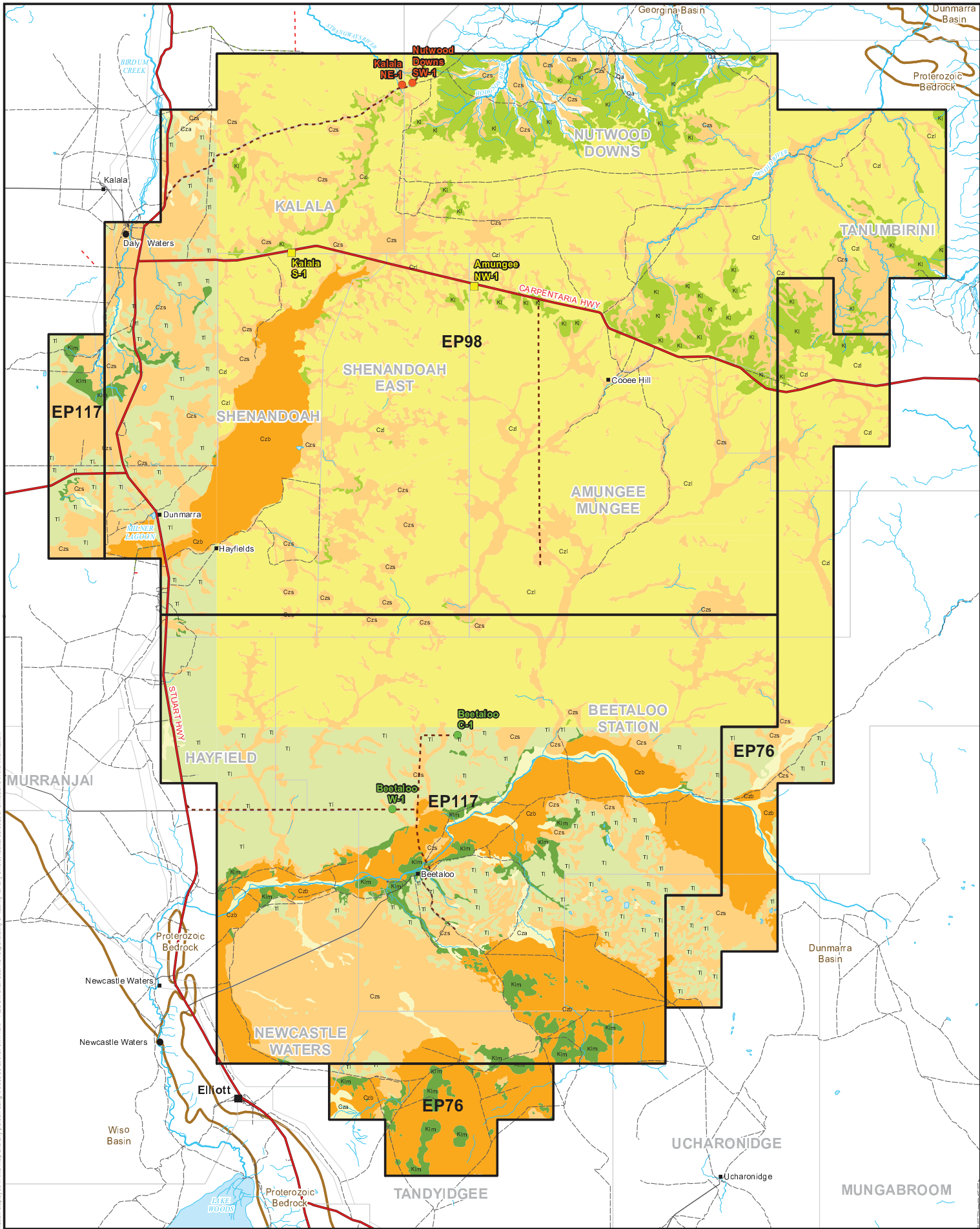
- \* **E** = Extreme (>225 mm); **H** = High (100+ to 225 mm); **M** = Moderate (45+ to 100 mm); **L** = Low (30+ to 45 mm); **VL** = Very Low (0 to 30 mm)


**Table 23** Erosion Risk Rating based on average monthly rainfall at Newcastle Waters

Item	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall (mm)	125.5	130.9	93.7	24.6	9.3	5.3	3.4	1.0	5.4	20.9	35.7	77.3
Erosion Risk*	H	H	M	VL	VL	VL	VL	VL	VL	VL	L	M

- \* **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)

The 2016 stimulation and testing sites, based on the sites soil descriptions are considered to have a none/slight erosion risk. The access track to the Beetaloo W-1 and Nutwood Downs Road do have areas that have a moderate risk of erosion in sections. Mitigation measures will need to be established to minimise the risk for erosion along the track/road and are stabilised leading up to the wet season.





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**LEGEND**

<p><b>Test Wells</b></p> <ul style="list-style-type: none"> <li>Existing 2016</li> <li>Proposed 2015</li> <li>Proposed 2016</li> <li>Homestead</li> <li>Place Name</li> <li>Populated Place</li> <li>Highway</li> <li>Minor Road</li> <li>Tracks</li> </ul>	<ul style="list-style-type: none"> <li>Access Routes</li> <li>Existing Tracks</li> <li>Proposed New Tracks</li> <li>River</li> <li>Creek</li> <li>Cadastre</li> <li>Permit Areas</li> <li>Geology Basins</li> <li>Geology</li> <li>Cza - Alluvium, lake deposits</li> </ul>	<ul style="list-style-type: none"> <li>Czb - Dark gray to brown clayey soils</li> <li>Czl - Laterite and lateritic rubble and soils</li> <li>Czs - Sand, sandy and loamy soils, some lateritic materials</li> <li>Kl - Laterised claystone, soft grey claystone, impure sandstone, white quartz sandstone, conglomerate</li> <li>Kim - Quartz sandstone, pebbly sandstone, siltstone and claystone with radiolaria</li> <li>Qa - Alluvium</li> <li>Tl - Laterite, ferruginous rubble, some red soil and sand</li> </ul>
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**LOCATION**



**ORIGIN ENERGY RESOURCES LIMITED**  
**2016 DRILLING ENVIRONMENTAL PLAN**

**Surficial Geology of the Permit Areas**

PROJECT ID: 60480548  
CREATED BY: justin.dwyer  
LAST MODIFIED: 07-Mar-2016  
VERSION: 1

Figure  
**7**

### 3.2.6 Surface Water and Drainage

The exploration permit areas are located within three main river basins, Roper River Basin to the north, Wiso River Basin in the centre and the Barkly River Basin in the south (Figure 8).

Two of the sites are located within the Wiso River Basin, Amungee NW-1H and Beetaloo W-1. The Wiso River Basin covers the southern half of EP98 (south of the Carpentaria Highway) and the majority of EP117 and is internally drained by Newcastle Creek and a number of small ephemeral creeks. Newcastle Creek ultimately flows into Lake Woods, which is located south of Newcastle Waters Station. Lake Woods covers an area of inundation of approximately 50,000 ha in normal rainfall years, extending to 80,000 ha in exceptionally wet years, after which it can retain water for several years (HLA, 2005). Lake Woods is described as a major quasi-permanent surface water body in the region, although some semi-permanent and many ephemeral waterholes are located across the permit area (HLA, 2006b).

The northern section of EP98 (north of the Carpentaria Highway) is located within the Roper River Basin which has an area of 81,794 km<sup>2</sup>. The catchment is drained by ten rivers and three major creeks, some of which are perennial: the Roper, Phelp, Hodgson, Arnold, Wilton, Mainory, Jalboi, Strangways, Chamers and Waterhouse Rivers, and Maiwok, Flying Fox and Elsey Creeks (DLPE, 2001). Surface water from the Nutwood Downs SW-1 drain into the Strangways River.

It is also noted that northern section of EP98 is situated within the Daly Roper Water Control District that encompasses the Roper River and its tributaries. The Daly Roper Water Control District also applies to groundwater resources that include major aquifers such as the Oolloo, Junduckin and Tindall aquifers. Legislation in Water Control Districts covers all aspects of sustainable water management, including the investigation, use, control, protection and allocation of water resources. Through the *Water Act*, water control districts and water allocation plans, allocation of water to various declared beneficial uses including; agriculture, aquaculture, public water supply, riparian and industry while ensuring that adequate provisions are made to maintain cultural and environmental requirements. Water control districts are geographical areas declared under the *Water Act* by the minister to allow for intensive management of water resources. Currently Petroleum and Mining activities are exempt from the *Water Act*. It is noted that although Petroleum activities are exempt from the *Water Act*, measures will implemented throughout the exploration program to minimise impacts from Origin activities.

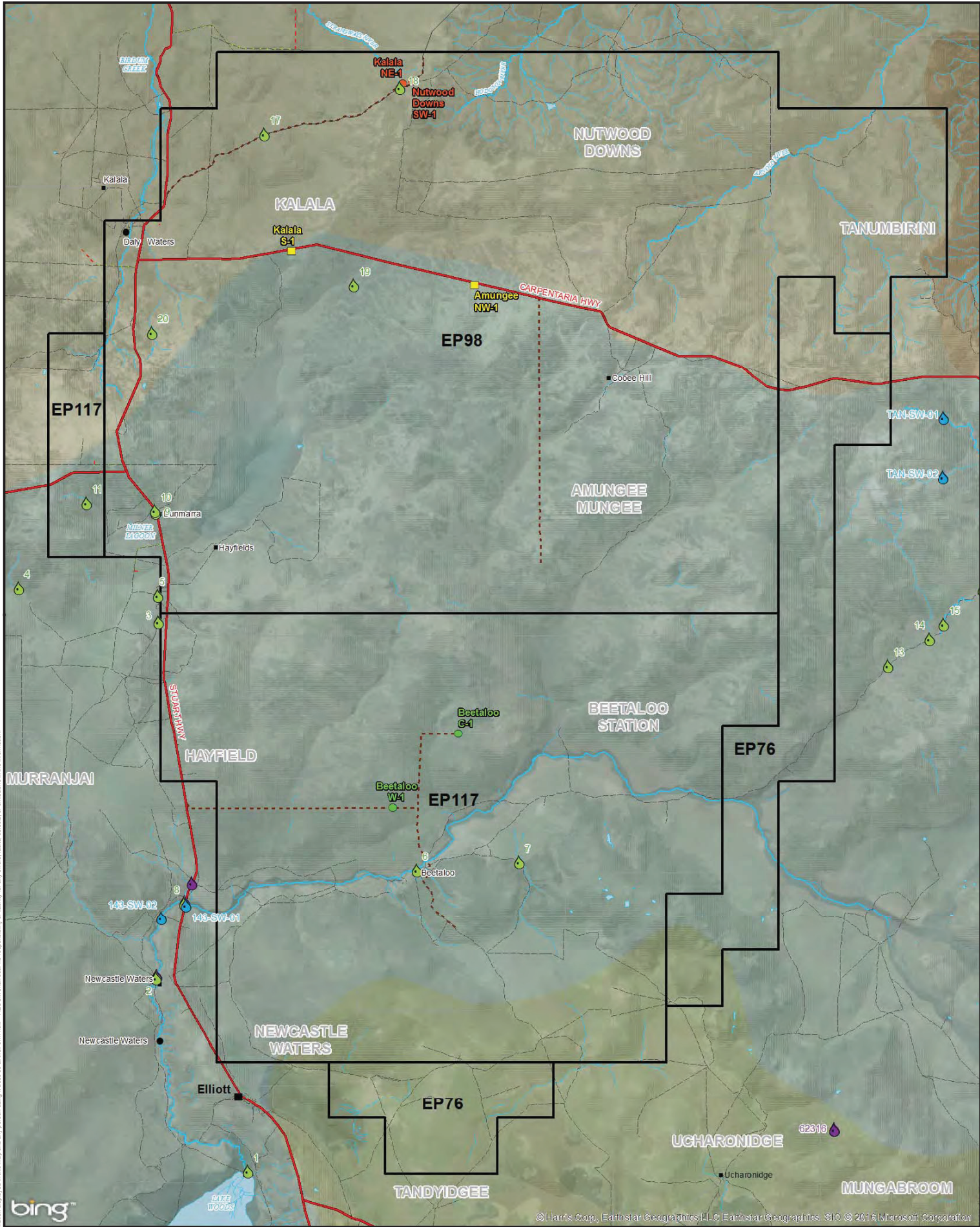
The Barkly River Basin only covers a small section of EP117 and EP76. The Barkly River Basin occurs within desert country which has little surface drainage. The remainder of the area is drained by short streams which peter out or empty into local drainage basins, usually bluebush (*Chenopodium auricomum*) swamps. The major streams are the Buchanan, Gosse and Playford rivers and Creswell, Puzzle, Phillip, Tennant and Brunette Creeks. The Barkly River Basin is unlikely to be impacted by current exploration activities.

#### 3.2.6.1 Surface Water Quality

Surface water quality in the permit area has previously been investigated (HLA, 2006a; 2006b), and it was concluded that the local surface waters carry a dominance of calcium, magnesium carbonate and bicarbonate, which is in contrast to generally held views of inland waters, which show sodium chloride dominance of ionic composition.

In April 2016, a surface water sample was collected from Malogie Water Hole, following approval from the Traditional Owners, to provide baseline conditions. The Malogie Water Hole was also tested during the 2006 monitoring program. Sample collection protocols were consistent with Australian Standards and the analysis of the samples was conducted by an independent laboratory accredited by the National Association of Testing Authorities (NATA).





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0 5 10 20  
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**LEGEND**

<ul style="list-style-type: none"> <li>Existing 2016</li> <li>Proposed 2015</li> <li>Proposed 2016</li> <li>Homestead</li> <li>Place Name</li> <li>Populated Place</li> <li>Surface Water 2007</li> <li>Surface Water 2015</li> <li>DLRM Surface Water</li> </ul>	<ul style="list-style-type: none"> <li>Highway</li> <li>Minor Road</li> <li>Tracks</li> <li>Access Routes</li> <li>Existing Tracks</li> <li>Proposed New Tracks</li> <li>River</li> <li>Creek</li> <li>Cadastre</li> <li>Permit Areas</li> </ul>	<p><b>River Basin</b></p> <ul style="list-style-type: none"> <li>Barkly</li> <li>Limmen Bight River</li> <li>Roper River</li> <li>Wiso</li> </ul>
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**LOCATION**

**ORIGIN ENERGY RESOURCES LIMITED  
2016 DRILLING ENVIRONMENTAL PLAN**

**Surface Water and Drainage**

PROJECT ID	60480548
CREATED BY	justin.dwyer
LAST MODIFIED	07-Mar-2016
VERSION	1

Figure  
**8**

Data sources: Permit Area, Cadastre, Basin - NT Gov 2014; Places - Aust Gov 2014; Highways, Roads, Drainage - StreetPro 2014

Filename: J:\2. Projects\60480548\_4. Tech Work Area\4.99 GIS\02\_MXD\60480548\_Map9\_Surfacewater\_20160226\_v1\_A3.mxd



### Physical Parameter Result Summary

The physical parameter results are presented in Table 23. Plate 3 represents the environment surrounding the sample location at the Malogie Water Hole. The water was only shallow and the banks showed disturbance from cattle.



Plate 3 SW-01 sample location at the Malogie Water Hole.

Table 24 presents the results from the 2016 surface water sample taken from the Malogie Water Hole, as well as the 2006 baseline surface water samples from three locations including the Malogie Water Hole (Point 19) and two from Newcastle Creek including the Beetaloo Station Water Hole (Point 6) and Newcastle Creek crossing on the Stuart Highway (Point 8).

Table 24 Surface Water Sample Description and Physical Parameters

Parameter	Sample Reference				2006 Baseline Data Range (HLA, 2006b)	ANZECC Guidelines 2000 (Tropical Australia - Lowland Rivers) <sup>^</sup>
	SW-1 Malogie Water Hole	Sample 19* Malogie Water Hole	Sample 06* Beetaloo Station Water Hole	Sample 08* Newcastle Creek, Stuart Highway		
Zone	53	53	53	53		
Easting	368816	368816	372292	335623		
Northing	8225090	8225090	8096530	8090797		
Date Sampled	19/04/2016	21/08/2006	19/08/2006	19/08/2006		
Time Sampled	14:05 pm	8:59 am	10:42 am	13:44 pm		
Temperature °C	32.7	21.7	20.1	18.9	18.9-23.2	--
pH	6.5	7.3	8.4	7.6	7.16-10.03	6.0-8.0
Turbidity (NTU)	99	15	49	>100	20-100, >100	2-15
E.C. (µS/cm)	79	62	73	97	48-228	0-2,500 <sup>#</sup>

<sup>^</sup> Table 3.3.5 Ranges of default trigger values for conductivity (EC, salinity), turbidity and suspended particulate matter (SPM) indicative of slightly disturbed ecosystems in tropical Australia.

The physical parameters collected from the Malogie Water Hole during the 2016 survey indicate a slightly acidic pH of 6.5, which is within the adopted ANZECC Guideline. Historical data shows that water bodies across the permit area recorded pH values that were varied with majority being mildly to moderately alkaline (HLA, 2006b).

Electrical Conductivity (EC), which is an indirect measure of the salt concentrations in water, indicates the surface water at these sites is fresh. This is consistent with results obtained by HLA (2006b), which when compared against the regional groundwater results which indicate relatively high EC (refer to Section 3.2.7.2), indicate that there is virtually no connection between the surface waterbodies and the deeper groundwater aquifers. This is not surprising considering most bores' standing water levels in the region are around 60 to 70 m deep. Thus, recharge waters reporting to the water bodies is essentially surface runoff and subsequent to such runoff, water infiltrating from the (highly leached) surface vadose zone.

The turbidity results for the permit area are considered high which are generally consistent with historical results for similar waterbodies. The elevated turbidity can be contributed to the high concentrations of fine and colloidal clays in the catchments of the receiving water bodies (HLA, 2006b). In addition, the disruption of the water's edge by cattle and native animals is a major influence, with Malogie and other water holes sampled showing evidence of cattle disturbance.

### Laboratory Analytical Result Summary

The surface water analytical results assessed against the adopted guidelines and the 2006 water quality results are presented in Table 24. Only those analytes which exceeded the laboratory limit of reporting (LOR) are

presented in the table.

Table 25 Surface Water Analytical Results, 20 April 2016 (presents results above detection limits)

Parameters	Units	Limit of Reporting (LOR)	Sample Reference		Guidelines		
			SW-1 Malogie Water Hole	Sample 19* Malogie Water Hole	ANZECC (2000) Ecosystems Fresh Water (95%)	ANZECC (2000) Stock Watering	Australian Drinking Water Guidelines 2011 - Health
Suspended Solids	mg/L	5	180	-			
<b>INORGANICS</b>							
Bicarbonate Alkalinity as $\text{CaCO}_3$ ( $\text{HCO}_3^{3+}$ )	mg/L	1	14	21			
Carbonate Alkalinity as $\text{CaCO}_3$ ( $\text{CO}_3^{2+}$ )	mg/L	1	LOR	-			
Sulfate as $\text{SO}_4$	mg/L	1	LOR	0.06	-	2,000	
Chloride ( $\text{Cl}^-$ )	mg/L	1	7	7.2			
Calcium ( $\text{Ca}^{2+}$ )	mg/L	1	4	2.7		1,000	
Magnesium ( $\text{Mg}^{2+}$ )	mg/L	1	2	1.2			
Sodium ( $\text{Na}^+$ )	mg/L	1	12	2.1			
Potassium ( $\text{K}^+$ )	mg/L	1	2	13.4			
<b>IONIC BALANCE</b>							
Total Anions	meq/L	0.01	1.02	-			
Total Cations	meq/L	0.01	0.94	-			
Ionic Balance	%	0.01	--	--			
<b>METALS (Dissolved)</b>							
Aluminium	mg/L	0.01	0.4	-	0.055 (pH >6.5)	5	--
Barium	mg/L	0.001	0.016	-	--	--	0.016
Boron	mg/L	0.05	0.08	-	0.37	5	0.08
Copper	mg/L	0.001	0.002	-	0.0014	0.4	2
Manganese	mg/L	0.001	0.005	-	1.9	-	0.5
<b>GASES IN WATER</b>							
Methane	mg/L	0.01	0.025	-	65 <sup>2</sup>	5	--

<sup>1</sup> ANZECC (2000) Table 3.3.4 Default trigger values for physical and chemical stressors for tropical Australia for slightly disturbed ecosystems – Lowland Rivers. Provided to allow for comparison.

<sup>2</sup> ANZECC (2000) *Primary Industries Recommended Water Quality Guidelines for Methane – Freshwater Fish*

A brief summary of the laboratory results is presented below:

#### Total Suspended Solids

The total suspended solid (TSS) results were elevated which is consistent with the high turbidity results reported in the field. The elevated TSS is likely the result of the high concentrations of fine and colloidal clays.

#### Cations/Anions

The ratio of positive to negative ion charge should be close to a value of 1. This is not the case for the surface water samples shown in Table 25, where the ratio falls out of acceptable limits with anions dominating. As described in 2006 baseline survey (HLA, 2006b), in cases where anions 'outweigh' the cations it is likely that ionic aluminium species are present (associated with elevated clay content). The coagulation and precipitation of suspended particles in the water body is closely associated with the concentration of cations and anions in the water body. The surface water samples indicate that Bicarbonate Alkalinity is the dominant anion reporting concentrations of 14 mg/L.

The laboratory data showed near equal ratio of cation concentrations within each sample. Sodium cation concentrations were the highest (12 mg/L). This emphasises that the major determinant of an Australian

freshwater body ionic composition is related to the geological and lithological nature of its catchment area (HLA, 2006b).

#### Metals

Dissolved metals were analysed for the Malogie Water Hole samples. Elevated concentrations of dissolved aluminium were reported above the ANZECC (2000) *Ecosystems Fresh Water 95%* guideline of 0.055 mg/L, respectively. Aluminium is one of the most common metals found in the earth's crust. Elevated concentrations above the ANZECC (2000) *Ecosystems Fresh Water 95%* guideline were also reported for copper.

#### Organic Compounds

Volatile Organic Compounds were analysed in the Malogie Water Hole, including TRH, BTEXN and PAH. All results were reported below the laboratory limit of reporting (LOR).

#### Gases in water

Methane and hydrogen sulphides were analysed in the surface water sample from Malogie Water Hole. Hydrogen sulphides reported concentrations below the laboratory LOR. However, the sample detected 0.025 mg/L of Methane, which is well below the ANZECC (2000) primary industry recommended guidance value of 65 mg/L for freshwater fish.

The methane concentrations at the Malogie Water Hole are likely the result of the breakdown of organic matter in the water body, such as faeces from cattle and native animals. The guidance value for methane was devised by ANZECC (2000) based on the reports by McKee and Wolf (1963) and Boyd (1990) who identified that methane levels below 65 mg/L had no effect on freshwater fish (ANZECC, 2000).

### 3.2.7 Groundwater

Origin commissioned CloudGMS to undertake a desktop hydrogeological study of the Beetaloo Basin (CloudGMS, 2015) to compile a current understanding of the groundwater regime in the Beetaloo and adjacent groundwater basins. The CloudGMS report is provided in Appendix B. The conceptual hydrogeological model described below is from the Beetaloo Basin Hydrogeological Assessment.

The Beetaloo Basin comprises a thick sequence of flat-lying mudstone and sandstone formations (Roper Group) that were deposited between 1,500 and 1,430 million years ago (Ma) (Table 25). The Roper Group is estimated to reach of 5,000 m in thickness in the centre of the basin and with the exception of the north and eastern margins occurs at an average depth of about 500 m. The Roper Group is overlain by the Georgina Basin (630 – 497 Ma), which includes widespread basalts and a thick limestone sequence that forms the Cambrian Limestone Aquifer (CLA), a significant water supply aquifer. The Georgina Basin is capped by Cretaceous mudstone and sandstone (145 – 66 Ma) and recent alluvial and laterite deposits.

Table 26 Summary of Beetaloo Basin Hydrostratigraphy

Province	Period/Age	Formation		Aquifer Status	Thickness (m)	Yield (L/s)	Ave EC ( )
CARPENTARIA BASIN	CRETACEOUS 145 – 66 Ma	Undifferentiated		<i>Local Aquifer</i>	0 - 130	0.3 - 4	1,800
GEORGINA BASIN	CAMBRIAN 497-630 Ma	Cambrian Limestone Aquifer (CLA)	Anthony Lagoon Beds	REGIONAL AQUIFER	0 – 200	1 - 10	1,600
			Gum Ridge Formation	REGIONAL AQUIFER	0 – 300	0.3 - >20	1,400
		Antrim Plateau Volcanics		REGIONAL AQUITARD	0 – 440	0.3 - 5	900
		Bukalara Sandstone		<i>Local Aquifer (not regionally connected)</i>	0 – 75	0.3 - 5	1,000
BEETALOO BASIN (ROPER GROUP)	NOT KNOWN	Hayfield Mudstone		REGIONAL AQUITARD	0 – 450	-	32,000
		Jamison Sandstone		<i>Local Aquifer (not regionally connected)</i>	0 – 150	-	138,000
	MESO-PROTEROZOIC	Kyalla Formation		REGIONAL AQUITARD	0 – 800	-	-

Province	Period/Age	Formation	Aquifer Status	Thickness (m)	Yield (L/s)	Ave EC ( )
	1,430-1,500 Ma	Moroak Sandstone	<i>Local Aquifer (not regionally connected)</i>	0 – 500	0.5 - 5	131,000
		Velkerri Formation	REGIONAL AQUITARD	700 – 900	-	-
		Bessie Ck Sandstone	<i>Local Aquifer (not regionally connected)</i>	450	0.5 - 5	-

The CLA, comprising the Gum Ridge Formation and the Anthony Lagoon Beds, is an extensive regional aquifer system that forms the principal water resource in the Beetaloo Basin. Limestone in the CLA is commonly fractured and cavernous; regionally bore yields of up to 100 l/s have been recorded from this aquifer. 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. Where the CLA is absent, has limited saturated thickness or is deep, local scale aquifers are targeted in Proterozoic fractured rock, Georgina Basin formations and the base of the Cretaceous sequence. Groundwater resources in these aquifers are of limited extent and have a lower yield (< 5 l/s) relative to the CLA. Limited information exists on the hydrogeological characteristics of the Roper Group sequence as it occurs at depth within the Beetaloo Basin. Sandstone dominated formations may behave as aquifers, however, drilling results suggest these formations have limited permeability and will only form marginal, very local scale aquifers. Groundwater in the Roper Group is highly saline and contrasts with the shallower, utilised aquifers in which groundwater is generally of drinking water quality.

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 100,000 ML/year (NALWTF, 2009). Existing groundwater use in the Beetaloo Basin is estimated at 6,000 ML/year. Unconventional gas exploration in the Beetaloo basin is at a very early stage and the volume of water required to develop any potential resource is uncertain. However a first order estimate of the water required to develop potential gas resources on Origin tenements is 1,000 ML/year over the development phase. Combined, current groundwater extraction and projected demand for gas development in the Beetaloo Basin represents 7% of the estimated water resource available from the CLA in the Georgina Basin.

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 including the Roper River at Elsey National Park and Red Lily/57 Mile Waterhole. These discharge features occur around 100 km north-west of the Beetaloo Basin. Dry season flow in the Roper River has been gauged at 95,000 – 126,000 ML/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 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.

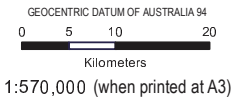
The Velkerri Formation represents the primary unconventional gas target in the Beetaloo Basin, although small hydrocarbons intersections have been encountered in other formations within the Roper Group. Vertical pressure gradients between the Roper Group and the CLA are not well characterised, however, previous exploration well formation tests indicate there is an upward pressure gradient from the Roper Group to the CLA. Over much of the basin the CLA is separated from these formations by multiple aquitards including the Antrim Plateau Volcanics and Hayfield Mudstone. Thick, unweathered and undeformed basalt sequences in the Antrim Plateau Volcanics and tight claystone beds within the Hayfield Mudstone form a barrier that restricts the mixing of hydrocarbons and brines in the Roper Group with high quality groundwater in the CLA and other utilised aquifers. Where these formations are absent or thinner, along the eastern margin and in the south of the Beetaloo Basin, there is greater potential for interconnection between the Roper Group and the CLA. Potential for interconnection also exists along the major faults and structures that bound the Beetaloo Basin. The potential for fluid migration through faults between formations is limited because most faults don't extend to the shallow formations.

### 3.2.7.1 Groundwater Bores in the Permit Area

Figure 9 shows the location of the groundwater bores in the permit area, and Table 26 summarises information for those bores that are closest to the stimulation and testing sites. Table 26 has been compiled from the NTG

groundwater database and exploration-related field activities.





- Test Wells**
- Bores
  - Existing 2016
  - Proposed 2015
  - Proposed 2016
  - Homestead
  - Place Name
  - Populated Place
  - Highway
- Minor Road  
--- Tracks  
- - - Access Route  
- - - Existing Track  
- - - Proposed New  
— River  
— Creek  
□ Cadastre  
□ Permit Areas



Data sources:  
Permit Area, Cadastre, Bore,  
Province - NT Gov 2014.  
Places - Aust Gov 2014  
Highways, Roads, Drainage -  
StreetPro 2014

## Groundwater Basins and Bores

PROJECT ID	60480548
CREATED BY	justin.dwyer
LAST MODIFIED	07-Mar-2016
VERSION	1

Figure 9

Table 27 Summary of Groundwater Bores near stimulation and testing sites

Drill Site	Proximity to Drill Site	Bore Reference	Date Installed	Purpose	Total Depth (mTOC)	SWL (mTOC)	Yield (L/s)	Physical Parameters
Amungee NW-1H	3.9 km West along Carpentaria Highway	RN005844	01/05/1967	ND	124.0	108.8	2.5	pH 7.8 EC 1,085 µS/cm
	12.3 km South East Amungee Mungee Station	RN036920	01/05/2010	Stock Bore (Banjo)	165.0	126.0	3.0	pH 6.84
	~14 km South East Amungee Mungee Station	RN038630	06/07/2014	Stock Bore	149.95	95.0	5.0	pH 8.08
	~18 km South East Amungee Mungee Station	RN038109	03/07/2014	Stock Bore (Brunette)	162.15	97.0	1.0	pH 8.59
	~21 km South East Amungee Mungee Station	RN038631	07/07/2014	Stock Bore (Bore at W30)	148.85	93.0	6.0	pH 8.16
	~24 km South East Amungee Mungee Station	RN038632	09/07/2014	Stock Bore (Toms)	140.1	97.0	3.5	pH 8.36
	27 km South East Amungee Mungee Station	RN006877	22/08/1969	Homestead Bore	140.0	114.3	1.89	pH 7.4 EC 900 µS/cm
Beetaloo W-1	15.1 km west of Beetaloo W-1	RN023591	29/11/1984	Production	91.0	70.5	2.1	pH 8.0 EC 870 µS/cm
		RN023592	28/11/1984	Production	97.0	70.5	2.5	pH 6.5 EC 570 µS/cm
	15 km west of Beetaloo W-1 (Water supply for Jingaloo Community)	RN023794	18/05/1984	Production – Jingaloo Community	110.4	72.0	1.8	pH 7.2 EC 990 µS/cm
	6.6 km east from Beetaloo W-1	RN004882	3/05/1965	Production Beetaloo	86.8	64.3	1.5 L/s	pH 7.9 EC 4,800 µS/cm
	12.7 km north east of Beetaloo W-1	RN036233	20/07/2008	Farming Beetaloo (A7 Jindalee)	126.0	88.2	2.0 L/s	pH EC 900 µS/cm
	11.4 km south of Beetaloo W-1	RN009197	27/10/1977	Farming (Beetaloo Homestead)	78.0	58.0	2.25 L/s	pH 7.1 EC 1,130 µS/cm
	7.4 km south south east Beetaloo W-1	RN029700	29/11/1996	Production	84.0	58.8	1.75 L/s	pH 7.3 EC 10,120 µS/cm
	15.8 km south west Beetaloo W-1	RN006251	30/09/1968	Production	70.7	56.4	1.75 L/s	pH 7.9 EC 1,600 µS/cm
	19.5 km NNW of Beetaloo W-1	RN035824	7/09/2007	Farming	114	80.2	3 L/s	EC 340 µS/cm
Nutwood Downs SW-1	9.3 km north east	RN038813	16/11/2014	Monitoring - NTG	126.2	95.0	ND	pH 6.94 EC 1,565 µS/cm



Drill Site	Proximity to Drill Site	Bore Reference	Date Installed	Purpose	Total Depth (mTOC)	SWL (mTOC)	Yield (L/s)	Physical Parameters
	8.8 km north	RN025208	18/09/1988	Investigation	102.0	73.0	3.0	NA
	8.7 km north east	RN000645	25/08/1952	Production - Abandoned	67.7	51.8	1.4	NA
	8.8 km north east	RN034175	20/08/2004	Farming -Nutwood Downs Station - Unequipped	78.0	55.5	5.0	NA
	9.7 km south east	RN002876	1/5/1959	NA - Abandoned	52	NA	1.24	pH 7.6 EC 950 $\mu$ S/cm (August 1968)
	3.6 km east	RN034182	13/11/2004	Farming – Nutwood Downs Station -- Unequipped	170	59	2.5	NA

### 3.2.7.2 Groundwater Monitoring

Groundwater monitoring has been carried out in support of the preparation of this Stimulation and Testing EP. Bores closest to the drill sites were sampled (where possible) between August 2014, December 2015 and April 2016. A description of the sampled bores, standing water levels and the field water quality parameters measured is presented in Table 27. Field water quality parameters were consistent with background concentrations for the region.

The groundwater analytical results assessed against relevant guideline values are presented in Table 28. Only those analytes which exceeded the laboratory limit of reporting (LOR) are presented in the table. All results were reported below the guideline values with which they were compared and are consistent with data from the DLRM bore database.

Samples were submitted for laboratory analysis. Sample collection protocols were consistent with Australian Standards and the analysis of the samples was conducted by an independent laboratory accredited by the National Association of Testing Authorities (NATA).

Groundwater monitoring will continue during the stimulation and testing program in accordance with Origin's Groundwater Monitoring Plan (NT-2050-15-MP-0011).

Table 28 Groundwater Sample Description and Physical Parameters, August 2014, December 2015 and April 2016

Parameters	Sample Site									
	RN023794 Jindaloo	RN036233 Jindalee A7	Beetaloo Homestead House Tap*	Amungee Homestead Tank*	RN038813 NTG Bore	RN038812 NTG Bore	RN038812 NTG Bore	Jump Up Tank#	RN035133 Jump Up	RN31635 KKK's Dam <sup>+</sup>
	2014 Sample Round				2015 Sample Round		2016 Sample Round			
Zone	53	53	53	53	53	53	53	53	53	53
Easting	352571	372657	372513	403270	377269	369535	369535	362693	362797	367332
Northing	8107481	8118653	8096210	8177447	8238028	8225238	8225238	8221883	8221806	8226065
Date Sampled	27/08/2014	27/08/2014	27/08/2014	28/08/2014	15/12/2015	15/12/2015	19/04/2016	19/04/2016	20/04/2016	20/04/2016
Time Sampled	10:30 am	14:00 pm	12:30 pm	9:30 am	12:00 pm	4:00 pm	10:00 am	16:30 pm	8:00 am	9:30 am
Temperature °C	28.8	28.7	20.5	17.7	35.9	34.3	30.0	27.8	27.8	25.9
pH	6.8	7.1	7.2	7.2	6.9	7.0	6.5	7.86	6.7	7.7
Turbidity (NTU)	5.8	0.2	0.2	5.8	-	-	117.3	4.8	4.9	3.1
E.C. (µS/cm)	937	1,162	1,350	763	1,565	1,399	1,617	1,116	1,297	1,167

\* Unable to access bores at Beetaloo Homestead and Amungee Mungee Homestead, however was given permission to obtain sample from the house water supply (Beetaloo) and tank (Amungee), which are both supplied by nearby bores.

^ Unable to sample from bore as pump connected to well not working, sampled from Dam bore water is supplied by RN035133 bore.

# Jump Up is water supply tank that is filled up by RN035133.

+ RN31635 bore was equipped, although no water was pumping up. As such sample taken from nearby Dam that is supplied by this bore.

Table 29 Groundwater Analytical Results (results above detection limits)

Parameters	Units	Limit of Reporting (LOR)	Sample Site										Guidelines			Regional Baseline
			RN023794 Jindaloo	RN036233 Jindalee A7	Beetaloo Homestead House Tap*	Amungee Homestead Tank	RN038813 NTG Bore	RN038812 NTG Bore	RN038812 NTG Bore	Jump Up Tank#	RN035133 Jump Up	RN31635 KKK's Dam+	ANZECC (2000) Ecosystems Fresh Water (95%)	ANZECC (2000) Stock Watering	Australian Drinking Water Guidelines 2011	NTG Data Base Min-Max for 56 bores
			2014 Sample Round				2015 Sample Round		2016 Sample Round							
Suspended Solids	mg/L	5	9	<5	<5	<5	13	<5	<5	<5	<5	<5				-
Total Dissolved Solids	mg/L	10	-	-	-	-	858	750	-	-	-	-		4,000		-
<b>INORGANICS</b>																
Total Alkalinity as Bicarbonate	mg/L	1	255	197	276	365	390	422	419	285	414	334				2-632
Sulfate as SO <sub>4</sub>	mg/L	1	108	60	118	144	162	69	118	128	117	183	-	2,000		1-979
Chloride	mg/L	1	72	76	194	101	88	92	78	104	82	85				3-518
Calcium	mg/L	1	57	40	71	102	136	120	127	73	121	89		1,000		6-303
Magnesium	mg/L	1	45	37	46	50	55	46	46	51	46	50				1-95
Sodium	mg/L	1	42	37	124	72	63	63	59	71	63	66				3-438
Potassium	mg/L	1	23	18	15	12	8	10	9	10	9	9				1-57
<b>METALS (DISSOLVED)</b>																
Aluminium	mg/L	0.01	LOR	LOR	LOR	LOR	0.01	0.02	0.01	0.06	LOR	0.04	0.055	5	-	-
Barium	mg/L	0.001	0.054	0.080	0.058	0.049	-	0.084	0.056	0.039	0.056	0.037	-	-	2	-
Boron	mg/L	0.05	0.08	0.08	0.28	0.16	0.17	0.17	0.15	0.16	0.15	0.16	0.37	5	4	-
Copper	mg/L	0.001	LOR	0.001	0.002	LOR	LOR	LOR	0.231	LOR	0.008	LOR	0.0014	0.4	2	-
Nickel	mg/L	0.001	LOR	0.001	0.001	LOR	0.001	0.001	0.012	LOR	LOR	LOR	0.011	1.0	0.02	-
Zinc	mg/L	0.005	0.324	0.017	0.012	LOR	0.037	0.012	0.012	0.006	0.02	0.007	0.008	20	-	-
Manganese	mg/L	0.001	0.305	0.001	LOR	0.006	0.135	0.139	0.014	LOR	0.006	LOR	1.9	-	0.5	-

Parameters	Units	Limit of Reporting (LOR)	Sample Site										Guidelines			Regional Baseline
			RN023794 Jindaloo	RN036233 Jindalee A7	Beetaloo Homestead House Tap*	Amungee Homestead Tank	RN038813 NTG Bore	RN038812 NTG Bore	RN038812 NTG Bore	Jump Up Tank#	RN035133 Jump Up	RN31635 KKK's Dam*	ANZECC (2000) Ecosystems Fresh Water (95%)	ANZECC (2000) Stock Watering	Australian Drinking Water Guidelines 2011	NTG Data Base Min-Max for 56 bores
			2014 Sample Round				2015 Sample Round		2016 Sample Round							
Uranium	mg/L	0.001	LOR	LOR	0.001	LOR	-	-	-	-	-	-	-	0.2	0.017	-
Iron	mg/L	0.05	1.43	LOR	LOR	LOR	0.11	0.53	0.13	LOR	LOR	LOR	-	-	-	0.1-8.9
<b>GASES IN WATER</b>																
Methane	mg/L	0.010	LOR	LOR	LOR	LOR	LOR	LOR	LOR	0.034	LOR	LOR	65 <sup>1</sup>	-	-	-

1. ANZECC (2000) primary industry recommended guidance value of 65 mg/L for freshwater fish

### 3.3 Natural Environment

#### 3.3.1 Bioregions

The Interim Biogeographic Regionalisation of Australia is a nationally recognised ecosystem classification system (Environment Australia, 2000). Bioregions are large, geographically distinct ecosystems that are distinguished by broad physical and biological characteristics, which can be further classified into Subregions. These regions and subregions are used as the basis for regional comparisons and conservation of flora and floristic communities.

Of the 85 bioregions mapped nationally, 20 occur within the Northern Territory and only two within the Beetaloo JV permit area, the Sturt Plateau bioregion and the Mitchell Grass Downs bioregion. A description of the bioregions within the permit area is described below:

- Sturt Plateau Bioregion - comprises undulating plains on sandstone, with predominantly neutral sandy red and yellow earth soils. Dominant vegetation associations included extensive areas of Lancewood (*Acacia shirleyi*) - Bullwaddy (*Macropteranthes kekwickii*) vegetation and associated fauna, including the Spectacled Hare-Wallaby (*Lagorchestes conspicillatus*). Land condition in the bioregion is moderate to good but is threatened by impacts from weeds, feral animals, pastoralism and changed fire regimes.
- Mitchell Grass Downs Bioregion - consists of clear, undulating country with predominantly calcareous grey or brown clays (Black Soil Plains). Vegetation largely comprises of Mitchell Grass (*Astrebla* spp.) with emergent *Acacia* spp. and *Eucalyptus* spp. The bioregion faces a high risk of weed invasion, particularly along drainage lines and in areas where over-grazing has occurred.

The 2016 stimulation and well testing sites are found in the Sturt Plateau Bioregion.

##### 3.3.1.1 Vegetation Communities

Vegetation communities have been ground-truthed during baseline assessments in 2004, 2006 (HLA, 2006; 2006c), 2010 (AECOM, 2011) and more recently in August 2014 and April 2016, along with assessments of weeds, habitat, erosion and land condition.

The existing vegetation at the proposed stimulation sites was evaluated through detailed habitat assessments. Habitat assessments included identification of vegetation community, dominant flora species at each strata, canopy cover and basal area, habitat condition, disturbance factors (fire, weeds, feral fauna species), and fauna attributes (e.g. tree hollows, logs, grass cover, mistletoe abundance).

The main vegetation communities within the exploration permit areas are woodlands, typically dominated by Bloodwoods (*Corymbia* spp.) and tall shrublands and woodlands of Bullwaddy and Lancewood with open grassland understorey (Cofinas and Creighton, 2001; ANRA, 2008). Other less common vegetation communities within the area include *Acacia* shrubland over spinifex and Bullwaddy-dominated woodland. Two of the well sites consist of Eucalypt woodland (Beetaloo W-1, Amungee NW-1H). However, the access track into the Beetaloo sites had a high density of Bullwaddy/Lancewood patches. These appeared to be in good condition during the August 2014 field assessment with Lancewood supporting a high density of Mistletoe.

Vegetation mapping of Nutwood Downs NW-1 site indicates that it is located in *Corymbia* low woodland / *Terminalia* (mixed) sparse shrubland/*Chrysopogon* (mixed) low tussock grassland corroborated by recent field assessments. Habitat at the Nutwood Downs NW-1 site was in good condition..

Lancewood/Bullwaddy communities are important as they represent Gondwanan remnants of the once dominant rainforests of the Australian tertiary period and are limited in distribution (PWCNT, 2005). Lancewood forests are the most extensive acacia dominated communities across northern NT. The Lancewood/Bullwaddy communities typically have a dense shady shrub layer, a few vines and creepers and a sparse grass understorey, compared to the sparse canopy and tall grass understorey of other tall dense grasslands (PWCNT, 2005). Bullwaddy is a unique plant with a multi-stemmed habit, very small leaves crowded along the branches and a very dense and heavy wood. Whilst technically being a shrub it can grow up to six metres tall with massive individual stems (PWCNT, 2005).

The Lancewood/Bullwaddy vegetation associations are fire sensitive. Inappropriate fire regimes may result in a community succession from Bullwaddy through Lancewood to a Eucalypt dominated open woodland (PWCNT, 2005). This process may be accelerated by the invasion of exotic pasture grasses such as Buffel Grass (*Cenchrus ciliaris*).

Detailed condition description and photographs of each of the stimulation sites (Amungee NW-1H, Beetaloo W-1 and Nutwood Downs SW-1) are provided in Table 29 to Table 31.

Table 30 Amungee NW-1H Condition Description

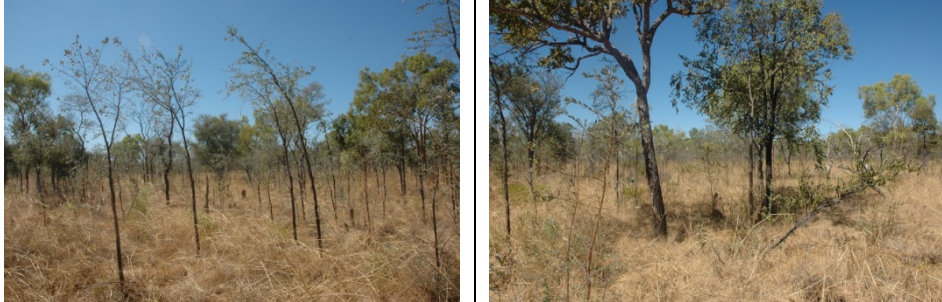
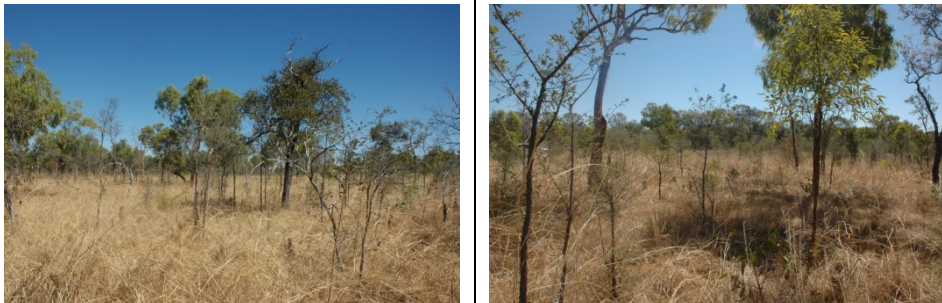

Site ID	Amungee NW-1	Habitat photos at central point of survey site (August 2014)	
Location	-16.34393668, 133.88409911		
Landform and soil	Two types: laterite, ferruginous rubble, some red soil and sandy and loamy soil with some lateritic material on undulating plain		
Broad habitat type	Very open eucalypt woodland		
Habitat description	Open woodland with dense shrub cover and grass cover. Denser woodland surrounds site		
Dominant flora species	Canopy (12%, 5 basal) dominated by <i>Corymbia drysdalensis</i> , <i>C. ferruginea</i> and <i>Erythrophleum chlorostachys</i> . Diverse subcanopy/shrub layer including <i>Petalostigma pubescens</i> , <i>Terminalia canescens</i> , <i>Atalaya hemiglauca</i> , <i>Hakea arborescens</i> , <i>Grevillea pteridifolia</i> , <i>Carissa lanceolata</i> , <i>Dodonea</i> sp., <i>Flueggia virosa</i> , <i>Grevillea striata</i> , <i>Alphitonia excelsa</i> . Very dense grass cover including <i>Themeda triandra</i> , <i>Chrysopogon fallax</i> , <i>Heteropogon contortus</i> , <i>Sarga plumosum</i> . Other species include <i>Grewia retusifolia</i> , <i>Ptilotus polystachyus</i> , <i>Evolvulus alsinoides</i> , <i>Cleome viscosa</i> .		
Habitat condition	Habitat disturbances include grazing and prior clearing. No recent fire. The weed <i>Hyptis suaveolens</i> present on access track. 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.		
Species recorded	Rainbow Bee-eater, Weebill, macropod scats, small mammal diggings.	Additional Habitat Photos across survey site (August 2014)	
Potential CEEVNT Species	Spectacled Hare-wallaby, Square-tailed Kite, Grey Falcon, Northern Nailtail Wallaby, Australian Bustard (especially after fire), Emu, Bush-stone Curlew, Western Chestnut Mouse, Chameleon Dragon, King Brown Snake.		



Table 31 Beetaloo W-1 Condition Description

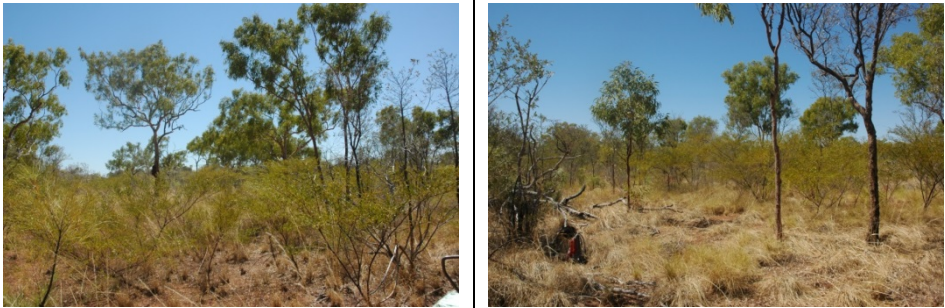


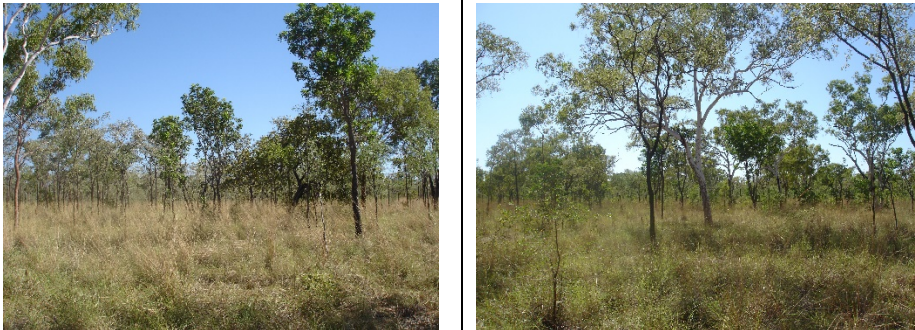
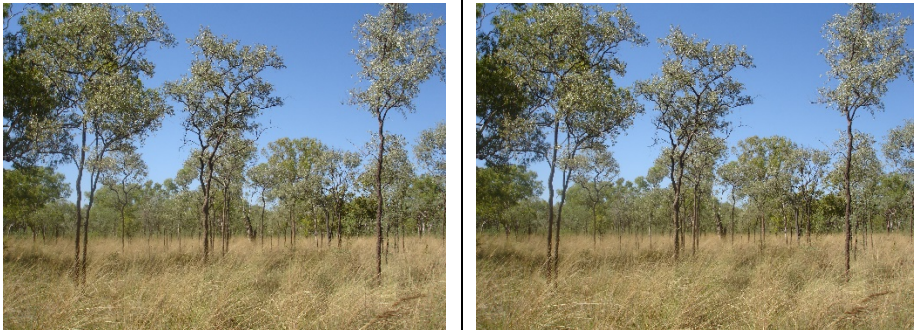

Site ID	Beetaloo W-1	Habitat photos at central point of survey site (August 2014)	
Location	-17.12050677, 133.76211983		
Landform and soil	Laterite, ferruginous rubble, some red soil and sand on undulating plain		
Broad habitat type	Open eucalypt woodland		
Habitat description	Open woodland with a dense shrub (Acacia) and grass layer		
Dominant flora species	Canopy (25% cover, Basal 1) dominated by <i>Corymbia drysdalensis</i> and <i>C. ferruginea</i> with a subcanopy of <i>Terminalia canescens</i> and <i>Grevillea striata</i> . Shrub cover includes dense patches of <i>Acacia lysiphloia</i> . Other common species include <i>Terminalia canescens</i> , <i>Grevillea striata</i> , <i>Distichostemon hispidulus</i> , <i>Hakea arborescens</i> , <i>Flueggia virosa</i> , <i>Bauhinia cunninghamii</i> , <i>Calytrix exstipulata</i> . Ground layer species include, <i>Chrysopogon fallax</i> , <i>Arsitida ingrata</i> , <i>Eriachne ciliata</i> , <i>Triodia</i> sp, <i>Gomphrena canescens</i> , <i>Waltheria indica</i> .		
Habitat condition	Good condition. Evidence of hot fire (likely last dry season), scars 1-3m in height. No evidence of tree mortality. No evidence of weeds or feral animals. The habitat contained good refuge opportunities in the form of a dense leaf litter, dense grass cover, large woody debris and a high abundance of smaller tree hollows (<10cm). Mistletoe ( <i>Amyema</i> sp.) present in survey site providing foraging opportunity for avian species.		
Species recorded	Peaceful Dove, Brown Quail, Brown Falcon, Red-backed Kingfisher, Budgerigar, Willie Wagtail, Singing Honeyeater, Weebill.	Additional Habitat Photos across survey site (August 2014)	
Potential CEEVNT Species	Pale Field Rat, Spectacled Hare-wallaby, Square-tailed Kite, Grey Falcon, Northern Nailtail Wallaby, Australian Bustard (especially after fire), Emu, Bush-stone Curlew, Western Chestnut Mouse, Chameleon Dragon, King Brown Snake.		

Table 32 Nutwood Downs SW-1 Condition Description

Site ID	Nutwood Downs SW-1	Habitat photos at central point of survey site (April 2016)	
Location	-16.02301358, 133.47311039		
Landform and soil	Laterite, ferruginous rubble with some red soil and sand on undulating plain		
Broad habitat type	Eucalypt woodland		
Habitat description	<i>Corymbia</i> dominated woodland (canopy cover 27%, Basal 23) with a diverse understorey and grass cover		
Dominant flora species	Canopy dominated by <i>Corymbia dichromophloia</i> (23%) but also includes <i>C. ferruginea</i> and <i>Erythrophleum chlorostachys</i> with a subcanopy dominated by <i>Terminalia canescens</i> . Diverse shrub layer including <i>Terminalia canescens</i> , <i>Erythrophleum chlorostachys</i> , <i>Brachychiton paradoxum</i> , <i>Clerodendrum floribundum</i> , <i>Carissa lanceolata</i> , <i>Distichostemon hispidulus</i> , and <i>Flueggea virosa</i> . Ground layer species include <i>Sarga plumosum</i> , <i>Chrysopogon fallax</i> , <i>Triodia pungens</i> , <i>Aristida holathera</i> , <i>Eriachne ciliaris</i> , <i>Grewia retusifolia</i> , <i>Sida</i> sp., <i>Evolvulus alsinoides</i> , <i>Spermacoce pogostoma</i> , and <i>Pterocaulon sphacelatum</i> .		
Habitat condition	Good condition. No evidence of recent grazing or fire. The habitat contained good refuge opportunities in the form of dense leaf litter and grass cover and medium to large woody debris. Numerous medium to large sized hollows were present in older <i>Corymbia</i> species providing potential shelter and breeding sites. Smaller termite mounds can also provide fauna habitat. Flowering <i>Corymbia</i> and fruiting shrubs also provide foraging opportunities for fauna at this site. Good continuous cover adjoining adjacent woodland habitat. No evidence of feral animals.		
Species recorded	Striated Pardalote, Red-backed Fairy-wren, White-throated Honeyeater, Pied Butcherbird, Black-faced Cuckoo-shrike, Rufous Whistler, Brown Honeyeater, Rainbow Lorikeet, White-throated Gerygone, Burton's Snake-lizard, Two-lined Dragon, <i>Carlia</i> sp.	Additional Habitat Photos across survey site (April 2016)	
Potential CEEVNT Species	Spectacled Hare-wallaby, Northern Nailtail Wallaby, Australian Bustard, Emu, Square-tailed Kite, Grey Falcon, Bush-stone Curlew, Western Chestnut Mouse, Chameleon Dragon, King Brown Snake, Grey Falcon (foraging).		



### 3.3.1.2 Flora

A total of 805 plant species have been recorded within the wider region, during the August 2014 survey 50 dominant flora species were identified across multiple locations. As the survey was conducted during the late dry season, grasses and other annual species were difficult or impossible to identify due to the lack of inflorescence or because they had already died-back.

No Commonwealth threatened plant species were identified as occurring by the Protected Matters Searches (Appendix C). One species, the prostrate, herbaceous vine *Ipomoea argillicola*, is listed as Near Threatened under Section 29 of the *Territory Parks and Wildlife Conservation Act 2000* (TPWC Act) and could potentially occur in the project sites. This species has been recorded from the Bullwaddy Conservation Reserve and at locations surrounding the area (ALA accessed September 2014; NTG, 2005). Additional mapping of threatened flora records with a 3.5 km radius around survey sites identified a record of the grass species *Acrachne racemosa*, Near Threatened (NT), in the vicinity of Kalala NE-1. This species is associated with vine thickets, coastal flats and monsoonal areas around creek lines in sandy soils, a habitat type not recorded at this site (Ausgrass2 accessed 3 May, 2016).

Four species within the permit area are listed as being 'Data Deficient', which is a term reserved for species known from few locations for which there is currently not enough information on population sizes, trends and threats for accurate classification. These species are:

- *Lepturus xerophilus* (an annual grass that occurs under Bullwaddy), and has previously been recorded twice in EP98
- *Centipeda nidiformis* (an annual daisy), previously recorded twice in EP98
- *Pasallidium gracile* (an annual grass), previously recorded twice in EP98 and twice in EP76
- *Panicum latzii* (an annual grass that grows on clay soils), previously recorded once in EP98 (HLA, 2005).

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 the Spectacled Hare-Wallaby (*Lagorchestes conspicillatus leichardtii*), which is listed as 'Near Threatened' in the NT. Records surrounding the survey area and a scat collected in the vicinity of the Beetaloo sites during the August 2014 survey confirmed the presence of this species. Additional species associated with the habitat type include Bush-stone Curlew (*Burhinus grallarius*) and the Northern Nailtail Wallaby (*Onychogalea unguifera*) both listed as Near Threatened by the NT Government.

It is noted that the extent of Bullwaddy in the permit area is far more extensive than that indicated by the NT Herbarium records.

### 3.3.1.3 Weeds

Previous surveys and the current DOTE Protected Matters search (Appendix C) and NRM database searches indicate that 15 listed weed species are known to occur or likely to occur within the permit areas. The listed weed species that are likely to occur within the permit area and the proposed drill sites are listed in Table 32. Under the NT *Weeds Management Act 2013*:

- a Class A weed is to be eradicated
- a Class B weed is to have its growth and spread controlled
- a Class C weed is not to be introduced to the NT.

Table 33 NT Listed Weeds likely to occur within the stimulation and testing sites

Scientific Name	Common Name	Status	Potential to Occur		
			Amungee NW-1H	Beetaloo W-1	Nutwood Downs SW-1
<i>Acacia nilotica</i>	Prickly Acacia	Class A and C, Weed of National Significance	-	-	-
<i>Alternanthera pungens</i>	Khaki Weed	Class B and C	Y	-	Y
<i>Cenchrus echinatus</i>	Mossman River Grass	Class B and C	-	Y	-
<i>Datura ferox</i>	Fierce Thornapple	Class A and C	Y	-	Y
<i>Hyptis suaveolens</i>	Hyptis	Class B and C	Y	-	Y
<i>Jatropha gossypifolia</i>	Bellyache Bush	Class B and C	-	Y	-
<i>Parkinsonia aculeate</i>	Parkinsonia	Class B and C, WONS	-	Y	-
<i>Pennisetum polystachion</i>	Mission Grass	Class B and C	-	-	-
<i>Prosopis pallida</i>	Mesquite	Class A and C, WONS	-	Y	-
<i>Senna obtusifolia</i>	Sicklepod	Class B and C	-	-	-
<i>Sida cordifolia</i>	Flannel Weed	Class B and C	Y	Y	Y
<i>Themeda quadrivalis</i>	Grader Grass	Class B and C	-	-	-
<i>Tribulus terrestris</i>	Caltrop	Class B and C	-	Y	-
<i>Xanthium occidentale</i>	Noogoora Burr	Class B and C	-	-	-
<i>Ziziphus mauritiana</i>	Chinee Apple	Class A and C	-	-	-
<i>Calotropis procera</i>	Rubber Bush	Class B and C	-	-	Y
<i>Parthenium hysterophorus</i>	Parthenium Weed	Class A and C	-	-	Y

In addition to the above listed weeds a range of annual grass weeds are known to occur along road corridors throughout the region. This includes Buffel Grass, a weed that has the potential to alter fire regimes, introduced and cultivated for livestock feed and useful in soil stabilisation.

The NRM search, which is based on the NT Government database, also identified a number of introduced plants that have previously been recorded within the proposed drill sites and have been identified as problem weeds in one or more locations across Northern Australia. It is noted that these are not listed under the NT *Weeds Management Act 2013*, but could be of concern elsewhere in Australia. Understanding the potential weeds likely to occur within the permit area is particularly important when proposed activities include transporting machinery and equipment during the construction process.

The unlisted weed species that are likely to occur within the permit area and the proposed drilling and stimulation sites are listed in Table 33.

Table 34 Unlisted weeds species likely to occur within the permit area

Scientific Name	Common Name	Potential to Occur		
		Amungee NW-1	Beetaloo W-1	Nutwood Downs SW-1
<i>Azadirachta indica</i>	Neem	-	Y	-
<i>Bothriochloa pertusa</i>	Indian Blue Grass	Y	-	Y
<i>Cenchrus biflorus</i>	Gallon's Curse	-	Y	-
<i>Cenchrus ciliaris</i>	Buffel Grass	Y	-	Y
<i>Citrullus lanatus</i>	Camel Melon	-	Y	-
<i>Cucumis melo</i>	Ulcardo Melon	Y	Y	Y
<i>Echinochloa colona</i>	Awnless Barnyard Grass	Y	Y	Y
<i>Eragrostis minor</i>	Smaller Stinkgrass	-	Y	-
<i>Gomphrena celosioides</i>	Gomphrena Weed	Y	-	Y
<i>Malvastrum americanum</i>	Spiked Malvastrum	Y	Y	Y
<i>Malvastrum coromandelianum</i>	Prickly Malvastrum	-	-	Y
<i>Phyla nodiflora</i> var. <i>nodiflora</i>	Lippia	-	Y	Y
<i>Quisqualis indica</i>	Rangoon Creeper	Y	-	Y
<i>Sida spinosa</i>	Spiny Sida	Y	Y	Y
<i>Sorghum almum</i>	Columbus Grass	Y	-	Y
<i>Sporobolus pyramidalis</i>	Giant Rat's Tail Grass	-	Y	-
<i>Stylosanthes hamata</i>	Caribbean Stylo	Y	Y	Y
<i>Urochloa mosambicensis</i>	Sabi Grass	Y	-	Y
<i>Vachellia farnesiana</i>	Sweet Acacia	Y	Y	Y

### 3.3.2 Fauna

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

- 78 bird, 33 reptile, 11 mammal and six frog species in the Bullwaddy Conservation Reserve (PWCNT, 2005)
- 148 bird, 47 reptile, 21 mammal and six 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).

During this survey, based on non-invasive observational data at the proposed drill sites, access tracks and incidental observations recorded 47 bird species, four mammal species and six reptile species.

### 3.3.3 Significant Fauna

A search of the DoTE Protected Matters database of nationally significant fauna and flora (Appendix C), the NT Government fauna database, and records from the Atlas of Living Australia (ALA) was undertaken with for each stimulation and testing sites. Buffers for the searches included 5 km buffer in addition to a 50 km buffer (PMST) and within the grid cells (NT Government database) to ensure the potential presence of all species was

captured adequately. The search results indicate the potential presence of 35 species listed as threatened under the *EPBC Act* and/or the *TPWC Act* (Table 34). These included 19 birds, 10 mammals, five reptiles and one fish.

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 stimulation and testing areas. As some areas have not been subject to any intensive survey and some species are very cryptic, a conservative approach has been taken to assess species presence. A full description of each species, their distribution and habitat associations is outlined in Table 34.

No species listed as either Critically Endangered, Endangered or Vulnerable were confirmed or considered likely to occur although three species are considered to possibly occur.. 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. The Gouldian Finch (*Erythrura gouldiae*), Vulnerable under the *TPWC Act* and Endangered under *EPBC Act*, may be present sporadically, although there are limited records in the study area. 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.

Near Threatened species are those that have been evaluated against the criteria but do not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for, or is likely to qualify for a threatened category in the near future. These species can therefore be considered to be of conservation significance.

Based on the likelihood assessment the following seven species listed as Near Threatened in the NT are considered likely to occur and two have been confirmed to occur based on the survey results:

- |  |   |
|--|---|
| - Australian Bustard <i>Ardeotis australis</i>               | (Confirmed, Near Threatened-NT)               |
| - Bush-stone Curlew <i>Burhinus grallarius</i>               | (Near Threatened-NT)                          |
| - Grey Falcon <i>Falco hypoleucus</i>                        | (Near Threatened-NT)                          |
| - Square-tailed Kite <i>Lophoictinia isura</i>               | (Near Threatened-NT)                          |
| - Spectacled Hare-wallaby <i>Lagorchestes conspicillatus</i> | (Confirmed -scat sample), Near Threatened-NT) |
| - Northern Nailtail Wallaby <i>Onychogalea unguifera</i>     | (Near Threatened-NT)                          |
| - Western Chestnut Mouse <i>Pseudomys nanus</i>              | (Near Threatened-NT)                          |
| - Chameleon Dragon <i>Chelosania brunnea</i>                 | (Near Threatened-NT)                          |
| - King Brown Snake <i>Pseudechis australis</i>               | (Near Threatened-NT)                          |

As records of species may be limited in remote areas the precautionary principle has been applied. There are some species that have been assessed as possibly occurring even though their primary habitat is not found within the proposed well sites or access tracks. These include species that are associated with ephemeral wetlands, low lying areas that may be seasonally inundated and creeks. During the wet and early dry season these areas may sustain threatened species such as wetland birds (including migratory species) and also the Plains Death Adder (*Acanthopis hawkei*). They also include species that may forage in the area, such as the Square-tailed Kite, that maybe present occasionally.

Table 35 EPBC and TPWC Listed Threatened Species and Likelihood of Occurrence in Stimulation and Testing Sites

Species	Conservation Status		Distribution	Habitat	Likelihood of Occurrence
	EPBC	NT			
Birds					
<i>Acrocephalus australis</i> Australian Reed-warbler	Marine	NT	Widespread species found throughout the eastern states and coastal WA (Pizzey and Knight, 2012).	Found in vicinity in association waterside vegetation such as with tall reeds, cumbungi and bamboos (Pizzey and Knight, 2012).	Possible  (suitable habitat not present at survey sites but potential sporadic occurrence in floodplain area near Beetaloo sites)
<i>Ardeotis australis</i> Australian Bustard	—	NT	Widespread in the NT (although generally found in low numbers), the Barkly Tableland is one of its strongholds (Woinarski, 2007).	This species prefers open grassland habitats including grassy shrublands and open woodlands but also pastoral and cropping lands (Pizzey and Knight, 2012; Woinarski, 2007). Often found in recently burnt habitat (Woinarski, 2007)	Confirmed  (access track in floodplain area)
<i>Burhinus grallarius</i> Bush-stone Curlew	—	NT	Found throughout the NT (Pizzey and Knight, 2012, ALA, 2016).	Occupies a variety of habitats including open woodland, coastal scrub, dry riparian habitat, orchards and cities in QLD (Pizzey and Knight, 2012).	Likely  (recent records and suitable habitat)
<i>Calidris ferruginea</i> Curlew Sandpiper	Marine Migratory	V	In the NT this species occurs around Darwin, north to Melville Island and Cobourg Peninsula, and east and south-east to Gove. It has been recorded inland from Victoria River Downs and around Alice Springs (Higgins and Davies 1996).	Coastal habitats, inland it has been found around lakes, dams and ephemeral/permanent waterholes (Higgins and Davies 1996).	Possible  (suitable habitat not present at survey sites but potential sporadic occurrence in floodplain area near Beetaloo sites)
<i>Dromaius novaehollandiae</i> Emu	—	NT	Widespread throughout Australia but not often found in densely populated areas (Pizzey and Knight, 2012).	Emus are found in semi-arid grassland and savannah woodlands (Pizzey and Knight, 2012).	Possible  (habitat and within distribution but no recent records)



Species	Conservation Status		Distribution	Habitat	Likelihood of Occurrence
	EPBC	NT			
<i>Erythrotriorchis radiatus</i> Red Goshawk	V	V	Found across most of Northern Australia, in the NT most records are from the Top End but there are records from central Australia.	Red goshawks occupy a range of habitats, often at ecotones, including coastal and sub-coastal tall open forest, tropical savannahs crossed by wooded or forested watercourses, woodlands, the edges of rainforest and gallery forests along watercourses, and wetlands that include <i>Melaleuca</i> and <i>Casuarina</i> species.	Unlikely (no records and core habitat absent)
<i>Erythrura gouldiae</i> Gouldian Finch	E	V	Formerly widespread across northern Australia. In the NT they are found in the Top End south past Daly Waters (NTG, 2012).	Gouldian Finches occupy different habitat types in the breeding and non-breeding season. Breeding habitat consist of hillsides with suitable nesting trees. In the non-breeding season they are found in lowland drainages to feed on suitable perennial grasses (Dostine and Franklin, 2002).	Possible (sporadic, foraging only, no recent records)
<i>Falco hypoleucos</i> Grey Falcon	—	V	This species has a widespread distribution and records for this species exist throughout the NT. However, most records are from arid and semi-arid regions (Pizzey and Knight, 2012).	Grey Falcons inhabit lightly treed inland plains, gibber desserts, sandridges, pastoral lands, timbered watercourses and, occasionally, the driest deserts. (Pizzey and Knight, 2012). Also found also in association with inland drainage systems.	Likely (probably not at survey sites but likely in floodplain area near Beetaloo sites)
<i>Falcunculus frontatus whitei</i> Crested Shrike-tit (northern)	V	NT	This species has a very patchy distribution with records from the Victoria River District to Maningrida. Only one record near Borroloola (1930), stronghold near Mataranka (NTG, 2012).	Occupies wet and semi-arid melaleuca and eucalypt open woodlands. May be associated with bloodwoods with flaky bark and ironwood (Ward, 2008).	Unlikely (no records in vicinity although some suitable habitat present, very rare)
<i>Geophaps smithii</i> Partridge Pigeon	V	V	Occurs across the Top End of the NT, declined/disappeared from lower rainfall areas (Woinarski, 2007).	Found predominantly in open eucalypt forest and woodland with grassy understories (Woinarski, 2007).	Unlikely (no records, occurs north of the Project Site although some habitat present)
<i>Grantiella picta</i> Painted Honeyeater	—	V	This species is found throughout eastern Australia but breeding is known from south-eastern Australia (Pizzey and Knight, 2012). This species is rare.	This species specialises on the fruit of mistletoes although it may also forage on nectar and insects (Garnett <i>et al.</i> , 2011). Numerous large tracts of <i>Acacia shirleyi</i> with abundant mistletoes were recorded in the vicinity of the Beetaloo sites.	Possible (records from Barkly tablelands but none in close vicinity, habitat present, foraging only)

Species	Conservation Status		Distribution	Habitat	Likelihood of Occurrence
	EPBC	NT			
<i>Heteromunia pectoralis</i> Pictorella Mannikin	–	NT	This species is found in tropical northern Australia, from Fitzroy River in Western Australia, to the south-west of Cape York Peninsula (Pizzey and Knight, 2012).	Found near water in a variety of habitats including acacia shrublands and woodlands, spinifex grasslands, and grassy flats. This species is highly mobile, and sometimes breeds in eucalypt woodland well north of their usual range (Woinarski and Tidemann, 1991). Pizzey & Knight (2012) note these mannikins occupy tall grass in acacia woodlands; grassy flats, spinifex.	Possible (not at survey sites but access tracks in vicinity of water)
<i>Lophoictinia isura</i> Square-tailed Kite	–	NT	This species is found throughout Australia although not often found in arid and treeless inland habitat (Debus, 2012).	In northern Australian, habitat for square-tailed kites includes areas dominated by eucalypts, pandanus, gallery forest and heath (Morcombe, 2000).	Likely (suitable habitat and within distribution)
<i>Phaps histrionica</i> Flock Bronzewing	–	NT	The Flock Bronzewing is a nomadic species with a widespread distribution from WA through the NT and into eastern QLD and western NSW. In the NT it can be found in the Barkly after good rains.	Preferring blacksoil grasslands, flooded claypans, open mulga and spinifex (Pizzey and Knight, 2012).	Possible (few records north of Kalala S-1 site, some suitable habitat in vicinity of Project sites along access tracks)
<i>Psephotus dissimilis</i> Hooded Parrot	–	NT	Found only in the Top End of the NT, most records are from Pine Creek south the Mataranka (Pizzey and Knight, 2012).	This species is found in dry open woodland, usually with termite mounds where the species nests, with a preference for active termite mounds > 2m (Cooney, 2009; Pizzey and Knight, 2012).	Possible (foraging only, one record north of Kalala S-1 site but not core area of where this species occurs)
<i>Polytelis alexandrae</i> Princess Parrot	V	V	Occupies arid lands in Australia where it is patchily distributed (Woinarski, 2007).	Found in sand dune habitat, spinifex with eucalypts, and shrubs such as acacias, hakeas, and eremophilas (Pizzey and Knight, 2012; Woinarski, 2007).	Unlikely (most records from southern arid region, not primary habitat)
<i>Rostratula australis</i> Australian Painted Snipe	E	V	In the NT, probably occurs in central and southern area although it also possible occurs in the northern portion of the area (Woinarski, 2007).	These birds prefer a habitat of recently flooded temporary vegetated wetlands during the non-breeding period and brackish temporary freshwater wetlands with minimum vegetation during breeding periods. Birds usually forage in thick, low vegetated areas during the day (Curtis and Dennis, 2012).	Possible (suitable habitat not present at survey sites but potential sporadic occurrence in floodplain area near Beetaloo sites)
<i>Tyto novaehollandiae kimberli</i> Masked Owl	V	V	Distributed in Northern Australia although not well known. In the NT, occurs from Cobourgh south to	This species inhabits tall open eucalypt forest in the NT, especially those associated with <i>E. Miniata</i> and <i>E. tetradonta</i> (Woinarski, 2007). Also found in riparian	Unlikely (primary habitat absent)

Species	Conservation Status		Distribution	Habitat	Likelihood of Occurrence
	EPBC	NT			
			Katherine and the VRD and east to the McArthur River (DOTE, 2014)	and monsoonal forest and rainforest (DOTE, 2014)	
<i>Stictonetta naevosa</i> Freckled Duck	–	NT	Predominantly found in southeastern Australia and southern WA, although an infrequent visitor to the NT.	Freckled ducks inhabit wetlands densely vegetated with lignum, in the interior regions of eastern Australia. They are typically nomadic, moving between inland wetlands that are ephemeral, but may disperse towards the coast after exceptionally wet years, during which they breed prolifically (Garnett and Crowley, 2000).	Unlikely (some records, no primary habitat)
<b>Mammals</b>					
<i>Dasyurus hallucatus</i> Northern Quoll	E	CE	Found throughout most of Northern Australia although now restricted to six main areas (Menkhorst & Knight, 2011). In the NT it is found in the Top End as far southeast as Boroloola (DOTE, 2014). One previous record from Shenandoah Pastoral Lease (unknown date).	Northern Quolls do not have highly specific habitat requirements although the most suitable appear to be rocky habitats (Woinarski, 2007). They occur in a variety of habitats across their range, including open forest and woodland. Daytime den sites provide important shelter. Shelter sites include rocky outcrops, tree hollows, hollow logs, termite mounds, goanna burrows and human dwellings.	Unlikely (no recent records, no core habitat)
<i>Isodon auratus</i> Golden Bandicoot	V	E	This species used to be found across northern, central and western Australia but decline after European settlement (Woinarski, 2007). Now only found on Marchinbar Island in the NT and small area of the NW kimberley (Fisher and Woinarski, 1994; Woinarski, 2007).	Previously inhabiting a range of arid and semi-arid habitats, in the NT it occupies heathland and shrubland and hummock grasslands on sandstone, vine thickets and grassy woodlands (Menkhorst and Knight, 2011; Woinarski, 2007).	Highly unlikely (only persists in NE Arnhemland)
<i>Lagorchestes conspicillatus</i> Spectacled Hare-wallaby	-	NT	Distributed in the northern region of NT and QLD and small area of WA, formerly distributed throughout the Great Sandy Desert but now reduced (Menkhorst and Knight, 2011).	Found in open woodland and shrubland with tropical tussock or hummock grasslands (Menkhorst and Knight, 2011).	Likely (multiple recent records, scat sample during 2014 survey, suitable habitat)
<i>Macrotis lagotis</i> Greater Bilby	V	V	This species occurs in south-western Queensland and in arid north-western Australia (Western Australia and Northern Territory). This species was previously widespread in arid and	In the NT, this species is found on sandy soils dominated by spinifex (Pavey, 2009). Low shrubs such as <i>Acacias</i> and <i>Melaleucas</i> are also common in this habitat. Also hummock grassland associated with low lying drainage systems and alluvial areas.	Unlikely (no recent records, primary habitat limited in Project Site to small area along Beetaloo access track, probably

Species	Conservation Status		Distribution	Habitat	Likelihood of Occurrence
	EPBC	NT			
			semi-arid Australia (Pavey, 2009). The most northern records are from Newcastle Waters and Wave Hill (Southgate and Paltridge, 1998).		present previously)
<i>Onychogalea unguifera</i> Northern Nailtail Wallaby	—	NT	Widespread in the drier regions of tropical savannas in northern Australia including the Kimberley, NT and NW Queensland (Menkhorst and Knight, 2011).	This species occupies tropical savannah woodlands, tussock grasslands, riparian habitat and floodplains (Menkhorst and Knight, 2011).	Likely (records and suitable habitat)
<i>Pseudomys nanus</i> Western Chestnut Mouse	—	NT	Found in Northern Australia from the Port Hedland east to NW QLD (Menkhorst and Knight, 2011). In the NT from the Tiwi islands south to approximately Tennant Creek (ALA, accessed Sep 2014).	Found in woodland or shrubland with a dense tussock grasses (Menkhorst and Knight, 2010).	Likely (recent records, suitable habitat present, Amungee)
<i>Rattus tunneyi</i> Pale Field-rat	—	V	Inhabiting higher rainfall area including the Top End of the NT (Menkhorst and Knight, 2011).	This species favours dense vegetation found along rivers where it occupies burrows in loose colonies (Cole and Woinarski, 2002). However, this species can be found in a variety of habitats including woodlands if a dense understorey of grasses is present (Menkhorst and Knight, 2011)	Unlikely (one record from 1999 in greater area, primary habitat absent)
<i>Rattus villosissimus</i> Long-haired Rat	—	NT	In the NT, this species is predominantly found in the Barkly Tablelands but its numbers and distribution are highly variable (Menkhorst and Knight, 2011). Records exist north of Project site but most are located south east of the Project site.	Predominantly found in moist habitat (e.g. riparian areas) but will occupy most habitat types when population increases (ie after high rainfall).	Possible (core habitat not present but may occur at certain times of the year)
<i>Saccolaimus saccolaimus nudiclunatus</i> Bare-rumped Sheath-tail Bat	CE	NT	In Australia this species has been recorded in coastal NE Queensland and the Northern Territory (Curtis and Dennis, 2012). Records in the NT are from Kakadu.	Occupies tropical woodland and tall open forests where it roosts in various eucalypt species. In the NT this species has been recorded from tall open eucalypt forest (Churchill, 2008).	Unlikely (no records and primary habitat not present)
<i>Trichosurus vulpecula vulpecula</i>	—	E	Previously widespread in the NT, this species is now found in isolated	This species occupies riparian habitat in the vicinity of rocky outcrops or slopes (Kerle <i>et al.</i> , 1992).	Unlikely (no records in the vicinity)

Species	Conservation Status		Distribution	Habitat	Likelihood of Occurrence
	EPBC	NT			
Common Brushtail Possum			locations in the southern NT (Woinarski, 2007).		of the Project Site and no suitable habitat)

Reptiles					
<i>Acanthopis hawkei</i> Plains death Adder	V	V	In the NT this species is found in the floodplains of the Adelaide, Mary and Alligator Rivers and the Barkly Tablelands.	Found on flat cracking soils in treeless floodplains where it forages on frogs, reptiles and rats.	Possible (Beetaloo floodplain area, dependent on Cane Toad densities)
<i>Acanthopis praelongus</i> Northern Death Adder	—	NT	Distributed in northern Australia from the Kimberley east to the Torres Strait island (Wilson and Swan, 2010). Most records are north of the Project Site (ALA, accessed Sep 2014).	This species inhabits grasslands and woodlands and rocky habitat (Wilson and Swan, 2010). This species prefers habitat with dense litter.	Possible (no records, but suitable habitat present)
<i>Chelosania brunnea</i> Chameleon Dragon	—	NT	Found in northern WA and NT (Wilson and Swan, 2010). In the NT is found south to Daly Waters.	Occupies tropical woodlands. In the NT records are from eucalypt woodland and forest with one record from Lancewood ( <i>Acacia shirleyi</i> ) (Trainor, 2005).	Likely (habitat present, within distribution)
<i>Elseya lavarackorum</i> Gulf Snapping Turtle	E	—	In the NT this species found in the Calvert and Nicholson River	Found in river systems. Inhabit larger rivers and their associated lagoons and lakes (Cogger, 2000).	Highly unlikely (no suitable habitat)
<i>Pseudechis australis</i> King Brown Snake	—	NT	A widespread species present throughout most of Australia (Wilson and Swan, 2010). Decrease in NT population attributed to cane toads.	Found in a variety of habitats including dry eucalypt woodlands, monsoon forest, desert etc. (Wilson and Swan, 2010).	Likely (records and suitable habitat)
Fish					
<i>Pristis microdon</i> Freshwater Sawfish	V	V	Distributed in northern Australia from Shark Bay in WA east to Cairns QLD (Curtis and Dennis, 2012)	Occupies shallow coastal waters, river mouths, rivers and waterholes (Curtis and Dennis, 2012).	Highly unlikely (no suitable habitat)

### 3.3.4 Migratory Species

The DoTE Protected Matters database search (Appendix C) also indicated the potential presence eight migratory species at the stimulation sites (Table 35).

One species, the Rainbow Bee-eater (*Merops ornatus*) was confirmed to occur at the stimulation and test sites. This is a widespread species that occurs in a variety of habitats (Pizzey and Knight, 2012). The other species that may occur include wetland species that have the potential to occur in the floodplain surrounding the Beetaloo access track. These species could be present during the wet season and early dry season when there is standing water. As the stimulation and testing activities are being undertaken during the dry season it is unlikely that these species will be impacted.

Table 36 Migratory (EPBC) species potentially occurring at the stimulation and test sites.

Scientific Name	Common Name	EPBC Act	Likelihood of Occurrence
<i>Apus pacificus</i>	Fork-tailed Swift	Migratory	Likely
<i>Ardea alba</i>	Great Egret	Migratory	Possible
<i>Ardea ibis</i>	Cattle Egret	Migratory	Possible
<i>Charadrius veredus</i>	Oriental Plover	Migratory	Possible
<i>Glareola maldivarum</i>	Oriental Pratincole	Migratory	Possible
<i>Haliaeetus leucogaster</i>	White-bellied Sea-eagle	Migratory	Unlikely
<i>Merops ornatus</i>	Rainbow Bee-eater	Migratory	Confirmed
<i>Rostratula benghalensis (sensu lato)</i>	Australian Painted Snipe	Migratory	Possible
<i>Cecropis daurica</i>	Red-rumped Swallow	Migratory	Unlikely
<i>Cuculus optatus</i>	Oriental Cuckoo	Migratory	Possible
<i>Hirundo rustica</i>	Barn Swallow	Migratory	Unlikely
<i>Motacilla cinerea</i>	Grey Wagtail	Migratory	Unlikely
<i>Motacilla flava</i>	Yellow Wagtail	Migratory	Unlikely
<i>Anseranas semipalmata</i>	Magpie Goose	Migratory	Unlikely
<i>Crocodylus johnstoni</i>	Freshwater Crocodile	Migratory	Unlikely

### 3.3.5 Feral Animals

Feral animals known to occur within the region include (PWCNT, 2005; ANRA, 2008):

- 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*).
- Black Rat (*Rattus rattus*)
- Domestic Cattle (*Bos Taurus*)

The Cane Toad is known to be present in the permit area and the Commonwealth Government (DOTE) recognises this species as a 'key threatening process' related to their impacts on biodiversity through



predation, competition, land degradation and poisoning. Cane Toads have been known to be common throughout the regional area.

Pest predators such as the Feral Cat are most likely common although their abundance difficult to assess due to the cryptic nature of this species. Introduced predators such as Feral Cats can impact many vertebrates (e.g. Dickman, 2009 and 1996). One of the primary concerns of introduced predators in the Project Site is the impact on CEEVNT species such as reptiles, and ground-dwelling birds. Species could be attracted to construction sites potentially increasing their abundance in the landscape.

It is of key importance during all phases of the project that care is taken to ensure that rubbish is securely contained (i.e. with suitable lids) and removed from the site as soon as possible to discourage attracting any feral animals.

### 3.3.6 Conservation Areas

There is one conservation reserve, the Bullwaddy Conservation Reserve, which occurs in proximity to the 2016 stimulation and testing sites. This area is excluded from any stimulation and testing activities proposed in this EP.

Lake Woods located on the south western side of the permit area on Newcastle Waters Station is listed as a Site of Conservation Significance by the Department of Land Resource Management and is listed on the Directory of Important Wetlands in Australia. Lake Woods is listed as a wetland of national significance in the Directory of Important Wetlands in Australia (DIWA: NT013 Lake Woods). The site meets criteria 1, 2, 3, 4, 5 and includes DIWA wetland types: B1, B6, B10, B13 and B14. Although Lake Woods is located outside of the Exploration Permit Areas, it is fed principally by surface inflow of Newcastle Creek originating more than 160 km north-east on Amungee Mungee Station.

During the period of inundation, Lake Woods supports over 100,000 waterbirds including internationally significant numbers of Plumed Whistling-Duck. Numerous bird species nest and feed in the diverse wetland habitat, and the conservation group 'Birdlife International' nominated Lake Woods as an 'Important Bird Area' (IBA). The lake also includes the largest area of lignum swamp in the Northern Territory and in tropical Australia.

There are no national or world heritage places, Commonwealth land or heritage places or reserves or critical habitat areas listed under the *EPBC Act* are located within or adjacent to the exploration areas (EP76, EP98 and EP117).

### 3.3.7 Ecological Integrity

A study of Australian landscape health was undertaken by the Commonwealth government (Department of the Environment and Heritage and the National Land and Water Resources Audit, supported by State and Territory agencies), in order to assess regional landscape health from the perspective of biodiversity and natural ecosystems. As part of this assessment, attributes indicative of landscape condition and trend were analysed. These attributes included:

- native vegetation extent
- fragmentation and clearing rates
- land use
- current extent and trend of dryland salinity
- changed hydrological conditions
- current extent and trend of weeds and feral animals
- the distribution of threatened species and ecosystems.

This resulted in the development of Landscape Health Database 2001, which provides spatial representation of the results. The majority of EP76 and EP98 have low grazing pressure (only 10-30% of this area is considered to have high grazing rates). Part of EP76 has high grazing pressure.

### 3.3.8 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 grassland by pastoral management in order to maintain forage throughout the dry season.

Historically, the majority of dry season fires (June to September) have occurred in the northern half of the permit area, in EP76, EP98 and EP117. At this time of year, the fires are likely to be high intensity (HLA, 2005).

Wet season fires (October to May) have occurred within the permit area. These fires are likely to be patchy and of lower intensity, depending on the state of curing of the fuel load.

A summary of the last time the exploration areas were burnt is as follows:

- Amungee NW-1H was last burnt 4 years ago. Amungee NW-1H has been burnt nine times between 2000 and 2013.
- Beetaloo W-1 was last burnt 2 years ago. Beetaloo W-1 has been burnt six times between 2000 and 2013.
- Nutwood Downs SW-1 was last burnt 1 year ago. Nutwood Downs SW-1 has been burnt eight times between 2000 and 2015.

### 3.4 Social Environment

#### 3.4.1 Native Title

Five Native Title determinations and one Indigenous Land Use Agreement (ILUA) are current over the permit areas. There is one Native Title Claim that is still under assessment (see Table 36).

Table 37 Native Title and IULA Agreements Current for the Permit Areas

Type	Name	Summary
Native Title	NTD21/2010 Shenandoah Pastoral Lease	Native Title exists in parts of the determination area and is held by the Kinbininggu and Bamarrnganja groups
	NTD27/2010 Beetaloo Pastoral Lease	Native Title exists in parts of the determination area and is held by the Karranjini group; the Bamarrnganja group; the Warranangku group; the Pinda (OT Downs) group; and the Lija/Muwartpi group
	NTD17/2010 Amungee Mungee Pastoral Lease	Native title exists in parts of the determination area and is held by The Karranjini group; the Bamarrnganja group
	NTD24/2010 Kalala Pastoral Lease	Native title exists in parts of the determination area and are held by the Badpa group, the Murrunggun Kunakingka group and Guyal Bardi Bardi group
	NTD26/2010 Hayfield Pastoral Lease	Native title exists in parts of the determination area and are held by the Kinbininggu group, the Warranangku group and the Marlinja group
	DC2013/004 Nutwoods Downs Pastoral Lease	Native Title Claim was not accepted for registration. The Native Title Applicants, which include Mambali Amaling-gan, Murungun Igalumba, Murungun Milgawirri, Budal Yuwaran and Guyal Bardi Bardi Dumbyun-Ngatanyana Estate Groups, resubmitted on 11 December 2013, with consent expected to occur within the second half of 2016
Indigenous Land Use Agreement	D12004/014 Jingaloo CLA ILUA	Registered for Community Living Area and Tenure resolution

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

#### 3.4.2 Archaeology Assessment

An archaeological assessment, involving searches of the NT Heritage Register and Australia Heritage Database and a field survey, has been carried out by AECOM archaeologists for the stimulation and testing sites. Surveys were carried out with assistance by representatives of the traditional owners and the Northern Land Council. The archaeological inspection involved a combination of both pedestrian and vehicular survey of the sites. During the inspections notes were taken on landform, ground surface visibility and areas of exposure. The aim of the inspection was to identify any surface expressions of Aboriginal archaeological and cultural heritage values within the exploration area. Photographic records were taken at each proposed drill locations.

A search of the Northern Territory Heritage Register identified 41 Aboriginal archaeological sites within a 125 km by 125 km area that encompasses the full Proposal area. No archaeological site are recorded within 15 km of the proposed drill locations. Two artefact scatters, Goochegoochena Creek Site 1 and Goochegoochena Creek Site 2, located adjacent to the Stuart Highway are recorded within 600 m and 350 m respectively of the access track entrance for the Beetaloo exploratory well location.

A search of the Australia Heritage Database identified that no statutory listed heritage places within the proposed impact areas. Three sites listed on the now non-statutory Register of the National Estate are located within a 125 km x 125 km search area that encompasses the full permit area. None of these heritage places are located within 10 km of the proposed impacts.

No culturally sensitive landforms were identified during the August 2014 survey of Amungee NW-1H and

Beetaloo W-1. One Aboriginal archaeological site (BT-IA1-14, an isolated artefact) was identified on the previously disturbed Beetaloo access track 5.3 km to the west of exploration drill site Beetaloo W-1. The isolated artefact was not insitu and has likely been redeposited as the result of low level fluvial agency across this area. It was determined to be of low scientific value.

During the April 2016 field survey, no culturally sensitive landforms were identified on Nutwood Downs SW-1. One Aboriginal isolated artefact (BT-16-IA2) was identified on the above-ground flow-line alignment. This artefact is not insitu and has likely been moved by hydrological processes common across this area during the wet season.

Appendix D presents the two Heritage Assessment Reports prepared by AECOM archaeologists for the stimulation and testing sites.

### 3.4.3 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 clearance surveys have been completed for the entire permit area. The most current clearance certificates issued for the Origin exploration program include:

- AAPA 2014/1021 (C2014/183) – EP117 for Beetaloo W-1
- AAPA 2014/1022 (C2014/184) – EP98 for Amungee NW-1H
- AAPA 2015/550 (C2015/212) – EP98 for Nutwood Downs SW-1.

The following provides a summary of the current AAPA clearance surveys and the identified Sacred Sites. The AAPA Certificate identified the following RWA:

- EP98 (C2015-212) (Nutwood Downs Sites) – A number of Sacred Sites are located along the length of Nutwood Downs Road:
  - AAPA #5565-1 (RWA-6) – a soak on the northern side of Nutwood Downs Road
  - AAPA #5665-6 (RWA-3) – a small hole in rocky ground in a patch of dense scrub approximately 100 m south of Nutwood Downs Road
  - AAPA #5665-5 (RWA-5) – a waterhole and surrounding trees on northern side of Nutwood Downs Road.
  - AAPA #5665-4 (RWA-4) – a waterhole on the southern side of Nutwood Downs Road.
  - AAPA #5665-2 (RWA-2) – two waterholes, a swamp and trees located near the proposed Kalala NE-1.

No works and no damage shall occur to these areas during maintenance of Nutwood Downs Road and development of the drill sites (noting development of the drill site will occur in accordance with Origin's 2016 Exploration Drilling Environmental Plan).

- EP98 (C2014/184) (Carpentaria Highway Sites) – AAPA #5665-7 – Waterhole located over 8 km away from Amungee NW-1H – no access or no works within 500 m.
- EP117 (C2014/183) – AAPA #5663-45 – Open country surrounded by dense vegetation on the road to Jingaloo – no access and no work permitted on south side of Beetaloo access track within a radius of 300 m (AAPA Certificate reference 2014/1021).

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

### 3.4.4 Natural Resources

In addition, during the archaeological survey, representatives of the traditional owners identified a number of natural resources of importance to Aboriginal people of the area (Table 37).

Table 38 Selection of Bush Food and Medicines identified within the Study Area

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

### 3.4.5 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 Murrniji 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 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 has in recent times seen commercial interest from the exploration for gas in the Beetaloo Sub-basin and the growth of the 'grey nomad' tourism market.

### 3.4.6 Historic Heritage Assessment

A search of relevant historic heritage registers identified a number of historic heritage sites within a 125 km by 125 km area that encompasses the full Proposal area. No previously identified sites are located within 20 km of the proposed works.

The nearest listed historic site is the Frew Ponds Overland Telegraph Poles listed on the NT Heritage Register, a series of poles located on the western side of the Stuart Highway within Hayfield Station, that are the remains of the original Overland Telegraph.

The next nearest site is the Daly Waters Aviation Complex, declared on the NT Heritage Register in October 1994. Entrance to the complex is located 5.5 km north of the Carpentaria Highway on the western side of the Stuart Highway.

The complex consists of a hangar, public lavatory block, shell oil store, accommodation buildings, radio and navigation buildings and an apron leading to the taxiway. The hangar, lavatories and shell oil store were constructed in 1930 while the accommodation, radio and navigation buildings were constructed in the 1940s. The complex is significant as a component of an international and military aerodrome during the pioneering and development period of North Australian aviation. The Daly Waters Aviation Complex holds significance to the Northern Territory's aviation heritage. It represents an era in aviation when the longest range aircrafts were unable to traverse Australia without several stops to refuel. The Aerodrome was also a refuelling stop for major airlines of the day travelling from the United Kingdom to Australia.

A number of historic homesteads and properties are scattered throughout the proposal area. None of these will be directly or indirectly impacted by the proposal.

No new sites of historic heritage were identified during the field survey.

### 3.5 Matters of National Environmental Significance

#### 3.5.1 Potential EPBC Act Controlling Provisions

The main focus of the MNES assessment was to consider potential obligations which may arise under the *EPBC Act* during the activities for the stimulation and well testing program at Amungee NW-1H and Beetaloo W-1 or Nutwood Downs SW-1.

When an action is proposed, such as the Origin's proposed exploration program, approval by the Commonwealth Minister for the Environment and Heritage under the *EPBC Act* may be required. This will only be the case if the action is likely to result in any significant impacts on matters of national environmental significance or if the action will have or is likely to have a significant impact on the environment.

Potential triggers under the *EPBC Act* include a significant impact on:

- the world heritage values of a declared World Heritage property
- the national heritage values of a listed National Heritage Place
- the ecological character of a declared Ramsar wetland
- a listed Threatened Ecological Community, or its habitat
- the members of a listed threatened species
- the members of a listed migratory species or their habitat
- a water resource, in relation to coal seam gas development and large coal mining development.

#### 3.5.2 Matters of National Environmental Significance

The DOTE Protected Matters Search Tool was used to generate a report for each of the stimulation and testing sites to identify whether matters of national environmental significance or other matters protected by the *EPBC Act* are likely to occur on or in the near vicinity of the stimulation and testing sites.

This section of the report is designed to provide general guidance to identify obligations under the *EPBC Act*. The results of the search are provided in Table 38.



Table 39 Summary of EPBC Aspects for the Stimulation and Testing Sites

Aspect	Amungee NW-1H	Beetaloo W-1	Nutwood Downs SW-1
<b>Matters of National Environmental Significance</b>			
World Heritage Properties	None	None	None
National Heritage Places	None	None	None
Wetlands of International Significance	None	None	None
Great Barrier Marine Park	None	None	None
Commonwealth Marine Area	None	None	None
Listed Threatened Ecological communities	None	None	None
Listed Threatened Species	8	5	9
Listed Migratory Species	8	8	11
<b>Other Matters Protected by the EPBC Act</b>			
Commonwealth Land	None	None	None
Commonwealth Heritage Places	None	None	None
Listed Marine Species	10	9	15
Whales and other Cetaceans	None	None	None
Critical Habitat	None	None	None
Commonwealth Reserves Terrestrial	None	None	None
Commonwealth Reserves Marine	None	None	None
<b>Extra Information (Information that may also be relevant to the Exploration sites)</b>			
Places on the Register for National Estate	None	None	None
State and Territory Reserves	None	None	None
Regional Forest Agreement	None	None	None
Invasive Species	8	7	8
Nationally Important Wetlands	None	None	None
Key Ecological Features (Marine)	None	None	None

### 3.5.3 Assessment of EPBC Act

The environmental review undertaken as part of the development of the Stimulation and Testing EP identified MNES that have the potential to occur within the proximity of the stimulation areas, however; the likelihood assessment concluded that no EPBC listed threatened ecological communities or threatened species are considered likely to occur within the proximity of the stimulation and well test sites.

No clearing of vegetation for the stimulation and testing program is required as the sites will have been cleared under Origin's 2015 and 2016 Exploration Drilling Environmental Plans. Several migratory species were indicated to occur in the sites, either in searches or from observations during field work. No habitat for these migratory species will be cleared as part of the stimulation and testing program.

The mitigation measures presented in Section 5 of this Stimulation and Testing EP would assist in minimising any potential impacts the stimulation and testing program may have on listed species. As such, it is considered that an EPBC Referral would not be required for the 2016 stimulation and well testing program.

A standalone MNES self-assessment report in accordance with the DOTE Guidelines has been prepared by AECOM.

#### 4.0 Stakeholder Consultation

Further to Origin's comprehensive stakeholder engagement outlined in its 2016 Exploration Drilling Environmental Plan, the following additional information and commentary is provided with specific regard to a growing interest in HFS, from sectors of the community.

Origin's local and directly impacted/affected stakeholders have been, and 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.

Origin's consistent approach to stakeholder engagement has been to ensure that those persons and/or groups most 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 even during this stage of low impact and small scale of exploration activities.

It is accurate, fair and reasonable to both acknowledge and accept that localised social license has been achieved given that the informed consent of Traditional Owners and pastoralists has been given where activity has occurred or is proposed. Land Access Agreements (LAAs) have been entered into with all pastoralists where Origin has undertaken activity, and no future activity will be considered without agreement with the relevant pastoralist.

Traditional Owners have also provided supplementary endorsement of the 2016 activities post the completion of a number of cultural heritage clearance surveys. A number of restricted work areas have been identified and Origin has employed the acceptable practice of ensuring buffer zones are in place around known and identified areas of importance and significance.

With specific regard to the pastoralist whose property Origin will conduct the 2016 HFS on, in-principle consent is conditional on confirmation from their independent consulting hydrogeologists of the methodology and results of an extensive baseline water monitoring program. Origin worked closely with the landholder to ensure that a robust data set was in place, prior to seeking the pastoralist's consent. Baseline data is of importance and relevance to both pastoralists and Origin. For the pastoralists - it provides them with the ability to assess impacts given a data set will exist for before, during and after the HFS activity. For Origin, it is equally important to be able to demonstrate to the landholder, Traditional Owners and regulators that our extraction processes are robust and measurable and environmentally sound. The formal, executed agreement is expected within the next two weeks and Origin will advise the NT DME and EPA upon receipt of the same.

These primary landowners and landholders reside on pastoral properties, in communities or townships either contained within or within proximity to, the permit acreage operated by Origin. Generally speaking, these stakeholders and their properties or communities are situated east of the Stuart Highway between Daly Waters and Elliot.

Other primary stakeholders that have been consulted include:

- Neighbouring traditional owners and indigenous custodians
- Neighbouring pastoralists and landholders/leaseholders
- Local businesses in and around the permit areas
- Northern Territory Government
- Local Government and Shire Councils
- NT Cattlemen's Association and other primary producer groups
- NGOs and Environmental groups
- Industry Associations and Agencies
- Community members and businesses in the townships of Katherine and Tennant Creek

Origin respects that there are genuine concerns, interests and questions that community members hold and in order to address legitimate concerns, Origin has worked diligently to be able to provide accurate and timely information to stakeholders. The majority of Origin's engagement with its primary stakeholders has been proactive and when required, Origin has also responded to additional requests for information, including that from stakeholders not impacted directly by the project.

Unlike mineral resource extraction in the NT, which many Territorians are familiar with, energy exploration activity in central NT has been limited. Compared with mineral exploration, it is also a slower exploration, testing and development process. As such, general knowledge of the onshore natural gas industry is not as 'commonplace' as mining - indeed, sometimes energy activities are incorrectly referenced as mining.

Notwithstanding that much of the increasing interest, including opposition to the continued development of the NT's onshore natural gas industry, comes from stakeholders not directly impacted by operational activities,

Origin has committed resources and time to allow competent and experienced personnel to participate in educational and community information sessions from Darwin in the North, to Alice Springs in the South and across to Borroloola in the East.

Additional stakeholder groups and events include, though are not limited to:

- Regional Economic Development Committee(s)
- Rotary Club(s)
- Chamber of Commerce and Industry (Darwin and regional offices)
- Darwin and Regional Shows
- Department of Tourism
- Department of Transport
- Regional Shire and Town Council Mayors and Alderman
- Darwin, Fred's Pass and regional shows
- Media (regional and Darwin)
- Attendance at APPEA events
- Environmental interest groups including Arids Land Council, Don't Frack Katherine, Don't Frack the Territory, Environmental Defenders Office, the Environment Centre
- Charles Darwin University
- International Association of Hydrogeologists
- NT Members of Parliament and nominated candidates for the August 2016 election
- Community members

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

Origin is confident that it has secured its local social license to operate and will continue to build on these local relationships and partnerships to deliver mutually beneficial outcomes that contribute to community health and wellbeing. Appendix F provides a summary stakeholder consultation log, together with copies of 'Storyboards' used as communication tools to aid further discussion and consultation in relation to the Origin permits as well as explain proposed processes and activities. The Storyboards have been used extensively with a broad cross-section of community, including, but not limited to, one-on-meetings, focus group/information sessions as well as being used at all regional Shows across the NT. The Storyboards also demonstrate the wide range of topics discussed with stakeholders. In addition to the Storyboards, Origin has also used tactile tools such fracture stimulation fluid, cores samples and well casings.

## 5.0 Potential Impacts and Management

The assessment of potential impacts and management aims to avoid and or minimise environmental impacts during the stimulation and well testing program. The Australian Petroleum Production and Exploration Association Limited (APPEA) *Code of Environmental Practice* (APPEA, 2008) and a range of State/Territory Government Exploration Guidelines have been used to develop the management strategies for each of the identified potential impacts. This EP defines management strategies for the potential impacts in Sections 5.3 to Section 5.18.

### 5.1 Potential Impacts of Project

The identification and assessment of potential environmental impacts and risks is carried out so as to avoid or reduce them to as low as reasonably practical through allocation of appropriate controls and management strategies.

The assessments and control and management strategies are informed by the APPEA *Code of Environmental Practice* (APPEA, 2008) and a range of State/Territory Government Exploration Guidelines.

Environmental risks associated with the 2016 program of works have been identified through a thorough hazard identification and risk assessment process. The identified risks have been assessed using the Origin corporate risk assessment criteria set out in the Origin risk management directive (ORG-RMS-DIR-001) using the Origin Risk Tool (ORG-RSK-TOOL-001). The purpose of the analysis was to identify risks and develop risk-reducing measures for preventing and mitigating impacts from the planned activities.

The assessed environmental risks are recorded in the detailed risk register, which is provided in Appendix E and Appendix B. The detailed risk assessment presents the range of potentially impact-causing activities, corresponding mitigation measures and pre- and post-mitigation risks based on their assessed worst-case consequence and likelihood of occurrence.

Table 39 provides a count of the environmental risks associated with the 2016 stimulation and well testing program. Note that the high risk contained within the CloudGMS report in Appendix B is not related to an environmental risk, however has been included in the report due to Origin's risk matrix assessing activities in addition to environment. As indicated in the CloudGMS report all mitigated environmental risks are either medium or low.

Table 40 Count of Mitigated Environmental Risks from the Stimulation and Well Test Program

	Risk Level				
	Low	Medium	High	Severe	Extreme
Count	24	3	-	-	-

## 5.2 Management of Environmental Impacts

Origin has strong Health, Safety and Environment Management System (HSEMS) and Health, Safety and Environment Policy (refer Appendix A). This stimulation and well test EP details how Origin intends to manage and minimise its impacts during exploration activities. This document is to be considered within the context of the wider Origin HSEMS.

### 5.2.1 Overarching Environmental Management Strategies

Detailed environmental objectives, monitoring requirements, performance indicators, resource implications and applicable legislation are discussed in each implementation plan below in regard to specific environmental factors and potential environmental impacts (refer to Section 5.3 to Section 5.18). Tables outline specific actions to mitigate risks and allocate responsibilities to appropriate staff and contractors. Contractors will be required to bridge their SMS to this EP.

### 5.2.2 Detailed Management Strategies

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

Each management area has been assigned to specific positions within the stimulation and well test team, as follows:

- **Asset Manager** – responsible for the overall operations in the Beetaloo JV.

- **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.
- **Completion Engineer** – Completion Engineer is an Origin Representative and is predominately office-based. The Completion Engineer is responsible for coordinating with the Operating Company Representative on the stimulation and well test program.
- **Operating Company Representative** – person based in the field responsible for ensuring all areas of operations are carried out in accordance with this EP and Origin' HSE Policy. All contractors report to this position, which is responsible to the Project Manager.
- **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.
- **Field Personnel** – All staff including Origin and contractors that are working on the Beetaloo project.



### 5.3 Soils and Erosion

Note that stimulation and well test activities will not require any additional ground disturbance to that which is created in accordance with Origin's 2015 and 2016 Exploration Drilling EPs.

#### 5.3.1 Potential impacts

Soil disturbance and degradation of soil profile resulting in:

- Soil instability or movement as a result of stimulation and well test activities
- Soil erosion as a result of stimulation and well test activities
- Soil compaction as a result of stimulation and well test activities
- Loss of topsoil and land suitability/capability
- Soil contamination as a result of stimulation and well test activities
- Dust impacts on built-up areas, vegetation and amenity as a result of stimulation and well test activities.

#### 5.3.2 Objectives

- To avoid, or minimise and control, soil erosion and discharge of sediment or soil into waterways or established drainage systems
- To minimise disturbance of soil, vegetation and drainage during site activities
- To minimise the creation of dust.

## 5.3.3 Soil and erosion management tasks and responsibilities

Activities	Management Tasks	Responsibility
<b>Stimulation / Well Test Operations</b>	<ul style="list-style-type: none"> <li>- Ensure site environmental inductions for all site personnel and contractors include the requirement to use only approved access tracks created under Origin's 2015 and 2016 Exploration Drilling EPs.</li> <li>- Monitor and maintain sediment fences around lease pad, in accordance with ESCP installed under Origin's 2015 and 2016 Exploration Drilling EPs.</li> <li>- Monitor lease pad and road conditions and implement management measures where required.</li> </ul>	Operating Company Representative
	<ul style="list-style-type: none"> <li>- Use only approved access tracks and established designated parking and vehicle movement areas.</li> </ul>	Field Personnel
<b>Camp Operations</b>	<ul style="list-style-type: none"> <li>- Ensure site environmental inductions for all site personnel and contractors include the requirement to use only approved access tracks created under Origin's 2015 and 2016 Exploration Drilling EPs.</li> <li>- Monitor and maintain sediment fences around camp, in accordance with ESCP installed under Origin's 2015 and 2016 Exploration Drilling EPs.</li> </ul>	Operating Company Representative

### 5.3.4 Monitoring requirements

Monitoring for soil erosion and related issues is best undertaken at critical stages, such as:

- After completion of a specific phase of activity. For example, after setup and completion of the stimulation works and then after the well testing for signs of compaction, erosion and soil degradation (generation of bulldust).
- When first re-accessing the site after the wet season to look for signs of erosion. If significant impacts are identified remediation works may need to be conducted prior to continued vehicular access.
- After more than 20 mm of rainfall.

Assessment should be made for:

- Erosion and sediment controls employed on site are in place and in working order.
- Evidence of erosion scalds, especially along the access tracks where vehicles have been moving.
- Evidence of erosion gullies. This may occur if access tracks, drill pad or camp sites were placed in sensitive environments, such as on steep hill slope, and considerable ground disturbance occurred.
- Records, including photographic records, will be maintained for documenting soil disturbance, including instances of unauthorised vehicle movement.

### 5.3.5 Performance indicators

The success of minimising soil erosion and sedimentation as a result of the proposed activities can be measured through the following:

- Minimum incidences of erosion and sedimentation occurring
- Prompt remediation of erosion fronts when recorded
- Avoidance of reasonable complaints from leaseholders about road/track conditions and/or erosion on properties.

### 5.3.6 Resource implications

In order to follow the above management strategies, the following resources will be required:

- Environmental Induction.
- Effective site design and stabilisation, including site specific ESCP prepared by a certified professional in Erosion and Sediment Control.
- Equipment to undertake soil stabilisation remediation works, including spare equipment on site for maintenance.
- Adequately trained and experienced contractors familiar with erosion minimisation techniques during exploration activities (contractors with a local understanding of the landscape are most suitable).
- Experienced operators who can implement erosion control works as required.
- Time to assess tracks and sites of activities for erosion and other soil issues after completion of activities.
- Reporting of results.

## 5.4 Surface water

### 5.4.1 Potential impacts

The potential impacts to surface water associated with the stimulation and well testing program may include:

- Contamination or pollution of surface waters through hydrocarbon or chemical spill or leak
- Contamination or pollution of surface waters through waste or waste water impact
- Impacts associated with soil erosion such as increased water turbidity
- Pollution of potable and stock water supply.

### 5.4.2 Objectives

- To avoid or minimise and control contamination caused by the discharge of pollutants to soils, waterways or established drainage systems
- To contain all potential contaminants for treatment or disposal
- To preserve water quality of potential potable water supplies
- To minimise the impacts on surface water drainage by preserving drainage system integrity and water quality.

## 5.4.3 Surface water management tasks and responsibilities

Activities	Management tasks	Responsibilities
<b>Stimulation / Well Test Operations</b>	<ul style="list-style-type: none"> <li>- Monitoring local weather and climate information to make informed decision regarding site operations.</li> <li>- Ensure site environmental inductions for all site personnel and contractors includes protective measures to prevent avoidable discharge into, or contamination of, waterways or established drainage systems.</li> <li>- Ensure appropriate storage of fuel and other <i>flammable and combustible liquids</i> in accordance with AS1940:2004 <i>The storage and handling of flammable and combustible liquids</i>.</li> <li>- Maintain stormwater containment system as required.</li> <li>- Have a procedure in place to manage large quantities of water. This may include pumping to an existing dam or watering point.</li> <li>- Regular inspection and integrity checks of flowback tanks. Test tank integrity during commissioning and prior to use.</li> <li>- All access roads, culverts and creek crossings will be maintained in proper working order.</li> <li>- Ensure adequate freeboard is maintained in and ponds. A minimum of 0.5 metre freeboard is to be maintained to allow for a 72 hour, 1 in 100 year average recurrence intensity rainfall event (370.8mm – based on BOM Daly Waters historical rainfall Intensity-Frequency-Duration data)</li> <li>- Ensure all pipes and hoses are in good condition and fit for purpose to minimise risk of leaks from pipe.</li> </ul>	Operating Company Representative
<b>Camp Operations</b>	<ul style="list-style-type: none"> <li>- Ensure site environmental inductions for all site personnel and contractors includes the issue of water pollution and protective measures to prevent avoidable discharge into, or contamination of, waterways or established drainage systems.</li> <li>- Ensure appropriate storage of fuel and other flammable and combustible liquids in accordance with AS1940:2004 <i>The storage and handling of flammable and combustible liquids</i>. Establish appropriate wastewater containment system as required.</li> <li>- Maintenance of all water using utilities, such as toilets, showers to ensure in working order.</li> <li>- Visual inspections of the sites stormwater and waste water containment systems should be undertaken weekly.</li> <li>- Refuel and transfer chemicals away from drainage lines.</li> </ul>	Operating Company Representative

#### 5.4.4 Monitoring requirements

Based on results of baseline surface water assessments, it is understood that the regional surface waters have high turbidity. Given the drilling program, which is proposed to occur during the dry season, and at which time surface water flows are unlikely (i.e. ephemeral creeks), there is low risk activities will impact on surface waters. As such, monitoring of surface waters associated with drilling is not recommended unless the program moves into production or surface waters are running from the site. Daily pH sampling of surface waters impacted by stimulation activities is recommended to monitor if contamination has occurred.

Visual inspections of the sites stormwater and waste water containment systems should be undertaken regularly or following a significant rainfall event (i.e. greater than 20 mm in a 24 hour period).

#### 5.4.5 Performance indicators

The performance indicators for surface water include:

- No release of site stormwater or wastewater exceeding baseline surface water quality
- No long-lasting change in soil and surface water quality from base line conditions.

The success of minimising surface water pollution as a result of the proposed activities can be measured through no complaints from pastoralists about fouling of water supplies for stock and/or domestic use.

#### 5.4.6 Resource implications

In order to follow the above management strategies, the following resources will be required:

- Environmental Induction
- Effective site design and stabilisation, as well as effective stormwater/waste water management system



## 5.5 Groundwater

Origin commissioned CloudGMS to undertake an independent groundwater-specific assessment of the risks associated with exploration activities and a potential development scenario (CloudGMS, 2015b). The conclusions of the risk assessment were:

- The principal aquifer (CLA) underlying the exploration sites are an extensive, regional aquifer. Generally, groundwater impacts resulting from the exploration activities are expected to be reasonably isolated and localised due to the deep water table (>60 m), overlying unsaturated clay layers, underlying regional aquitards and large storage capacity of the principal aquifer, CLA.
- The groundwater risk assessment identified nine potential environmental impacts to groundwater system in the Beetaloo basin associated with Origin's 2016 program (both for its exploration drilling and stimulation / well testing programs). These impacts are ranked below according to the assessed risk level.

### MEDIUM

- Exploration drilling enables cross formational flow between shallow aquifers in contravention of Water Act regulations. Note this was assessed as High in the CloudGMS report for impacts other than environmental
- Cross formational flow of formation water/hydrocarbons from deeper formations to a utilised aquifer causes groundwater contamination and impacts existing groundwater users.

### LOW

- Spill of fuel/additives/produced water causes groundwater contamination.
- Leakage from mud/flare pits causes groundwater contamination.
- Groundwater extraction causes declining water levels in utilised aquifers which impacts on existing groundwater users/environmental values.
- Loss of drilling fluids into an aquifer impairs capacity in existing bores.
- Cross flow of water from a utilised aquifer to another formation causes declining water levels.
- The loss of a radioactive source during geophysical logging results in groundwater contamination.
- Hydraulic fracturing induces seismicity increasing connection between formations and enhancing the potential for cross formational flow.

More extensive investigations utilising groundwater modelling techniques were undertaken to assess the likelihood of water level drawdown impacting existing groundwater users and leakage of drilling fluids from drilling pits contaminating the water table aquifer.

The drawdown assessment found that it is unlikely that significant drawdown will result due to groundwater abstraction from the CLA system for exploration well construction. This extraction poses a low risk to other users with respect to reducing yields of adjacent pastoral bores.

The drilling fluid leakage modelling found that the likelihood of groundwater contamination resulting from surface spillage is low when taking into consideration the water table depth (>60 m), the retention properties of subsurface clay layers, spill volumes, timeframe for spill containment / remediation and existing controls.

### 5.5.1 Potential impacts

CloudGMS (2015b) only identified one environmental hazard at a risk level greater than low: Well integrity issues resulting in cross-flow between formations and associated changes in groundwater pressure/and or quality.

### 5.5.2 Objectives

- To manage exploration activities to prevent contamination of groundwater
- Preserve groundwater quality and quantity for potable and stock supplies.

## 5.5.3 Groundwater management tasks and responsibilities

Activities	Management Tasks	Responsibility
<b>Stimulation and Well Test Operations</b>	<ul style="list-style-type: none"> <li>– Ensure site environmental inductions for all site personnel and contractors include protective measures to prevent avoidable discharge into, or contamination of, groundwater.</li> <li>– Ensure appropriate storage of diesel fuel and other combustible and flammable liquids in accordance with AS1940:2004 The storage and handling of flammable and combustible liquids.</li> <li>– Ensure site is equipped with spill clean-up equipment.</li> </ul>	Operating Company Representative
	<ul style="list-style-type: none"> <li>- Have a procedure in place to manage large quantities of water. This may include pumping to an existing dam or watering point.</li> <li>- Regular inspection and integrity checks of flowback tanks. Test tank integrity during commissioning and prior to use.</li> <li>- Ensure well control critical equipment and systems on stimulation equipment are fit for purpose, certified, maintained in good working order and tested as required.</li> <li>- Ensure appropriate well control training/certification for rig personnel.</li> <li>- Pressure test verifying integrity of the string.</li> <li>- Ensure sufficient distance between HFS target and aquifers commensurate with HFS design. Presence of natural frac barriers and high perm zones to contain fracture height growth.</li> <li>- Continuous real-time pressure, rate and volume monitoring during HFS to stop pumping as soon as potential loss of containment identified.</li> </ul>	Completion Engineer
<b>Camp Operation</b>	<ul style="list-style-type: none"> <li>- Ensure site environmental inductions for all site personnel and contractors includes the issue of groundwater pollution and protective measures to prevent avoidable discharge into, or contamination of, groundwater.</li> <li>- Maintain all waste water systems in working order to minimise impact on groundwater</li> <li>- Ensure appropriate storage of fuel and other flammable and combustible liquids in accordance with AS1940:2004 <i>The storage and handling of flammable and combustible liquids</i>.</li> </ul>	Operating Company Representative

#### 5.5.4 Monitoring requirements

Origin will drill a water supply bore within 500 m each exploration well. These water supply bores will be located down hydraulic gradient from the wells and will also be used for groundwater monitoring purposes. The location of the water supply / monitoring bores will be north of the Amungee NW-1H and Beetaloo W-1 wells based on the groundwater flow direction in this area and will be drilled to the Anthony Lagoon Beds or Cambrian Limestone aquifer.

Monitoring of groundwater levels/ groundwater quality will be undertaken before and after stimulation activities.

Groundwater samples will be collected in accordance with AS/NZS 5567.11:1998: Water quality – Sampling Part 11: Guidance on sampling of groundwaters. All analyses will be conducted at a NATA certified laboratory.

#### 5.5.5 Performance indicators

The performance indicators for groundwater include:

- No long-lasting change in groundwater quantity or quality from base line conditions.

The success of minimising groundwater pollution as a result of the proposed activities can be measured through no complaints from pastoralists about fouling of groundwater supplies for stock and/or domestic use.

If groundwater monitoring indicates any significant changes in groundwater quality compared to baseline, the following investigation and response framework will be instigated (refer to Figure 10).

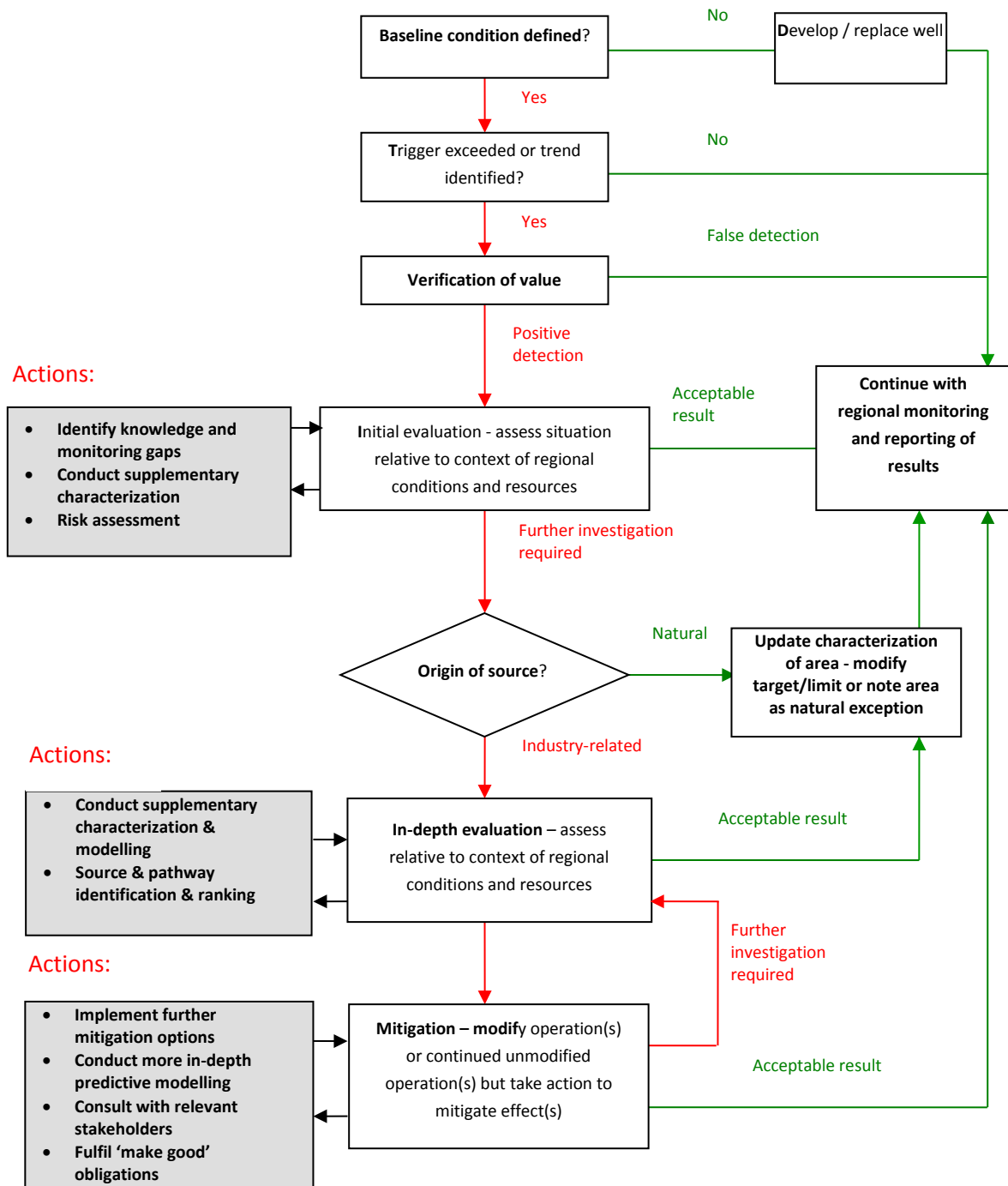


Figure 10 Groundwater investigation and response framework

**5.5.6 Resource implications**

In order to follow the above management strategies, the following resources will be required:

- For drilling of groundwater supply wells, drillers must be appropriately licensed and qualified.
- For drilling of exploration test wells, any intersected groundwater aquifers need to be appropriately sealed off as part of well construction.
- A bore that will allow monitoring data to be collected within 500 m of exploration well hole centre.
- Appropriate groundwater sampling procedures.
- Calibrated field equipment.
- Adequately trained and experienced personnel to collect water samples and take field readings (as required)
- Laboratory supplied sample bottles.
- Assessment and compilation of results for reporting.
- Reporting of feedback from pastoralists.

## 5.6 Noise, Vibrations and Lighting

### 5.6.1 Potential Impacts

The potential impacts associated with the drilling program may include:

- occupational health and safety issues such as physical damage to humans through short-term exposure to loud noise and/or long term exposure to noise sources through use of mechanical equipment
- nuisance noise impacts on surrounding communities or exploration workers through use of mechanical equipment
- disrupting or altering fauna feeding, breeding or other activities through noise, vibration and lighting from use of mechanical equipment
- interference with pastoral activities if noise, vibration and lighting affects behaviour of stock.

Impacts to fauna could potentially include disturbance to activity levels (particularly for birds and amphibians).

### 5.6.2 Objectives

- To manage activities in accordance with occupational health and safety guidelines for noise, vibration and light exposure
- To minimise nuisance noise and vibration impacts on surrounding communities or exploration workers
- To minimise disruption to fauna and stock.



## 5.6.3 Noise, Vibrations and Lighting management tasks and responsibilities

Activities	Management Tasks	Responsibility
<b>Stimulation / Well Test Operations</b>	<ul style="list-style-type: none"><li>- Ensure site environmental inductions for all site personnel and contractors include the issue of noise, vibration and light and protective measures to prevent disturbance.</li><li>- Existing noise attenuation devices fitted to drill rig and other machinery used on site will be maintained in good working order.</li><li>- Lighting used on drill site to minimise offsite disturbance, while maintaining safety standards.</li><li>- Ensure 30 to 40 m on either side of fault has been blanked.</li></ul>	Operating Company Representative
<b>Camp Operations</b>	<ul style="list-style-type: none"><li>- Existing noise attenuating devices fitted to camp equipment, such as generators used on site will be maintained in good working order.</li><li>- Lighting used on camp site to minimise offsite disturbance, while maintaining safety standards.</li></ul>	Operating Company Representative

#### 5.6.4 Monitoring requirements

The study area consists of pastoral properties with dwellings concentrated in small areas. As such, it is not expected that impacts on the public will be significant. However, exploration personnel will be exposed to varying amounts of noise, vibration and lights, which can be mitigated through best practise OH&S procedures.

Exploration activities within the permit areas are unlikely to impact on built up areas. No further monitoring requirements unless complaint received from the public.

#### 5.6.5 Performance indicators

Noise levels should not exceed those recommended in standard OH&S procedures for petroleum industry activities.

#### 5.6.6 Resource implications

Should monitoring be required, monitoring equipment will need to be sourced and operated.

## 5.7 Waste Management

### 5.7.1 Potential impacts

The potential impacts associated with the stimulation and well test program may include:

- Contamination of soil or water through generation of or use of hazardous materials, domestic and industrial wastes and wastewater.
- Encouragement of pest species to sites.

### 5.7.2 Objectives

- To minimise impacts on soil, surface water groundwater, sensitive habitat and air quality
- To minimise creation of food sources or habitat for pest species.
- To minimise waste generation through reduce, reuse, recycle programs.

## 5.7.3 Waste management tasks and responsibilities

Activities	Management Tasks	Responsibility
<b>Stimulation / well Test Operations</b>	<ul style="list-style-type: none"> <li>- Ensure site environmental inductions for all site personnel and contractors include the safe storage and segregation of wastes; and disposal of wastes in appropriate containers.</li> <li>- Segregate and safely store and label chemical packaging, lube oils, batteries, tyres, maintenance and other industrial wastes for proper disposal to recycling and approved landfill facilities.</li> <li>- Carry Material Safety Data Sheets (MSDS) and handling procedures for hazardous chemicals stored on site.</li> <li>- Ensure site is equipped with spill clean-up equipment.</li> <li>- Have a procedure in place to manage large quantities of water. This will include storage, evaporation and/or transportation to an approved disposal site as per section 2.2.4. If waste fluids are transported between states and territories it will be undertaken as per the NEPM guidelines.</li> <li>- Regular inspection and integrity checks of flowback tanks. Test tank integrity during commissioning and prior to use.</li> <li>- All waste material introduced to site will be removed from the lease area and disposed of, e.g. discarded drilling equipment, oil drums, machinery, engine debris, food and drink packaging etc.</li> <li>- All sample bags, waste materials and contaminants must be removed from site and disposed of in an appropriate manner, following the completion of the program.</li> <li>- Solid returns from completion operations should be diverted to the existing sump on site.</li> <li>- Flowback water would be contained with an onsite tank and at completion would be managed in accordance with the waste management hierarchy.</li> </ul>	Operating Company Representative
	<ul style="list-style-type: none"> <li>- Undertake inspection of waste storage areas regularly, or after significant rainfall event (greater than 20 mm in 24 hour period).</li> </ul>	HSE Representative
<b>Camp Operations</b>	<ul style="list-style-type: none"> <li>- The site assessment criteria provided in the DoH Code of Practice for Small On-site Sewage and Sullage Treatment Systems and the Disposal or Reuse of Sewage Effluent, 2014 (Section 7.2) should be reviewed when determining siting of effluent disposal systems, including consideration of soil depth, proximity to drainage lines or areas prone to flooding, proximity to water bores or wells and ground slope.</li> <li>- Grey water from kitchen and showering facilities will be managed in accordance with Part 6 of the DoH Code of Practice for Small On-site Sewage and Sullage Treatment Systems and the Disposal or Reuse of Sewage Effluent, 2014.</li> <li>- Toilet facilities should consist of pit or chemical systems, as described in Part 4 of the DoH Code of Practice for Small On-site Sewage and Sullage Treatment Systems and the Disposal or Reuse of Sewage Effluent, 2014. For chemical systems, the contents should be disposed of off-site. If pit toilets are necessary, the pit should be covered with at least a metre of fill.</li> <li>- Domestic refuse to be disposed of in accordance with NT waste guidelines. No incineration of wastes on site.</li> </ul>	Operating Company Representative and HSE Representative
	<ul style="list-style-type: none"> <li>- Mini-camps at well sites will accommodate 8 people and have their own sewage treatment. Treated water will be dispersed via drainage away from the mini-camp to the edge of the lease, but inside the lease area in accordance with the <i>Code of Practice for Small On-site Sewage and Sullage Treatment Systems and the Disposal or Reuse of Sewage Effluent</i>, issued by the NT Department of Health.</li> </ul>	Operating Company Representative and HSE Representative

#### 5.7.4 Monitoring requirements

Monitoring requirements for wastewater management are covered under the monitoring requirements for soil, surface water and groundwater monitoring.

Effluent from the sewage treatment plant unit at the camp and well lease will be monitored to ensure it meets the discharge requirements from Department of Health. The frequency of the monitoring will be in accordance with the Department of Health approval for each wastewater unit.

#### 5.7.5 Performance indicators

The outcomes of waste management practices can be assessed against the performance criteria for monitoring of soil, surface water and groundwater.

#### 5.7.6 Resource implications

- Waste registers need to be maintained for the duration of the project and will be provided to the DME at the conclusion of the 2016 stimulation and testing program. Table 40 provides an indicative waste register.
- Waste disposal records to be kept for audit purposes.
- All wastes requiring offsite disposal within the NT are to be transported by an appropriately NT government licensed person and disposed at an appropriately licence NT government facility.

**Table 41** Waste Register

Waste Stream	Disposal Method	Disposal End Point
Gas	Disposal	Burnt via the onsite flare
Waste oil and oily rags	Disposal	Waste oil and oily rags generated from stimulation activities and machinery maintenance to be collected by a licensed waste contractor and disposed of at the nearest available disposal centre, depending on the waste contractor selected.
Sand/Proppant	Disposal	Sand/proppant will be filtered from the flowback fluid and directed to an onsite mud sump. The liquid contents of the sump will be evaporated and the sump backfilled.
Stimulation flowback fluid (including residual solids)	Storage / Evaporation and Disposal	Storage in above ground flexiponds whilst evaporation occurs with any remaining liquid and/or solids disposed at a licensed facility prior to commencement of the wet season. Liners from the flexiponds will be disposed at a suitably licensed facility.
Paper, cardboard, steel	Recycled	To be collected by a licensed waste contractor for offsite recycling at the nearest available recycling centre depending on the waste contractor selected.
General / domestic waste	Disposal	Local landfill in accordance with NT waste guidelines.
Sewerage from camp sites	Recycled/Irrigated	Treated effluent to be used for irrigation around the sites. To be done in accordance with NT Department of Health guidelines.
Naturally Occurring Radioactive Material (NORMs)	Disposal	NORMs are not likely to be generated, however, if NORMs do occur a separate waste management plan will be developed for handling of NORMs material at an appropriate licensed waste disposal facility.

## 5.8 Air Quality and Emissions

Potential sources of air emissions associated with the stimulation and well test program are associated with dust, vehicle emissions and flaring.

### Dust

The road network to the sites is almost entirely unsealed and dust is generated as a result of vehicle movements upon these roads during the dry season.

### Vehicle Emissions

Vehicle exhaust emissions are a current occurrence in the region as a whole, from users of the national highways and pastoral machinery. Portable diesel or petrol fuel generators may be used during the stimulation and well test program and a larger diesel generator may be the only source of power and lighting for camp facilities.

It is noted that emissions should be a consideration when selecting plant and equipment. The Origin tender and prequalification process rewards companies that attempt to reduce their environmental footprint.

### Flaring

Flaring during well testing will be kept to a minimum length of time necessary to determine resource and production parameters. All gas volumes will be monitored and reported to the DME. The integrity of all surface equipment will be pressure tested during commissioning to minimise the potential of fugitive emissions at surface. Potential fugitive emissions, as a result of migration along the well bore, is mitigated by constructing the well to Origin standards and industry best practices. These require the presence of cemented casing strings, assessment of the cement quality with logging tools and monitoring the well during flowback.

#### 5.8.1 Potential Impacts

- Increase in dust during from vehicular traffic resulting in decreased functioning of the surrounding vegetation
- Increase in exhaust emissions from contractors' vehicles and generators.
- Potential for increase in air emissions as a result of exploration activities.

#### 5.8.2 Objectives

- To minimise increases in air emissions.
- To minimise the creation of dust.



## 5.8.3 Air quality management tasks and responsibilities

Activities	Management Tasks	Responsibility
<b>Stimulation Operations</b>	<ul style="list-style-type: none"> <li>- Ensure site environmental inductions for all site personnel and contractors include protective measures to control or report air emissions and fire prevention, including smoking and hot work in designated areas.</li> <li>- All vehicles and equipment used on site will be well maintained with mufflers fitted, in accordance with NT Work Safe requirements and/or Motor Vehicle Registration requirements.</li> <li>- All access roads, culverts and creek crossings will be maintained in proper working order.</li> <li>- Use water truck where applicable to manage dust emissions from vehicle movement or drilling operations on the site.</li> </ul>	Operating Company Representative HSE Representative
<b>Well Testing</b>	<ul style="list-style-type: none"> <li>– Keep flaring to a minimum length of time necessary to determine resource and production parameters.</li> <li>– Monitor gas volumes and report to the DME.</li> <li>– Pressure test all surface equipment during commissioning to minimise the potential of fugitive emissions at surface.</li> <li>– Potential fugitive emissions, as a result of migration along the well bore, are mitigated by constructing the well to Origin standards and industry best practices. These require the presence of cemented casing strings, assessment of the cement quality with logging tools and monitoring the well during flowback.</li> </ul>	
<b>Camp Operations</b>	<ul style="list-style-type: none"> <li>- Minimise vehicle movement to that necessary in the camp area.</li> <li>- Use water truck where applicable to manage dust emissions from vehicle movement.</li> </ul>	Operating Company Representative

#### 5.8.4 Monitoring requirements

There is no expectation that air emissions or dust will be required to be monitored as any impacts are expected to be short-lived and transient and not significantly different to impacts created from existing activities in the region, given the permit area includes parts of two national highways – Stuart Highway and Carpentaria Highway.

#### 5.8.5 Performance indicators

The success of minimising dust and other air emissions will be indicated from feedback from pastoralists and other stakeholders. It would be desirable to have a minimum number of complaints regards dust, odour or air emissions.

#### 5.8.6 Resource implications

No additional resources are required as the management of air emissions is included in other aspects of the EP.

## 5.9 Vegetation and Flora

Note that stimulation and well test activities will not require any additional ground disturbance or removal of vegetation or flora to that which is removed in accordance with Origin's 2015 and 2016 Exploration Drilling EPs. As such no direct impacts to vegetation or flora is predicted

### 5.9.1 Potential Impacts

Indirect Impacts:

- Spread of introduced plants and plant diseases
- Increased incident and intensity of fire
- Dust generation

### 5.9.2 Objectives

- To minimise potential impacts on vegetation
- To prevent potential impacts on significant vegetation communities.

## 5.9.3 Vegetation and flora management tasks and responsibilities

Activities	Management Tasks	Responsibility
<b>Stimulation and Well Test Operations</b>	- Ensure site environmental inductions for all site personnel and contractors include the management of onsite vegetation and flora, including personnel to only use access tracks and vehicle weed hygiene requirements.	Operating Company Representative HSE Representative
<b>Camp Operations</b>	- Stay within designated access roads and work areas.	Operating Company Representative HSE Representative

#### 5.9.4 Monitoring requirements

Monitoring of natural regeneration of vegetation can be efficiently undertaken through aerial rapid assessment, following the wet season, as has occurred previously. This rapid assessment technique includes bushland assessment, incorporating estimation of ground cover, weed cover and vegetation cover. However, used in isolation, this technique provides limited information on species diversity. Should it be required by DME, a formal monitoring program could be implemented using monitoring plots, to confirm the success of rehabilitation. Suggested methods are monitoring plots or photo-monitoring.

Monitoring plots should be established in areas where rehabilitation works have been undertaken, as well as in areas adjacent to disturbed sites (undisturbed). Monitoring sites should be representative of the vegetation communities in which they occur. It is not necessary to include monitoring sites on all areas of rehabilitation, but there should be sufficient sites to provide confidence in the results. The monitoring results for disturbed, and subsequently rehabilitated, sites are compared against undisturbed sites, to determine the success of regeneration.

Photo-monitoring is also an effective and inexpensive way of recording rehabilitation success. In this technique, a monitoring point is selected and repeatedly visited (once per annum) and the same site is photographed on each visit.

#### 5.9.5 Performance indicators

The results of the vegetation monitoring program should be assessed against the density and diversity of surrounding vegetated areas and any pre-disturbance records. Sites that have a comparable density and species diversity can be considered to be successfully rehabilitated.

Regrowth of natural vegetation should be visible within a few weeks of the wet season commencing, and the plugged and abandoned drill sites should generally be well covered within six months.

#### 5.9.6 Resource implications

In order to follow the above management strategies, the following resources will be required:

- Security Bond for rehabilitation.
- Vegetation assessments undertaken progressively, as directed by DME.
- Reporting of assessment results.

## 5.10 Fauna and Habitat

### 5.10.1 Potential impacts

#### - Direct Impacts Fauna:

- disturbance of fauna –exploratory drilling and the construction of drill pads would not normally be expected to have a significant regional impact on fauna. However, short-term impacts to fauna, primarily through the physical presence of machinery and people, are likely to occur.
- disturbance to and loss of habitat, particularly through the clearing of drill and camp sites
- loss or endangerment of Threatened species – exploratory drilling and the construction of drill pads may also have an impact on listed Threatened species where, for example, it adversely impacts on habitat for these species.

There are a couple of issues of animal welfare caused by the clearing of habitat and transport along the access roads. Clearing operations could directly result in the death of some native fauna. Fauna may be killed or injured by the machinery involved in the site works or could be killed fleeing from the area of works by falling trees or debris. Often reptiles and frogs are most affected by machinery as they tend to remain hidden in ground cover. Arboreal mammals, bats and birds are more likely to be impacted by falling trees and other debris. However, SMPs and the presence of a spotter catcher during clearing works should minimise the impacts.

Fauna mortality from road collisions is most likely the highest risk factor for fauna due to an increase in vehicles operating in the area. Suitable habitat surrounds the access tracks and observations during the previous survey suggest a high density of species use the access tracks. This is especially true at night time, dawn and dusk when many species are particularly active including multiple CEEVNT species.

It has been noted that Dingoes have been attracted to waste generated during civil works. All waste should be managed as per waste management requirements so as not to attract fauna to operational areas.

#### - Indirect Impacts:

- Spread of introduced plants and plant diseases which competes with native fauna food source
- Increased pest fauna
- Increased incident and intensity of fire
- Dust generation
- Light, noise and vibration disturbance.

### 5.10.2 Objectives

- To minimise damage to or loss of habitat.
- To minimise localised impacts on fauna populations.
- To prevent loss or endangerment of threatened species.



## 5.10.3 Fauna and habitat management tasks and responsibilities

Activities	Management Tasks	Responsibility
<b>Stimulation / Well Test Operations</b>	<ul style="list-style-type: none"> <li>- Site inductions are to ensure that all personnel are aware their obligations and the correct procedures for fauna encounters.</li> <li>- Minimise vehicle movements during dawn and dusk.</li> <li>- Restrict vehicle movement to existing or specifically designated access roads and impose suitable speed limits.</li> <li>- Lease pad to be stock fenced.</li> <li>- Ensure waste is managed correctly so as not to attract fauna.</li> </ul>	Operating Company Representative
<b>Camp Operations</b>	<ul style="list-style-type: none"> <li>- Site inductions are to ensure that all personnel are aware their obligations and the correct procedures for fauna encounters.</li> <li>- Employees will be prohibited from bringing firearms, traps and domestic animals into lease area.</li> <li>- Avoid interactions with fauna where practicable.</li> <li>- Ensure waste is managed correctly so as not to attract fauna.</li> <li>- The workforce will be prohibited from bringing domestic animals into the lease area (recognising that pastoralists don't need to comply with this instruction).</li> <li>- Restrict vehicle movement to existing or specifically designated access roads and impose suitable speed limits.</li> <li>- Although there is no specific volunteer organisation contact in the Barkly Region, Wildcare NT may be able to assist in getting the sick, injured or orphaned animals to the right Wildlife Carer's. Contact Wildcare NT with one of the following numbers: <ul style="list-style-type: none"> <li>• Darwin: 89 886 121 or 0408 885 341</li> <li>• Alice Springs: 0419 221 128</li> <li>• Katherine: 0412 955 336</li> </ul> </li> </ul>	Operating Company Representative HSE Representative Field Personnel

#### 5.10.4 Monitoring requirements

It is not expected that a formal fauna monitoring program would be required. The potential impacts relating to the proposed drilling and stimulation program are short-lived and dispersed, rather than long-lived and concentrated. Instead, the vegetation assessments recommended above will provide a good indication of the degree of reinstatement of fauna habitat.

#### 5.10.5 Performance indicators

The performance indicators for fauna and habitat are the same for the vegetation monitoring program provided in Section 5.9.5.

The results of the vegetation monitoring program should be assessed against the density and diversity of surrounding vegetated areas and any pre-disturbance records. Sites that have a comparable density and species diversity can be considered to be successfully rehabilitated.

#### 5.10.6 Resource implications

In order to follow the above management strategies, the following resources will be required:

- Security Bond for rehabilitation
- Vegetation assessments undertaken progressively, as directed by DME
- Maintain register of injury/death of native species from vehicle strike
- Reporting of assessment results.

## 5.11 Weeds

### 5.11.1 Potential Impacts

- Transport of weeds or other exotic species and plant diseases between regions through transport operations that may compromise existing habitats or vegetation and impact on pastoral or cultural activities in the area. If possible locally sourced machinery and transport will be used to reduce the risk of pests being transported and introduced from other regions
- Degradation of the existing environment as a result of altering existing landscapes through exploration activities and enhancing opportunities for weeds species to become established and/or spread
- Harmful effects of some weed species on livestock or native fauna
- Harmful effects of some weed species on humans.

### 5.11.2 Objectives

- To ensure exotic species and plant diseases are not imported to or exported from the site
- To ensure that disturbance or replanting does not encourage infestation of weed species.

## 5.11.3 Weeds management tasks and responsibilities

Activities	Management Tasks	Responsibility
<b>Stimulation / Well Test / Camp Operations</b>	<ul style="list-style-type: none"><li>- Site inductions are to ensure that all personnel are aware of vehicle weed hygiene requirements and staying on designated access tracks.</li><li>- Ensure vehicles, machinery and equipment entering the permit areas have been cleaned and are free of vegetative matter, or have a valid weed hygiene certificate in accordance with Origin's <i>Vehicle and Mobile Plant Weed Hygiene Procedure</i> (OEUP-1000-PRO-ENV-025).</li><li>- All vehicle, equipment and rig movements to stay on formed access tracks, well leases and camp areas.</li></ul>	Operating Company Representative

#### 5.11.4 Monitoring requirements

The current status of all weed species in the study area is not fully documented, but the nationally and regionally significant environmental weeds (noxious or declared weeds) known to occur in the area are well known and several guides have been produced to aid in their identification. In addition, individual pastoralists may/may not be aware of the weed issues on their own properties. The existing road corridors within the permit areas, including those on individual properties, already contain a variety of weed species, as noted during the land condition assessment (August 2014 and April 2016).

Monitoring of weed establishment would be included in the rapid assessment of vegetation regeneration.

#### 5.11.5 Performance indicators

It is unlikely that rehabilitated areas will remain weed free if weeds are already established in adjacent areas, because weeds typically thrive in disturbed environments. Therefore, the presence or absence of weed species alone, is not a good measure of performance. Instead, successful management of weeds will be indicated by no new weed species, not already present in the area, becoming established and/or no increase in the existing level of infestation. Wherever practicable, it would also be desirable to demonstrate an overall reduction of weeds in the immediate surrounds of the work sites, as a result of active control of weeds. This would not apply to areas where pastoralists request that introduced pasture grasses are planted as part of site rehabilitation instead of native species.

#### 5.11.6 Resource implications

Survey of weed species can be undertaken during vegetation and/or soils and erosion monitoring. The use of existing material on noxious or declared weeds will allow identification by non-professionals, or, alternatively, a suitably experienced person could be enlisted to undertake the monitoring. In addition, a budget should be allowed for weed control works to be undertaken in rehabilitated areas, during the early stage of rehabilitation, when native species are establishing. It would be unreasonable to require long-term weed control once the area has been returned to a state resembling the undisturbed environment surrounding the site, because of the existing weed infestations in the permit areas. However, the operator must undertake weed control at all sites where disturbance occurs.

It is also noted that a number of species, not considered a pest in the NT, may be a pest in a different jurisdiction. As such, when demobilising from site and returning equipment to other locations across Australia good hygiene practices should be implemented.

## 5.12 Feral Animals and Other Pest Species

### 5.12.1 Potential Impacts

Feral animals threaten populations of native wildlife in two main ways: direct predation (e.g. cats, dogs) or competition for limited resources (e.g. bird species, rabbits, rodents, cane toads, pigs). Feral species are more likely to penetrate areas of habitat that have been disturbed. Hence, habitats that have been disturbed or are suffering the impacts of edge effects will often be associated with a population of feral species. An increase in pest vermin species, such as rats, due to uncontrolled rubbish in the construction and operational phases, can lead to an increase in predation and nesting failure of avian species.

The potential impacts include:

- Introduction of feral animals and pest species may compromise existing habitats, vegetation or native fauna through predatory behaviour or competition.
- Introduction of feral and pest species may impact upon livestock.
- Introduction of diseases associated with feral and pest species may impact upon existing habitats, vegetation, native fauna and livestock.
- Damage of vegetation or natural habitat through feral animal activity.
- Feral animal nuisance around campsites and domestic waste material.
- Damage to equipment or creation of safety risks through burrowing.

### 5.12.2 Objectives

- To prevent introduction or spread of feral animals and pest species.
- To ensure that management practices associated with feral animals and pest species are in accordance with local requirements and do not compromise other stakeholder management practices.



## 5.12.3 Feral animal and other pest species management tasks and responsibilities

Activities	Management Tasks	Responsibility
<b>Camp / Stimulation / Well Test Operations</b>	<ul style="list-style-type: none"><li>- No rubbish (<i>i.e.</i> food packaging) to be left on sites.</li><li>- Domestic refuse will be disposed of in accordance with NT waste guidelines.</li><li>- Ensure waste is managed correctly so as not to attract fauna.</li><li>- Wastes will be stored in dedicated waste storage areas.</li></ul>	Operating Company Representative HSE Representative

#### 5.12.4 Monitoring requirements

As per Section 5.9.5 performance indicators for the vegetation monitoring program. Monitor, specifically for, obvious increase in feral animals around the camp and drill sites.

#### 5.12.5 Performance indicators

The successful management of feral animal and pest animal control will be indicated by:

- No new feral animal or pest species becoming established and/or no increase in the existing level.
- No complaints from pastoralists.

#### 5.12.6 Resource implications

No additional resources are required.

## 5.13 Bush Fires

### 5.13.1 Potential Impacts

Increased incident and intensity of bushfires can lead to vegetation degradation and habitat modification. Fire can travel over large areas; therefore its effects can be felt outside of the project site. As discussed in Section 3.3.8, and recorded during this survey, Bullwaddy and Lancewood communities are fire sensitive and hot fires have the ability to reduce habitat quality for both flora and fauna species.

Research suggests that fauna diversity may be impacted by a hot fire, particularly for diurnal reptiles (e.g. Legge *et al.*, 2008). Fire can result in both direct and indirect mortality of fauna. Direct mortality results from species not being able to escape a fire and indirect mortality can result from a lack of cover (resulting in higher predation rates) or a reduction in food resources.

As such the potential impacts from bush fires include:

- Impacts upon fauna and habitat.
- Increased erosion and impacts upon soil and surface water as a result of vegetation loss.
- Impacts upon other stakeholder activity and resource use.
- Damage to or loss of culturally significant sites.
- Damage to or loss of public infrastructure, private infrastructure and equipment or community lands.
- Possible safety risk to humans (i.e. personnel on site).
- Creation of greenhouse gases.

### 5.13.2 Objectives

- To minimise impacts on environmental habitat and fauna, soil erosion, impacts on stakeholders, impacts on culturally significant sites, public infrastructure and community lands
- To ensure proper health and safety plan for activities
- To prevent accidental fire risk and ensure safe storage of chemicals to prevent fire damage.

## 5.13.3 Bushfire management tasks and responsibilities

Activities	Management Tasks	Responsibility
<b>Stimulation / Well Test Operations</b>	<ul style="list-style-type: none"> <li>- Site inductions are to ensure that all personnel are aware of designated smoking areas and hot work permit requirements.</li> <li>- Fire or unprotected flame must be kept at least 45 m from unprotected sources of flammable vapour.</li> <li>- Ensure appropriate storage of fuel and other flammable and combustible liquids in accordance with AS1940:2004 <i>The storage and handling of flammable and combustible liquids</i>.</li> <li>- Smoking only allowed in designated areas.</li> <li>- Any hotwork activity requires a work permit before proceeding.</li> <li>- Whenever hotwork activities are undertaken, the area surrounding the work site should be cleared combustible materials and appropriate firefighting equipment kept on hand during such operations.</li> <li>- Hazardous area diagram for drilling rig is to be developed and implemented.</li> <li>- Diesel engines must not be used within 15 metres of a well or other source of flammable vapour unless fitted out appropriately.</li> <li>- Where safe to do so attempt to put out natural fires in the vicinity of operational areas.</li> <li>- Fit all fixed engines operating at drilling site with adequate spark arrestor and emergency shut-down devices.</li> <li>- In accordance with section 275 of the NT <i>Schedule of Onshore Petroleum Exploration and Production Requirement 2012</i>, fire precautions including at least four 9 L and one 68 L dry-chemical type extinguishers (or their equivalent) shall be kept at strategic locations on or around the rig.</li> <li>- Siting of flares or flare lies should follow the recommendations included within Section 230 of the Schedule of Onshore Petroleum Exploration and Production Requirements 2012.</li> <li>- A flare pit shall be sited and constructed so as not to create a hazard to property of natural vegetation.</li> </ul>	Operating Company Representative HSE Representative Field Personnel
<b>Camp Operations</b>	<ul style="list-style-type: none"> <li>- Firefighting equipment should be signposted, accessible and ready for operations.</li> <li>- Any rubbish, debris or oil refuse that could constitute a fire hazard shall be removed to a safe distance away from all buildings and installations, wells and production facilities.</li> <li>- Fire breaks to be maintained around the camp (minimum of 4 m wide).</li> </ul>	Operating Company Representative

#### 5.13.4 Monitoring requirements

No formal fire monitoring is required, but all incidents of fire should be recorded in an incidents register and be reported to DME, the NLC and AAPA.

#### 5.13.5 Performance indicators

Successful fire management will be indicated by having minimum number of fires occurring as a result of exploration activities or associated personnel.

#### 5.13.6 Resource implications

Limited additional resources are required. The resources that are required are expected to include mainly human resources for personnel training and incident reporting, personnel available to participate in emergency drills and personnel to prepare an emergency procedures manual. From time to time, site personnel may be requested by local authorities or pastoralists to assist in firefighting operations.

If there is damage caused to a Sacred or significant site from a fire created by operations, Origin will need to liaise with the NLC and AAPA. In addition, there maybe a requirement to liaise with the NT Cattleman's Association with regard to appropriate compensation to pastoralists for loss of pasture from fire attributable to the exploration activities.

## 5.14 Social Environment

The proposed drilling and stimulation program is conditional on the identification and mitigation of the social and cultural impacts within the region. This section of the EP addresses this condition and provides strategies to ensure that any negative social impact resulting from the proposed exploration is addressed. Certain social and cultural aspects associated with the proposal have been addressed in Section 3.4 (Social Environment), Section 5.6 (Noise), Section 5.15 (Cultural Sites of Significance) and Section 5.16 (Access), and as such will not be addressed here.

### 5.14.1 Potential Impacts

The potential social and economic impacts within the region where the exploration permits are located are varied. Considered at a regional level these impacts may be relatively minor and difficult to attribute to this proposal due to other industries and developments that are occurring. The exploration works, however, may contribute to broad socio-economic changes that are occurring in the region (HLA, 2005).

The major areas that may potentially be affected include residents of Tennant Creek, Elliott, Daly Waters, Newcastle Waters, Mayfield, Dunmarra, various pastoral properties and Aboriginal outstations.

The foreseeable impacts from the proposed exploration activities may include a range of economic, health, socio-cultural and service access issues. These impacts are also interrelated in that, for example, a change in the economic situation of a community or region will be expected to affect service access or health provision. It is difficult to predict the magnitude of these impacts however, as industries, for example tourism resources and pastoralism, which are developing or changing will also have socio-economic impacts. Additionally, the implementation of regional development plans, such as the Barkley Blueprint which addresses social issues and economic development within the region, will also impact on the social environment in the area of the continuation of oil and gas exploration in the region.

The proposed drilling and stimulation program could potentially provide direct or indirect opportunities for employment for local people. The indirect roles may include, weed management and vegetation rehabilitation that can also offer employment. The extent to which employment is locally sourced is uncertain but it is expected that some roles will be met by local people. In addition there will be services and goods sourced locally.

### Economic Impacts

The stimulation and well testing activities may be expected to induce a primary impact of positive economic benefit. This may include greater employment opportunities for people within the region, higher earnings and general increased economic activity. This positive economic activity is likely to extend to local service providers, such as fuel retailers and accommodation providers.

Secondary-level economic impacts may include a range of both positive and negative contributions to the region. The range of these possible secondary impacts may include:

- increased training provision as a result of higher regional employment
- an increase in the incidence of substance abuse and domestic violence
- an increase in crime and prostitution
- an increase in economic inequality resulting in community disharmony
- increased traffic on major and minor roads.

### Health Impacts

There may be several health impacts associated with increased community wealth and possible decreased access to health providers. The health services in the proposed exploration area are very limited with Tennant Creek and Katherine Hospital being the closest major medical facilities. The other health services that are relevant in the area are the health clinics, the aero-medical evacuation service and community health services. These services are restricted and additional demands may reduce the capacity of health care providers to attend to local health issues.

Additionally, the addition of non-local exploration employees into local areas may result in health impacts. These impacts may include:

- An increased incidence of communicable diseases, such as sexually transmitted diseases resulting from increased prostitution



- An increase in the incidence and spread of bacterial infections or mosquito-borne diseases.

These impacts may also place additional demands on the health services in the region and affect the level of care received by local people.

### Service Access Impacts

The staff and activities associated with the proposed drilling and stimulation program may have an effect on local residents' access to services. While it is expected that a relatively small staff will be employed in the region there is limited capacity of public and private service providers for existing residents. The range of service providers that may face an increased demand may include health care providers, recreational facilities, retailers and suppliers and government agencies such as Centrelink or Police services. This increased demand on services may cause local frustration and resentment towards the proposed drilling program and the associated staff because of perceived longer waiting times and competition for service.

### Socio-cultural Impacts

The extent of the impacts on the socio-cultural environment will largely depend on many uncertain variables. For example, the possible employment of local Aboriginal people in the proposed drilling and stimulation area may have benefits in terms of encouraging people back on country. This then has additional health, educational and cultural knowledge transmission impacts.

Conversely situations whereby groups within the region are benefiting economically from the project while others are not may create resentment and community disharmony because of perceived inequalities.

The large indigenous population in the region may experience some socio-cultural impacts that may not traditionally be considered. The indigenous people in this region, based on the 2001 ABS census, have:

- Very low levels of education attainment
- Low levels of employment, with CDEP being the largest employer of Aboriginal people
- Very low incomes.

Additional issues relating to substance abuse, health, lack of housing and overcrowding are also significant for the Aboriginal population of the area.

In addition it should be recognised that while the land tenure associated with the proposal is mainly pastoral lease Aboriginal people may have a spiritual and genealogical connection to this land. The extensive history of pastoralism in the area may have reduced the opportunity for Aboriginal people to actively maintain links with particular "country" however relationships may still exist. Similarly, despite reports (Parks and Wildlife Commission of the NT, 2004) regarding the lack of Aboriginal people being able to speak on certain areas and "dreaming" trails or songlines, it should not be assumed that there is no Aboriginal connection to any part of the proposed exploration area.

The possible impacts that the proposed drilling program may contribute to include:

- Economic inequality resulting from lack of Aboriginal employment contributing to continued issues regarding individual and collective self-esteem, substance abuse, domestic violence and other social problems
- Greater economic equality by a culturally diverse workforce that may assist in addressing social problems
- Loss of cultural knowledge, language and traditions due continued social inequalities
- The maintenance of cultural knowledge, language and traditions facilitated by access to employment and land
- Increased participation in training programs resulting in increased literacy and capacity to enter the workforce
- Increased collective understanding of contemporary Australian political and economic systems and institutions resulting in an enhanced capacity to enact change
- Greater cross-cultural appreciation between Aboriginal and non-Aboriginal residents of the area resulting from opportunities to work collaboratively or from the success of possible Aboriginal employment in the project.

While many of these issues are not able to be directly addressed by the proposed exploration, certain strategies can be used to prevent further exacerbating these issues and possibly contributing to improving the social and economic situation of Aboriginal people in the region.

### 5.14.2 Objectives

- To maximise opportunities for local Indigenous and non-indigenous employment and training
- To minimise impacts on local services
- To enhance cross-cultural exchange.

## 5.14.3 Social management tasks and responsibilities

Activities	Management Tasks	Responsibility
<b>Stimulation / Well Test / Camp Operations</b>	<ul style="list-style-type: none"><li>- Site inductions are to ensure that all personnel are aware of the Origin Code of Conduct Policy - ORG-HRMS-POL-003.</li><li>- Origin requires all employees and internal contractors to complete Code of Conduct Training – Training reference - ORG-ALL-WBT00049.</li></ul>	Civil Construction Supervisor Operating Company Representative

#### 5.14.4 Monitoring requirements

Monitoring of the management of adverse social impacts may be conducted by using community advisory groups or by monitoring the extent to which complaints are resolved and the extent of satisfaction with the outcome and resolution process. The community advisory groups need to represent the entire community but may require different forums and techniques because of the diverse cultural backgrounds of the affected residents. The community advisory groups may also be able to provide information on the means of maximising the social and economic benefits, and provide on-going advice on maximisation strategies.

#### 5.14.5 Performance indicators

Indicators of performance could be measured as follows:

- An overall social and economic benefit as compared to perceived adverse impacts as derived from consultations with community advisory groups
- High level of satisfaction with complaint outcomes and complaint resolution processes
- Inclusion of Aboriginal employment in the proposed exploration program.

#### 5.14.6 Resource implications

The resources required to undertake the monitoring include:

- An appropriately experienced person to facilitate discussions with community advisory groups
- Staff available to resolve complaints as per agreed processes
- Transportation and accommodation for visiting facilitators/researchers
- The production of plain English complaints process booklets initially and annually to inform the community of the means by which complaints can be made
- The provision of an 1800 number to allow free-of-charge telephone complaints / concerns / queries and feedback to be made.

## 5.15 Cultural Heritage and Sacred Sites

### 5.15.1 Potential impacts

- Misunderstandings arising as a result of non-Indigenous workers being unfamiliar with the Aboriginal traditions, life-style, customs and cultural values.
- Damage to or loss of culturally significant artefacts, areas or species.
- Disruption of activities of Indigenous stakeholders in culturally significant areas.
- Cultural and environmental awareness issues may lead to a lack of protection of sacred sites or culturally significant places and artefacts.
- Lack of cultural and environmental awareness may lead to intrusion on Aboriginal land of special significance to the local people.

### 5.15.2 Objectives

- To avoid disturbance of or damage to Aboriginal or cultural heritage artefacts or Sacred Sites
- To minimise impacts upon or disruption to activities of Indigenous stakeholders in culturally significant areas
- To ensure adequate background information and training is provided to employees and contractors working in culturally significant areas
- To ensure that the health and safety of exploration workers and the community is not compromised through management of cultural and environmental awareness.

## 5.15.3 Cultural sites of significance management tasks and responsibilities

Activities	Management tasks	Responsibility
<b>Stimulation / Well Test / Camp Operations</b>	<ul style="list-style-type: none"> <li>- Site inductions are to ensure that all personnel are aware of cultural awareness obligations, such as: <ul style="list-style-type: none"> <li>• Regulations applying to the area, including specific conditions on the exploration permits and agreements with the NLC.</li> <li>• Awareness of the conditions outlined in the Aboriginal Areas Protection Authority (AAPA) Authority Certificate.</li> <li>• Ensure all site personnel and contractors are aware of any potential Restricted Work Areas (RWAs) and conditions outlined in the AAPA Certificates.</li> <li>• Brief personnel on the rules and regulations and disciplinary measures for breaches of the RWAs.</li> <li>• Considerations and special procedures to be used for protection of archaeological and cultural sites in the define work areas.</li> <li>• Work practices that avoid or minimise impacts – particularly for operators of machinery such as graders and dozers</li> <li>• Landowner or manager sensitivities, including Aboriginal communities and their specific cultural requirements</li> <li>• Ensure that site personnel and contractors report all new discoveries of archaeological or cultural artefacts, as per Origin's Unexpected Aboriginal Cultural Heritage Find procedure (OEUP-Q1000-PRO-BUS-001). Cease work and effect practical protection measures until the area can be assessed by DLRM personnel.</li> </ul> </li> </ul>	Operating Company Representative

#### 5.15.4 Monitoring Requirements

A register should be kept of all occurrences of archaeological sites identified during the Project for provision to the NLC, the AAPA and Heritage Branch within DLPE.

#### 5.15.5 Performance Indicators

A measure of successful cultural site management is no incidences of disturbance of archaeological sites or sites of cultural significance, or if disturbance is required, an application to disturb is submitted and approved prior to disturbance.

#### 5.15.6 Resource Implications

No additional resources will be required for management of cultural sites, other than training of all workers in cultural awareness. Should sites be discovered (which is a possibility), additional fees may be required for additional site clearance to be undertaken.



## 5.16 Access

### 5.16.1 Potential impacts

- Inadequate consultation regarding access to the drill site may lead to misunderstandings and have an impact on the drilling program.
- Access to properties affects land use and use of resources by other stakeholders (e.g. farmers, community and Indigenous groups).
- Access may contribute to disturbance of natural resources and vegetation.
- Access routes may require import of external materials for construction.
- Access routes may increase public access to infrastructure or unauthorised use of land.

### 5.16.2 Objectives

- To limit public access to infrastructure and prevent unauthorised use of land.

## 5.16.3 Access management tasks and responsibilities

Activities	Management Tasks	Responsibility
<b>Stimulation / Well Test / Camp Operations</b>	<ul style="list-style-type: none"><li>- A TMP should be prepared by the Operating Company to provide mitigations to minimise the risk related to the general public, site visitors, and site based workers, whilst providing a method to minimise traffic flow disruption during operation works.</li><li>- Register should be kept of all incidences relating to access issues, unauthorised access and requirements of pastoralists, recognising that these requirements may change seasonally.</li></ul>	Operating Company Representative

#### 5.16.4 Monitoring requirements

A register should be kept of all incidences relating to access issues, unauthorised access and requirements of pastoralists, recognising that these requirements may change seasonally.

#### 5.16.5 Performance indicators

An indication of success in management of access issues is a minimum number of complaints or incidences arising and, over time, an increase in stakeholder satisfaction.

#### 5.16.6 Resource implications

Preparation of TMP to be lodged and approved by the Department of Transport and must comply with AS 1742.3:2009 *Traffic control devices for works on roads*.

No additional resources are required other than for monitoring and reporting access management issues. Time should also be allowed for ongoing consultation with pastoralists, to ensure adequate communication is maintained.

## 5.17 Visual Amenity

### 5.17.1 Potential Impacts

- Creation of scars on the landscape.
- Encouragement of unauthorised access along tracks and roads, because they are visible.

### 5.17.2 Objective

- To minimise the extent and longevity of scars on the landscape, from the installation of temporary facilities

**5.17.3 Visual Amenity Management Tasks and Responsibilities**

Activities	Management Tasks	Responsibility
Project Management and Design	- Locate in area that minimises visual impact as far as practicable	Project Manager
	- The degree of light spread and potential impacts on landowners should be considered	
	- Minimise visual impact, by deviations around topographical features or stands of vegetation, doglegs at road crossings, where feasible.	
	- Position major infrastructure so that it is offset back from roads and highways.	

#### 5.17.4 Monitoring Requirements

There are no formal monitoring requirements for managing visual amenity.

## 5.18 Communications

### 5.18.1 Potential Impacts

- Impedance to the stimulation and testing program through inappropriate consultation and communication.
- Loss of good relations with leaseholders and other stakeholders.

### 5.18.2 Objectives

- To ensure the stimulation and testing program is implemented according to the proposed schedule.
- To ensure that leaseholders and other stakeholders have every opportunity to comment on aspects of the exploration program, including the timing.



## 5.18.3 Communications Management Tasks and Responsibilities

Activities	Management Tasks	Responsibility
All Activities	<ul style="list-style-type: none"><li>- Consult with land users and public interest groups, such as landholders, Aboriginal communities, natural resource managers, conservation groups, tourism operators and other affected parties, early in the planning phase to exchange information and facilitate good working relationships.</li><li>- Provide a Work Program for each year's proposed activities to the NLC and other regulatory bodies, which includes site-specific environmental and cultural issues, likely impacts and their mitigation.</li><li>- Prior to commencement onsite, communicate with leaseholders for access permission. Provide detail of the time and dates proposed to be on site, and the location, at least one month in advance of works commencing.</li></ul>	Project Manager

#### **5.18.4 Monitoring Requirements**

A register should be kept of all correspondence regarding access and site disturbance, as well as notifications provided to leaseholders.

#### **5.18.5 Performance Indicators**

An absence of issues arising, which have the potential to affect the work program, is a good indication of successful communications.

## 6.0 Implementation Strategy

### 6.1 Systems and policies

Origin has a strong Health, Safety and Environment Management System (HSEMS) and Health, Safety and Environment Policy (see Appendix A).

This Stimulation and Testing EP details the systems, policies and procedures that Origin has in place to manage and minimise its impacts during stimulation and testing activities in the Beetaloo Sub-basin.

This document is to be considered within the context of the wider Origin system. This Stimulation and Testing EP has been framed by a range of guidelines and good oilfield practices to minimise environmental impacts during Origin's drilling and stimulation program.

This EP influences the content of inductions, procedures and protocols and forms part of the overall Management strategy for the project. This document influences the Project Health, Safety and Environmental Management Plans (HSEMPs) which are utilised for the practical management of the project and project activities. The Project HSEMPs are developed in alignment with the broader Origin HSE Management System.

### 6.2 Training and Induction

Origin has very effective HSEMS policies and procedures including education and induction of personnel and these are appropriate for this project. Specific procedures that will be enhanced include those relating to:

- Weed management
- Refuelling procedures
- Procedures for avoidance of potential fauna habitat and any identified heritage sites
- Process for rehabilitation.

An environmental and safety induction package will be developed for the program and include:

- 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 with particular regard to safe use of vehicles, equipment and explosives first aid and
- HSE in remote area operations.
- 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.

All staff and contractors entering the site will be required to attend a site specific induction.

### 6.3 Routine Reporting

Internal and government reporting on performance standards will be carried out by the Origin authorised representative, and distributed to Origin management and the DME, in accordance with the Schedule of Onshore Petroleum Exploration and Production Requirements 2012 as per clause 712. This includes a weekly report to the Director stating progress of the program and a summary report no later than six months after completion of the program. This is separate to the quarterly and annual reports required for Exploration Title reporting.

Routine reporting is followed, in accordance with monitoring and auditing requirements as described above. This includes the summary of activities, summary of audits, the meeting of EP objectives, standards and criteria, and incidents as discussed below. Table 41 presents the frequency, reporting requirements and recipient for external reporting requirements of the exploration program.

Table 42 Routine reporting requirements

Frequency	Report name	Recipient
Monthly	Monthly Recordable Incident Report Incidents with an actual or potential consequence of moderate or more are included in the Monthly Recordable Incident Report.	Senior Petroleum Engineer Petroleum.Operations@nt.gov.au
Weekly	Weekly Progress Report A weekly report shall be forwarded to the Director stating progress of the survey.	Director

## 6.4 Incident Management

An Origin Emergency Response Plan (OEUP-NT2000-PLN-SAF-001) and Oil Pollution Emergency Plan (NT-2050-35-MP-0006) has been prepared which will bridge to the stimulation contractors Emergency Response Plan. These plans provide the details required for emergency response and preparedness during the drilling and stimulation program, including responsibilities and reporting arrangements; and the interaction between Origin, the stimulation contractors and key third parties.

### 6.4.1 Incident Reporting

Incident reporting and investigation provides the mechanism to prevent a recurrence. 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. At the conclusion of the proposed stimulation and testing program, Origin will provide a summary of the environmental incidents that occurred during the duration of the exploration campaign to the DME. Recordable incidents will be reported to DME in a written report every calendar month by the project team (at latest by the 15th of the following month).

### 6.4.2 Reportable Environmental Incident Reporting

On occurrence, as required under the Onshore Schedule (Division 4, paragraph 289), Origin will report to DME the following:

- any spills of petroleum of greater than 300 L on land
- any spills of petroleum of greater than 80 L in inland waters
- unintentional gas release greater than 500 m<sup>3</sup>.
- accidental clearing of vegetation adjacent to the drill site
- fire started as a consequence of the activities.

The report will include:

- the nature of the incident
- the date, time and place of the occurrence
- the estimated quantity of liquid/gas that escaped
- particulars of damage caused by the escape
- the events so far as they are known or suspected that caused or contributed to the escape.

In accordance with the Onshore Schedule, reportable environmental incidents will be reported to DME Environment Section.

The verbal report to DME must be followed up by a written report from the Environment Advisor, as soon as practicable.

## 6.5 Environmental monitoring

The responsibility for general environmental monitoring rests with all personnel engaged on the project. More specifically the Project Manager / Field Manager shall ensure each element of the stimulation and testing program is monitored to ensure that appropriate environmental protection/procedures are in place.

## 6.6 Environmental auditing

In addition to regular monitoring as set out in this document, EP audits will be regularly undertaken by a suitably qualified person. 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.

Origin shall also comply with any auditing regime set by relevant external Authorities. Table 42 presents the current Audit Schedule for the 2016 activities.

**Table 43** EP Audit Schedule

Audit Type	Scope of Audit	Frequency	Responsibility
Site Inspections	Significant issues to be inspected as required with results recorded on checklist. Items to be actioned as required	Weekly	HSE Representative, Civil Construction Supervisor and Operating Company Representative
Internal compliance audit	Review of EP performance and Environmental approval compliance	At least one audit per annum, and preferably undertaken within one month of commencement of activities	Project Manager

## 6.7 EP Review

Origin management shall review and update this Stimulation and Testing EP as required to ensure that they meet operational requirements and relevant environmental legislation and standards.

The Stimulation and Testing EP should be reviewed after each work program and updated where necessary.

Additional review of the Stimulation and Testing EP may occur as result of the following:

- identification of deficiencies or opportunities for improvement
- following recommendations from audits
- changes to operations or activities within the permit areas
- changes to legislation.

Implementation of the Stimulation and Testing EP will be continually monitored and the Stimulation and Testing EP revised as required based on monitoring and audit results, complaints, employee and stakeholder feedback and change to the program. A formal management review will be undertaken annually.

Origin management, or their delegates, will be responsible for preparation and ongoing review of the Stimulation and Testing EP.

## 7.0 Rehabilitation Strategy

### 7.1 Broad Rehabilitation Strategy

The stimulation and testing program will be conducted on land that was disturbed in accordance with Origin's 2015 and 2016 Exploration Drilling EPs. At the conclusion of the stimulation and testing program rehabilitation of the land will be conducted in accordance with the requirements of those EPs. The following is a summary of the rehabilitation strategy outlined in those EPs.

The proposed rehabilitation strategy for this program is based on assisted natural regeneration. This approach allows natural regeneration in disturbed areas, combined with monitoring to determine the success of this approach, and then, if necessary, use of locally collected native seed and soil preparation, to enhance germination success. However, regeneration is also dependent on rainfall and so recovery may take several years. The monitoring program proposed for the rehabilitation activities will take into consideration factors that affect rate of recovery, such as rainfall.

Areas of greater disturbance consisting of drill pads and sumps will require more intensive rehabilitation requiring:

- Stockpiling of topsoil and vegetation during clearing.
- Reshaping the site to as close to natural form as possible and filling in sumps at the completion of the program.
- Ripping or scarifying the surface and covering with the stored topsoil and vegetative material.
- Spreading seed of suitable local native species.

If these steps are undertaken prior to the next wet season the area should be non-erosive and will rehabilitate when the rains come in the wet season.

## Appendix A – HSE Policy

# OUR HEALTH, SAFETY AND ENVIRONMENT POLICY

## OUR PRINCIPLE OF DUE CARE

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

## OUR HSE ASPIRATION

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

## OUR HSE ACTIONS

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

### Always mindful of risk

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

### Enabled and accountable

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

### Continuously learning

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

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

A handwritten signature in black ink, appearing to read 'Grant King'.

**Grant King**  
Managing Director



## Appendix B – Cloud GMS Report

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# **Beetaloo Basin 2015/2016 Exploration Drilling Program Groundwater Impact Risk Assessment**

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Prepared for	Origin Energy Pty Ltd	February 2016
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Version 1.0

Prepared for Origin Energy by  
Simon Fulton and Anthony Knapton  
CloudGMS Pty Ltd

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# 1 Introduction

## 1.1 Background

Origin Energy is the operating partner for exploration permits EP76, EP98, EP99 and EP117 in the Beetaloo Basin. Combined these permits cover an area of approximately 18,500 km<sup>2</sup> that is subject to a joint venture agreement between Origin Energy Resources Ltd, Falcon Oil and Gas Ltd and Sasol Ltd. In 2015, as part of a five year exploration campaign, Origin drilled two wells Kalala S-1 and Amungee NW-1 on EP98. In 2016, Origin expects to drill an additional two wells on EP98 and EP117, one at Beetaloo W-1 and one at either Kalala NE-1 or Nutwood Downs SW-1 (see Figure 1).

CloudGMS was engaged by Origin Energy to prepare a risk assessment to identify specific impacts to the groundwater system associated with the exploration drilling phase of Origin' s 2015/2016 work program, and to consider these potential risks in the context of an operational development.

## 1.2 Scope

The groundwater risk assessment has the following scope:

- Undertake a qualitative groundwater impact assessment covering the drilling, operation, Diagnostic Fracture Injectivity Tests (DFIT), potential hydraulic fracturing and abandonment phases of Origin' s exploration drilling program.
- Assess potential groundwater level drawdown associated with extraction from water bores used to supply drilling and construction water requirements.
- Assess the likelihood and potential groundwater impact of leakage from mud pit and flare pits (and other above ground liquid storages) used during drilling works.

The groundwater risk assessment prepared by CloudGMS is independent of the broader drilling environmental plan prepared for Origin' s 2015/2016 exploration program by AECOM, 2015.



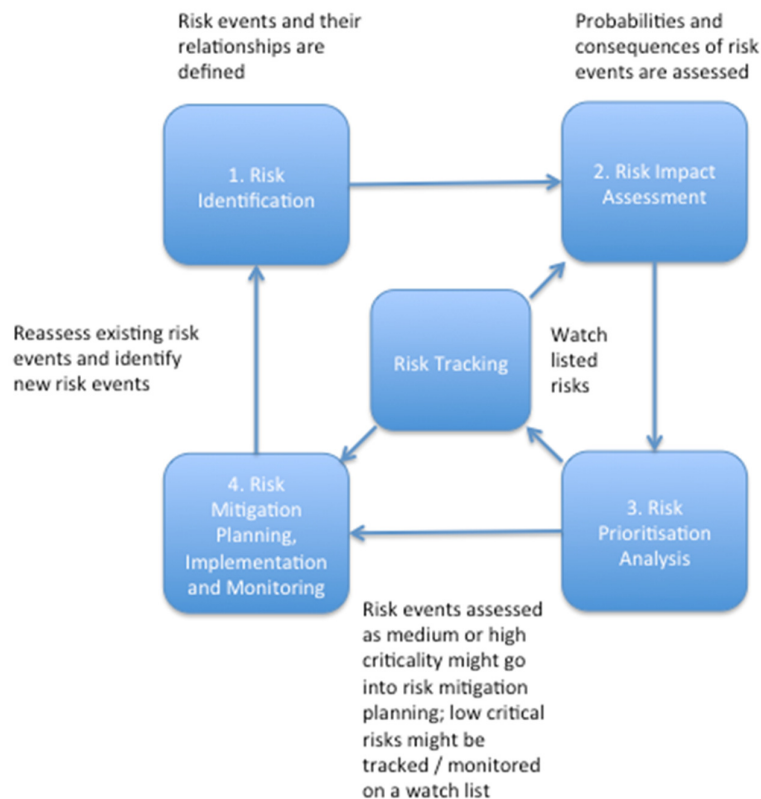
Figure 1 Proposed locations of exploration wells and associated groundwater supply bores.

## 2 Groundwater Impact Assessment

### 2.1 Introduction

Risk is an event that, if it occurs, adversely affects the ability of a project to achieve its objectives. Risk management is the process of identifying risk, assessing risk, and taking steps to reduce risk to an acceptable level. The fundamental steps of risk management are outlined Figure 2 and include:

1. Risk identification
2. Risk impact assessment
3. Risk prioritisation
4. Risk mitigation planning, implementation and progress monitoring



**Figure 2 Fundamental steps of risk management (www.mitre.org)**

#### Step 1. Risk Identification

Risk identification is the critical first step of the risk management process. Its objective is the early and continuous identification of risks.

## Step 2. Risk Impact or Consequence Assessment

In this step, an assessment is made of the impact each risk event could have on the project objectives. Typically this includes how the event could impact cost, schedule, or technical performance objectives as well as broader project drivers such as political, social and environmental consequences. The impact of a risk is generally assessed using a risk matrix considering the severity of the consequence if the impact occurs and the likelihood of the risk occurring an example of such a matrix is presented below in Figure 3.

## Step 3. Risk Prioritization

At this step, the overall set of identified risk events are ordered to derive a most critical to least critical ranking. A major purpose for prioritizing risks is to form a basis for allocating critical resources.

## Step 4. Risk Mitigation Planning

This step involves the development of mitigation plans designed to manage, eliminate, or reduce risk to an acceptable level. Risk mitigation plans should involve the continual monitoring of risks and revision to ensure control measures are effectively managing risks.

This report discusses the results of a study to examine the first two steps in the Risk Management process identified above by identifying risks associated with drilling and undertaking a risk impact or consequence assessment of the risks identified.

## 2.2 Methodology

The groundwater impact assessment aims to identify potential hazards to groundwater resulting from activities directly associated with Origin's 2015/2016 exploration drilling program.

A literature review was completed to establish a list of groundwater impacts associated with shale gas exploration drilling. This review covered Northern Territory, national and international studies and inquiries into shale gas exploration drilling and hydraulic fracturing activities. Sources reviewed include the Hawke Inquiry (Hawke, 2014), RSRAE (2012), CCA (2014), Frogtech (2013), Ecological Australia (2012), API (2009), King (2010), King (2012) and King (2013).

Potential groundwater impacts identified from the literature were reviewed in a face to face meeting with the Origin staff responsible for the implementation of the drilling program. The relevance of each risk was reviewed relative to specific geological and hydrogeological conditions expected in the Beetaloo Basin and proposed drilling controls, well construction and abandonment design.

Results from the literature review and face to face meeting informed a qualitative risk assessment of potential groundwater impacts stemming from the exploration drilling program. The risk assessment was completed using the Origin Energy Risk Assessment framework. The consequence and likelihood of each risk were assessed according to the following risk matrix (Figure 3), further detail on likelihood and consequence levels is provided in Appendix A.

		COLOUR RATING		Low	Medium	High	Severe	Extreme
		LIKELIHOOD						
CONSEQUENCE		REMOTE	HIGHLY UNLIKELY	UNLIKELY	POSSIBLE	LIKELY	ALMOST CERTAIN	
	CATASTROPHIC	H	H	S	S	E	E	
	CRITICAL	M	M	H	S	S	E	
	MAJOR	M	M	M	H	S	S	
	SERIOUS	L	M	M	M	H	S	
	MODERATE	L	L	M	M	M	H	
	MINOR	L	L	L	M	M	M	

**Figure 3 Origin Risk Matrix**

Consequences were considered for three categories: impact to the environment and natural system, social and cultural impacts, and legal impacts (i.e. breach of laws or regulations). The category with the most severe consequence rating was used for the final risk rating. The likelihood of the risk takes into consideration proposed control measures documented in the drilling plan (Origin Energy, 2015a) and Environmental Plan (AECOM, 2015). In some cases a risk will have a number of potential causes (e.g. the risk of groundwater contamination from surface spills of fuel/chemicals can be caused by a breach of storage, spillage during transport to site or leakage during transfer onsite). Where an impact has more than one cause, the risk level has been discussed and assessed for each specific cause.

The groundwater impacts assessed relate to exploration drilling activities planned for the 2015/2016 program (see Section 2.3) with two exceptions. The first exception relates to hydraulic fracturing. There is no hydraulic fracturing program proposed in the 2015 exploration program, however, Origin requested that CloudGMS consider the groundwater risks associated with possible future hydraulic fracture treatments. This assessment is based on conditions at the five potential drilling sites targeted in the 2015/2016 exploration program. Origin also requested the impact assessment to consider the cumulative risk to groundwater that may occur if a gas resource is identified and developed, specifically the impact of groundwater extraction required for development.

Origin required a more rigorous characterisation of pit leakage and groundwater drawdown risks. The impact assessment for each of these risks is informed by separate modelling investigations which are discussed briefly in section 3 and in detail in Appendix C and Appendix D.

### 2.3 Assumptions and Limitations

- The groundwater impact assessment only considers hydrogeological risks, a broader risk assessment that covers all risks associated with the 2015/2016 exploration drilling program can be found in the Drilling Environmental Plan (AECOM, 2015).
- The 2015/2016 exploration activities covered by the risk assessment are the drilling and construction of the four proposed exploration wells, in addition to DFITs and wireline

logging. DFITs provide data for fracture stimulation design and reservoir modelling. They involve the injection of fluid - in this program drilling fluid already in the well - into the target formation through a small (approximately 5 cm) perforation in the casing. The fluid is injected under pressure for a short time (typically minutes) to create a fracture, the injection is then stopped and the pressure in the well is allowed to fall-off naturally. Full detail on the proposed DFIT design and control measures is provided in the Origin Energy internal document "Beetaloo DFIT Campaign - Project Overview".

- The risk assessment is based on and limited to the five proposed drilling sites for the 2015/2016 program (Kalala S-1, Kalala NE-1, Nutwood Downs SW-1, Amungee NW-1, Beetaloo W-1). The risk assessment does not cover additional unspecified drilling locations in other areas of the basin where different geological conditions may affect the risk profile.
- For the purpose of this risk assessment groundwater impacts are only considered where they will affect a utilised aquifers or an aquifer containing groundwater with a beneficial use. Beneficial use is defined for this assessment as a groundwater quality less than 10,000 mg/l (the upper limit of water tolerance of cattle (ANZECC, 2000), which represents the main groundwater use in the region). For a list of described aquifers and recorded water quality attributes refer to the Beetaloo Basin Hydrogeological Baseline Study (Fulton and Knapp, 2015).
- The risk assessment directly relies on operational inputs specifically the drilling program plan (Origin Energy, 2015a) and detail provided at the face to face meeting (Origin Energy, 2015). Any risks arising from subsequent variations to these inputs are outside the scope of the assessment.
- The risk assessments relating to DFITs, hydraulic fracturing and the development of the gas resource are general in nature.

## 2.4 Identified Risks

The literature review identified the following nine potential groundwater impacts relating to Origin's 2015/2016 exploration drilling activities and possible future hydraulic fracture treatments.

- 1) A surface spill of drilling fluids/diesel/stimulation additives/flow back water leads to the contamination of groundwater resources.
- 2) Leakage of drilling fluids/formation water from mud pits/flare pits leads to the contamination of groundwater resources.
- 3) Groundwater extraction required to supply water for the project results in drawdown of water levels which impacts existing groundwater users and/or the environment.
- 4) The loss of drilling fluids into a utilised aquifer leads to localised groundwater contamination and impaired capacity in adjacent groundwater bores.
- 5) Cross flow of groundwater from a utilised aquifer to another formation causes declining groundwater levels leading to impacts on existing groundwater users and/or the environment.

- 6) Exploration drilling causes cross formational flow between shallow aquifers in contravention of Water Act (NT) Regulations.
- 7) Cross flow of water/hydrocarbons/gas from deeper formations to a utilised aquifer results in groundwater contamination.
- 8) Hydraulic fracturing induces seismicity which increases connectivity between formations and enhances the potential for cross flow of water/hydrocarbons/gas.
- 9) The loss of a radioactive source during geophysical logging results in groundwater contamination of a utilised aquifer.

## 2.5 Risk Impact Assessment

The risk assessment including the likelihood, consequences, assumptions and controls for each of the nine identified impacts is detailed in Appendix B. The following sections provide a summary of the risks and brief discussion of the impact assessment results.

- 1) **SPILL OF FUEL/ADDITIVES/PRODUCED WATER CAUSES GROUNDWATER CONTAMINATION**  
 Assessed Risk Level: LOW  
 Consequence: Moderate  
 Likelihood: Remote to Highly Unlikely

There is a risk that surface spillage of mud products/diesel/stimulation additives/flow back water during transport, storage or transfer onsite will lead to the contamination of groundwater resources. This has the potential to impact groundwater users close to the spill site and environmental receptors. Risk causes for surface spills include:

- Vehicle accident during transport leading to an uncontrolled discharge of diesel.
- Leakage from onsite storage due to a tank/storage integrity breach.
- Loss of containment during transfer onsite (e.g. leakage from pipes, hoses, fitting).
- Uncontrolled surface discharge of formation water/hydrocarbons due to well integrity failure.

The risk level of surface spills leading to groundwater contamination for all causes is assessed as low, primarily because of a deep watertable (>60 mBGL) and the presence of thick clay layers between the surface and the watertable aquifer which will impede the downward movement of the spilled fluid. Leakage modelling (see Appendix D) suggests the volumes that can reasonably be expected from a spill/leakage event are insufficient to mobilise fluid and any associated contaminant to the watertable under expected site conditions.

- 2) **LEAKAGE FROM MUD/FLARE PITS CAUSES GROUNDWATER CONTAMINATION**



Assessed Risk Level: LOW

Consequence: Moderate

Likelihood: Remote

The leakage of drilling fluids/formation water/hydrocarbons from mud/flare pits during drilling has the potential to contaminate groundwater resources and impact groundwater users and environmental receptors. Identified causes which may result in mud/flare pit leakage include:

- Inadequate storage capacity.
- Storm water ingress.
- Failure of pit liner or pit design.

The risk level of groundwater contamination resulting from mud/flare pit leakage is assessed as low. Leakage modelling (see Appendix D) indicates that with expected site conditions, proposed pond dimensions and drilling timeframes leakage from an unlined mud/flare pit is not predicted to infiltrate further than 30 mBGL and is therefore unlikely to impact the watertable which is in excess of 60 mBGL at the three investigation sites.

This impact assessment is also relevant for leakage from retention ponds storing flow-back water from hydraulic fracturing. However, Origin has advised that flow-back water from hydraulic fracturing will be contained in sealed storage tanks mitigating the risk of retention pond leakage (Origin Energy, 2015).

### **3) GROUNDWATER EXTRACTION CAUSES DECLINING WATER LEVELS IN UTILISED AQUIFERS**

Assessed Risk Level: LOW (Exploration/Development)

Consequence: Serious

Likelihood: Remote (Exploration/Development)

There is potential that groundwater extraction required for road construction/drilling/hydraulic fracturing may lead to a decline in water levels in a utilised aquifer. This may result in impaired capacity (i.e. reduced bore yields) in existing groundwater bores and a reduction in environmental flows in connected springs/rivers.

Groundwater supply bores will most likely be constructed in the Cambrian Limestone Aquifer (CLA). This is a regional aquifer with significant storage capacity. Water level drawdown modelling based on exploration water demand (see Appendix C) suggests that the water level drawdown will be limited to 0.3 m at a distance of 500 m from the project supply bores. The nearest pastoral bore (i.e. bore that is regularly used) is located 1900 m from the proposed supply bore locations. The nearest recorded groundwater dependencies are located over 100 km north of the drilling sites at Mataranka (Fulton and Knapton, 2015). The risk of projected groundwater extraction impacting existing groundwater users or the environment is assessed as low for the exploration program.

Projected water demand under a development scenario is estimated to be in the order of 1000 ML/year during development. While significantly greater than exploration requirements this volume represents around 1% of estimated annual water availability from the Georgina Basin

(NALWTF, 2009). Under a development case Origin intends to implement additional controls such as the use of non-potable water from brackish aquifers (if available), treating and recycling recovered water, and entering into "make good" agreements with existing users (K Horton 2015, pers comm., 28 Aug). Assuming water supply bores are located with a reasonable offset from existing groundwater bores the risk of groundwater extraction impacting on existing users or the environment under a development scenario is also assessed as low.

**4) LOSS OF DRILLING FLUIDS INTO AN AQUIFER IMPAIRS CAPACITY IN EXISTING BORES.**

Assessed Risk Level: LOW

Consequence: Moderate

Likelihood: Remote

There is a risk that the significant loss of drilling fluid into a utilised aquifer will lead to the local contamination of the aquifer. This may result in impaired capacity in existing groundwater bores near the drilling site. The level of this risk is assessed as low. Significant mud loss is expected in the CLA (Gum Ridge Formation and Anthony Lagoon Beds) due to the presence of cavernous limestone. Drilling of these formations is proposed to be undertaken using air methods (Origin Energy, 2015), mitigating the risk of fluid loss into the CLA. These formations will be isolated with a casing barrier before the drilling method is changed to a mud system for the drilling of deeper formations. In the instance that fluid loss does occur in the CLA the available mud volume is a limiting factor on the dispersion of the drilling fluid into the aquifer. Fluid loss is likely to only occur in the immediate vicinity of the drilling site and is highly unlikely to approach existing bores, the closest of which is a roads bore located 1000 m from the proposed drilling locations.

**5) CROSS FLOW OF WATER FROM A UTILISED AQUIFER TO ANOTHER FORMATION CAUSES DECLINING WATER LEVELS**

Assessed Risk Level: LOW

Consequence: Serious

Likelihood: Remote

There is a risk that uncontrolled cross flow of groundwater from a utilised aquifer to another formation/s could lead to declining groundwater levels. This may result in impaired capacity (i.e. reduced bore yields) in existing groundwater bores and a reduction in environmental flows in connected springs/rivers. Likely causes of groundwater cross flow include:

- Wellbore failure due to incomplete cement placement or casing failure during operation or post abandonment.
- The breach of aquitard layers by hydraulic fracture propagation.

The magnitude of any potential cross flow is dependent on the relative permeability of the aquifer and the formation receiving the flow and also the pressure gradient between the two formations. The potential for migration of groundwater from the main regional aquifer (CLA) to deeper formations is limited by:

- The low permeability of the deeper formations.

- An upward pressure gradient between deep formations and the CLA (Fulton and Knapton, 2015)

These factors suggest that any drawdown response resulting from cross flow will be localised and is unlikely to result in a water level decline that will affect existing users/environmental dependencies. The level of this risk is assessed as low.

**6) EXPLORATION DRILLING ENABLES CROSS FORMATIONAL FLOW BETWEEN SHALLOW AQUIFERS IN CONTRAVENTION OF WATER ACT REGULATIONS.**

Assessed Risk Level: HIGH

Consequence: Serious

Likelihood: Likely

There is potential that incomplete casing/cementing of shallow utilised aquifers will allow cross formational flow. This will contravene Water Act (NT) regulations, which require effective isolation of multiple aquifers to prevent cross formational flow. Assuming there is a contrast in water quality between the aquifers and a driving pressure gradient, potential also exists for the deterioration in groundwater quality, which in turn could impact existing groundwater users and/or environmental dependencies.

The risk that incomplete casing/cementing of shallow aquifers will allow cross formational flow in contravention of Water Act (NT) regulations is assessed as High for drilling site Beetaloo-W1 where multiple aquifers (basal Cretaceous Sandstone, Anthony Lagoon Beds, Gum Ridge Formation) are expected. The risk is lower at the northern well sites (Amungee-NW1, Kalala-S1, Kalala NE-1, Nutwood Downs SW-1) where the Gum Ridge Formation is the only expected aquifer above the proposed surface casing shoe. The high risk level specifically relates to legal/regulatory implications, the consequence level for environmental and community impact is assessed as medium – see Appendix B for further detail.

**7) CROSS FORMATIONAL FLOW FROM DEEPER FORMATIONS TO A UTILISED AQUIFER RESULTS IN GROUNDWATER CONTAMINATION.**

Assessed Risk Level: LOW to MEDIUM

Consequence: Serious

Likelihood: Remote to Unlikely

There is potential that the cross formational flow of water/hydrocarbons/gas from deeper formations to a utilised aquifer will result in groundwater contamination and impact existing users and environmental dependencies. Possible causes leading to cross-formational flow include:

- Well failure due to incomplete cement placement or casing failure during operation or post abandonment
- Blow out during drilling causes annular leakage
- Breach of aquitard by hydraulic fracture propagation
- Hydraulic fracturing opens pathway through an abandoned exploration well
- Leakage along faults intersected by drilling or induced fracturing

The level of risk associated with cross formational flow leading to groundwater contamination is assessed as Low to Medium for the range of risk causes (see Appendix B for further detail). The risk of well failure is mitigated by the exploration well design. Utilised aquifers will be isolated from producing formations by a triple barrier of cemented casing (surface casing, intermediate casing and production casing). Aquitards separating utilised aquifers from fracture targets are generally of significant thickness (>100 metres) in the Beetaloo basin (Fulton and Knapton, 2015). The combined aquitard thickness at the proposed well sites is likely to be significantly greater than any potential fracture growth resulting from hydraulic fracturing. Well locations Kalala S-1, Amungee NW-1 and Beetaloo W-1 are located away from major structural zones, which limits the likelihood of intersecting and inducing leakage along existing faults. The likelihood of intersecting faults is higher for proposed sites Nutwood Downs SW-1/Kalala NE-1 as they are situated closer to the Walton High which forms the bounding structure in the north of the Beetaloo Basin and is associated with regional fault structures.

**8) HYDRAULIC FRACTURING INDUCES SEISMICITY INCREASING CONNECTION BETWEEN FORMATIONS AND ENHANCING THE POTENTIAL FOR CROSS FORMATIONAL FLOW**

Assessed Risk Level: LOW

Consequence: Serious

Likelihood: Remote

There is a risk that hydraulic fracturing induces local seismicity leading to greater connection between deeper formations and utilised aquifers. This may enhance the potential for cross formational flow of saline groundwater/hydrocarbons/gas causing groundwater contamination in utilised aquifers and impacting existing groundwater users and environmental dependencies.

The pressure exerted in hydraulic fracture stimulations is not sufficient to induce seismicity of a magnitude capable of deforming the volume of rock (>1500 m, Origin Energy, 2015a) separating the target formation and utilised aquifers. Most induced seismicity associated with fracture stimulation is microseismicity. Larger events are uncommon and generally associated with pre-stressed faults (RSRAE, 2012).

**9) THE LOSS OF A RADIOACTIVE SOURCE DURING GEOPHYSICAL LOGGING RESULTS IN GROUNDWATER CONTAMINATION.**

Assessed Risk Level: LOW

Consequence: Moderate

Likelihood: Remote

There is a risk that during wireline logging a radioactive source could be lost leading to groundwater contamination of a utilised aquifer with potential impacts on existing groundwater users and the environment. The loss of a radioactive source is likely to be associated with the tool becoming stuck and the wireline cable breaking during logging.

Wireline logging in the exploration wells is only proposed for the lower formations. This will occur after shallow utilised aquifers are sealed with a cemented casing string. Wireline tools are less likely

to become stuck in a cased section of the well. The cemented casing will also isolate water supply aquifers from any contamination in the event a tool is lost while logging the deeper formations.

## 3 Detailed risk assessment studies

### 3.1 Groundwater drawdown impact assessment

#### 3.1.1 Introduction

To investigate the likely impacts of groundwater extraction from the Cambrian Limestone Aquifer (CLA) during the construction phase of the exploration wells, drawdown studies were conducted to examine the probable magnitude and extent using a Monte Carlo approach and analytical methods.

A full description of the drawdown assessment is provided in Appendix C and is summarised below.

#### 3.1.2 Methodology

The likely range of hydraulic parameters (transmissivity and storage) for the CLA were determined from available information. The range of hydraulic parameters were then used to define probability distributions function (PDF) for both transmissivity and storage parameters. The drawdown at increasing distance from the pumping well was then calculated after a period of 60 days using a random combination of transmissivity and storage generated from the PDF for 10000 different realisations.

#### 3.1.3 Results

The results from the drawdown analysis suggest that for the scheduled drilling duration of 60 days that there was a 50% probability of a drawdown of less than 0.3m at distances greater the 500 m from the pumping bore and there was a 95% probability of a drawdown of less than 0.6 m at distances greater the 500 m from the pumping bore.

### 3.2 Drilling fluid leakage risk assessment

#### 3.2.1 Introduction

This section discusses the results of a study to examine the leakage that could be expected from the unlined mud pit and flare pits used during the drilling phase of the exploration well construction. A full description of the drilling fluid leakage assessment is provided in Appendix D.

#### 3.2.2 Methodology

Unsaturated parameters were derived from soil and water bore lithological logs in the vicinity of the proposed exploration wells. Based on the bore information three representative base cases were identified to investigate potential leakage from the pits.

#### 3.2.3 Results

For all cases investigated it was found that the infiltrated water did not migrate further than approximately 30 m below the land surface. Based on the scenarios modelled the likelihood of surface spillage migrating to the watertable is low when taking into consideration the water table depth (>60 m), spill volumes, timeframe for spill containment / remediation and existing controls.

## 4 Conclusions

The principal aquifer (CLA) underlying the exploration sites is an extensive, regional aquifer. Generally, groundwater impacts resulting from the exploration activities are expected to be reasonably isolated and localised due to the deep watertable (>60 m), overlying unsaturated clay layers, underlying regional aquitards and large storage capacity of the CLA.

The groundwater risk assessment identified nine potential impacts to groundwater system in the Beetaloo basin associated with Origin's 2015/2016 exploration drilling program. These impacts are ranked below according to the assessed risk level.

### HIGH

- Exploration drilling enables cross formational flow between shallow aquifers in contravention of Water Act regulations.

### MEDIUM

- Cross formational flow of formation water/hydrocarbons from deeper formations to a utilised aquifer causes groundwater contamination and impacts existing groundwater users.

### LOW

- Spill of fuel/additives/produced water causes groundwater contamination.
- Leakage from mud/flare pits causes groundwater contamination.
- Groundwater extraction causes declining water levels in utilised aquifers which impacts on existing groundwater users/environmental values.
- Loss of drilling fluids into an aquifer impairs capacity in existing bores.
- Cross flow of water from a utilised aquifer to another formation causes declining water levels.
- The loss of a radioactive source during geophysical logging results in groundwater contamination.
- Hydraulic fracturing induces seismicity increasing connection between formations and enhancing the potential for cross formational flow.

More extensive investigations utilising groundwater modelling techniques were undertaken to assess the likelihood of water level drawdown impacting existing groundwater users and leakage of drilling fluids from drilling pits contaminating the watertable aquifer.

The drawdown assessment found that it is unlikely that significant drawdown will result due to groundwater abstraction from the CLA system for exploration well construction. This extraction poses a low risk to other users with respect to reducing yields of adjacent pastoral bores.

The drilling fluid leakage modelling found that the likelihood of groundwater contamination resulting from surface spillage is low when taking into consideration the water table depth (>60 m),

the retention properties of subsurface clay layers, spill volumes, timeframe for spill containment / remediation and existing controls.



## 5 References

- AECOM (2015) Drilling Environmental Plan Beetaloo Sub-basin, Northern Territory. Prepared for Origin Energy.
- Allison, G.B., Cook, P.G., Barnett, S.R., Walker, G.R., Jolly, I.D. and Hughes, M.W. (1990) Land clearance and river salinisation in the western Murray Basin, Australia. *Journal of Hydrology*, 119 (1990) 1-20.
- API (2009) Hydraulic fracturing operations: well construction and integrity guidelines, API guidance document HF1, American Petroleum Institute: Washington DC.  
<http://www.shalegas.energy.gov/resources/HF1.pdf>
- Australian and New Zealand guidelines for fresh and marine water quality (2000) Volume 1, The guidelines / Australian and New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand.
- Barnett B, Townley L.R., Post V., Evans R.E., Hunt R.J., Peeters L., Richardson S., Werner A.D., Knapton A. and Boronkay A. (2012) Australian groundwater modelling guidelines, Waterlines Report Series No. 82, National Water Commission, Canberra.
- Carsel, R. F., and R. S. Parrish (1988), Developing joint probability distributions of soil water retention characteristics, *Water Resources Research.*, 24(5), 755–769,
- Castelbaum, D. and C. Shackelford, (2009) "Hydraulic Conductivity of Bentonite Slurry Mixed Sands." *J. Geotech. Geoenviron. Eng.*, 135(12), 1941–1956.
- CCA. (2014) Environmental Impacts of Shale Gas Extraction in Canada: The Expert Panel on Harnessing Science and Technology to Understand the Environmental Impacts of Shale Gas Extraction. Council of Canadian Academies from:  
[http://www.scienceadvice.ca/uploads/eng/assessments%20and%20publications%20and%20news%20releases/Shale%20gas/ShaleGas\\_fullreportEN.pdf](http://www.scienceadvice.ca/uploads/eng/assessments%20and%20publications%20and%20news%20releases/Shale%20gas/ShaleGas_fullreportEN.pdf).
- Cossens, B., McAuley, C., Evans, R., Cook, P., Howe, P., et al. (2007) *A framework for assessing the environmental water requirements of groundwater dependent ecosystems*, Resource & Environmental Management Pty Ltd, Kent Town, S. Aust.

- Eco Logical Australia (2012) Shale Gas Development in Australia: Potential Impacts and Risks to Ecological Systems. Final report prepared for the Australian Council of Learned Academies (ACOLA). January 2013' .
- Frogtech, (2013) Potential Geological Risks Associated with Shale Gas Development in Australia. Final report prepared for the Australian Council of Learned Academics (ACOLA). January 2013.
- Fulton, S. and Knapton, A. (2015) Beetaloo Basin Baseline Hydrogeological Assessment. Prepared by CloudGMS for Origin Energy Pty Ltd. February 2015.
- Golden Software (2015). Grapher™ Version 11. <http://www.goldensoftware.com/>
- Hawke, A., 2014. "Report of the Independent Inquiry into Hydraulic Fracturing in the Northern Territory" <http://www.hydraulicfracturinginquiry.nt.gov.au/index.html>
- Jolly, P., (2002) Daly River catchment water balance. NTG Dept. of Lands, Planning and Environment, Natural Resources Division Technical Report WRD02010.
- Jolly, P., Knapton A. and Tickell, S. (2004) Water Availability from the Aquifer in the Tindall Limestone South of the Roper River. NTG Dept of Infrastructure, Planning and Environment. Technical Report WRD04034.
- Karp, D. (1985) Bore Completion Report: Bore 23794: Beetaloo Outstation. Water Resources Division Report No. 56/89D. Northern Territory Government.
- King G. E. and King. D. E., (2013) Environmental Risk Arising From Well-Construction Failure- Differences between Barrier and Well Failure, and Estimates of Failure Frequency across Common Well Types, Locations, and Well Age. Society of Petroleum Engineers. SPE Production and Operations. Volume 28/04. November 2013.
- King (2010) Thirty years of shale gas fracturing: what have we learned?, Society of Petroleum Engineers Annual Technical Conference and Exhibition: Florence.  
[http://www.spe.org/atce/2010/pages/schedule/tech\\_program/documents/spe1334561.pdf](http://www.spe.org/atce/2010/pages/schedule/tech_program/documents/spe1334561.pdf)
- King (2012) Hydraulic fracturing 101: what every representative, environmentalist, regulator, reporter, investor, university researcher, neighbours and engineer should know about

- estimating frac risk and improving frac performance in unconventional gas and oil wells,  
Society of Petroleum  
Engineers.[http://www.kgs.ku.edu/PRS/Fracturing/Frac\\_Paper\\_SPE\\_152596.pdf](http://www.kgs.ku.edu/PRS/Fracturing/Frac_Paper_SPE_152596.pdf)
- Knapton, A., (2006) Regional Groundwater Modelling of the Cambrian Limestone Aquifer System of the Wiso Basin, Georgina Basin and Daly Basin. Alice Springs, NTG Dept. Natural Resources, Environment and The Arts. Technical Report WRA06029.
- McKenzie, N.J., Jacquier, Ashton, L.J. and Crewel, H.P. (2000) Estimation of Soil Properties Using the Atlas of Australian Soils. CSIRO Land and Water TR11-00.
- NALWTF, (2009) Sustainable Development in Northern Australia, A report to Government from the Northern Australia Land and Water Taskforce. Published by the Department of Infrastructure, Transport, Regional Development and Local Government. Commonwealth of Australian, 2009.
- Neuman, S. P. (1982) Statistical characterization of aquifer heterogeneities: an overview. In: Recent Trends in Hydrogeology, 81-102. Spec. Pap. Geol. Soc. Am. no. 189.
- Origin Energy, (2015) Risk Assessment Meeting Minutes. Brisbane.
- Origin Energy, (2015a) Beetaloo Exploration Drilling Campaign #1 Concept Select Report. Project No. UPA0460, Report NT-2050-35-TR-001.
- Rawls, W. J., D. L. Brakenstiek and K. E. Saxton (1982) "Estimation of soil water properties." Transactions of the ASAE **25**(5): pp 1316-1320.
- Royal Society and Royal Academy of Engineering. (2012) Extraction in the UK: A Review of Hydraulic Fracturing. June 2012.
- Schaap, M. G., (2000) Rosetta Ver 1.2, US Salinity Lab., Riverside, CA
- Schaap, M. G., F. L. Leij and M. T. v. Genuchten (2001) "ROSETTA: a computer program for estimating soil hydraulic parameters with hierarchical pedotransfer functions." Journal of Hydrology **251**: pp 163-176.

Theis C. V. (1935) The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage. Trans Amer Geophys Union 16: 519-524.

## Appendix A Origin Risk Matrix

Table A—1 Risk matrix risk likelihood description

		COLOUR RATING					
		Low	Medium	High	Severe	Extreme	
		LIKELIHOOD					
CONSEQUENCE		REMOTE	HIGHLY UNLIKELY	UNLIKELY	POSSIBLE	LIKELY	ALMOST CERTAIN
	CATASTROPHIC	H	H	S	S	E	E
	CRITICAL	M	M	H	S	S	E
	MAJOR	M	M	M	H	S	S
	SERIOUS	L	M	M	M	H	S
	MODERATE	L	L	M	M	M	H
	MINOR	L	L	L	M	M	M
		1 REMOTE <1% chance of occurring within the next year. Occurance requires exceptional circumstances. Exeptionally unlikely event in the long term future. Only occur as a 100 year event	2 HIGHLY UNLIKELY >1% chance of occurring within the next year. May occur but not anticipated. Could occur years to decades	3 UNLIKELY >5% chance of occurring within the next year. May occur but not for awhile. Could occur within a few years	4 POSSIBLE >10% chance of occurring within the next year. May occur shortly but a distinct probability it won't. Could occur within months to years.	5 LIKELY >50% chance of occurring within the next year. Balance of probability will occur. Could occur within weeks to months.	6 ALMOST CERTAIN 99% chance of occurring within the next year. Impact is occurring now. Could occur within days to weeks.

Table A—2 Risk matrix consequence categories

	Natural environment	Community damage/impact/social/cultural heritage	Breach of law or criminal prosecution or civil action (eg. OHS, environment, industrial relations, trade practices, industry acts)
Catastrophic - 6	Long term destruction of highly significant ecosystem or very significant effects on endangered species or habitats.	Multiple community fatalities, complete breakdown of social order, irreparable damage of highly valued items or structures of great cultural significance.	Potential jail terms for executives and or very high fines for the Company. Prolonged multiple litigations.
Critical - 5	Major offsite release or spill, significant impact on highly valued species or habitats to the point of eradication or impairment of the ecosystem. Widespread long-term impact.	Community fatality. Significant breakdown of social order. Ongoing serious social issue. Major irreparable damage to highly valuable structures/ items of cultural significance.	Very significant fines and prosecutions. Multiple prosecution and fines.
Major - 4	Offsite release contained or immediately reportable event with very serious environmental effects, such as displacement of species and partial impairment of ecosystem. Widespread medium and some longterm impact.	Serious injury to member of the community, Widespread social impacts. Significant damage to items of cultural significance.	Major breach of regulation and significant prosecution including class actions.
Serious - 3	Moderate effects on biological or physical environment and serious short term effect to ecosystem functions.	Media attention and heightened concerns by local community and criticism by NGOs. Ongoing social issues. Permanent damage to items of cultural significance.	Serious breach of law/regulation with investigation or report to authority with possible prosecution. Performance Infringement Notice (PIN)
Moderate - 2	Event contained within site. Minor short term damage to area of limited significance. Short term effects but not affecting ecosystem functions.	Medical treatment injury to a member of the community, Minor adverse local public or media attention and complaints. Minor medium term social impact on local population, mostly repairable.	Breach of law/regulation or non-compliance. Minor legal issues, minor litigation possible.
Minor - 1	Minor consequence, local response. No lasting effects. Low level impacts on biological and physical environment to an area of low significance.	Public concern restricted to local complaints, low level repairable damage to common place structures.	Local investigation, minor breach of regulation, on the spot fine or technical noncompliance. Prosecution unlikely.

## Appendix B Groundwater Impact Risk Assessment

RISK IDENTIFICATION										RA			COMMENT	
RISK IDENTIFICATION				CONSEQUENCES	POTENTIAL EXPOSURE	CONSEQUENCE CATEGORY			EXISTING CONTROLS		LEVEL OF RISK WITH CONTROLS			
Risk ID	Risk Title <i>There is a chance that...</i>	Phase of Works	Risk Causes <i>Because...</i>	Consequences <i>(This will mean ...)</i>	Assumptions	Community	Environment	Legal	Control Title	Control Type	Consequence	Likelihood		Assessed Level of Risk
1	Spillage of mud products/diesel/stimulation additives/flow back water during transport, storage or transfer onsite leads to the contamination of shallow groundwater resources	Exploration DFIT Hydraulic Fracturing Development/Production	1) Vehicle accident during transport leads to uncontrolled discharge of diesel	Contamination of shallow aquifers by flowback/formation water impacts existing groundwater users and environmental dependencies	- Relatively shallow groundwater occurrence - Unsaturated zone sediments are permeable and provide pathway to watertable aquifer	2 - Moderate	2 - Moderate		Oil Pollution Emergency Plan NT-2050-15-MP-004	Corrective	2 - Moderate	1 - Remote	LOW	Refer to leakage modelling results for assessment of likelihood of impact from spill Likelihood of groundwater contamination resulting from surface spillage is low when taking into consideration watertable depth, spill volumes and existing controls
			2) Leakage due to tank/storage integrity breach			2 - Moderate	2 - Moderate		Oil Pollution Emergency Plan NT-2050-15-MP-004	Corrective	2 - Moderate	2 - Highly Unlikely	LOW	
			3) Loss of containment during transfer onsite (leakage from pipes, hoses, fittings etc)			2 - Moderate	2 - Moderate		Oil Pollution Emergency Plan NT-2050-15-MP-004	Corrective	2 - Moderate	2 - Highly Unlikely	LOW	
			4) Uncontrolled surface discharge of formation water/hydrocarbons due to well integrity failure			2 - Moderate	2 - Moderate		Blow-out protection/flare pit Oil Pollution Emergency Plan NT-2050-15-MP-004	Preventative Corrective	2 - Moderate	2 - Highly Unlikely	LOW	
2	Leakage of drilling fluids/flow back/formation water from mud pits/flare pits/retention ponds	Exploration DFIT Hydraulic fracturing Development/Production	1) Inadequate storage capacity in mud/flare pits 2) Storm water ingress 3) Failure of pit liner/design	Contamination of shallow aquifers by flowback/formation water impacts existing groundwater users and environmental dependencies	- Drilling program uses open mud pit system.	2 - Moderate	2 - Moderate		Oil Pollution Emergency Plan NT-2050-15-MP-004	Detective Corrective	2 - Moderate	1 - Remote	LOW	Refer to leakage modelling results for assessment of likelihood of impact from spill. Risk only relates to mud pits and flare pits as flowback fluids will be stored in sealed tanks Classed as unlikely given possibility that in future works Orign workplan might approach the wet season and possibility of storm water ingress increases substantially
3	Groundwater extraction for the project impacts on existing users and/or environmental values	Exploration	Groundwater extraction for project activities causes the decline of groundwater levels in the Cambrian Limestone Aquifer (CLA)	1) Pastoral groundwater bores suffer impaired capacity (i.e. reduced bore yields) 2) Reduced environmental flows in connected springs/rivers	- Groundwater from the CLA is used to supply the project	2 - Moderate	3 - Serious		Groundwater level and use monitoring (NT-2050-15-MP-0011) Response to observed change in accordance with follow-up framework	Detective	3 - Serious	1 - Remote	LOW	Consequence of impacting ecosystems in Roper River is significant, however, likelihood of this occurring is remote considering the expected production volumes, the large storage in the regional aquifer, distance from the discharge points and risk controls (water re-use, targeting brackish groundwater from alternative aquifers)
		Development/Production				2 - Moderate	3 - Serious		Groundwater level and use monitoring (NT-2050-15-MP-0011) Response to observed change in accordance with follow-up framework	Detective	3 - Serious	1 - Remote	LOW	
4	Significant loss of drilling fluids into utilised aquifer	Exploration Development	Intersection of cavernous rocks during drilling with mud system	Local contamination of utilised aquifer may lead to impaired water quality or capacity in pastoral bores	- Cambrian Limestone Aquifer is drilled with mud system	1 - Minor	2 - Moderate		Drilling through CLA completed using air system	Preventative	2 - Moderate	1 - Remote	LOW	Drilling through CLA is proposed to be undertaken with mud balanced air methods rather than mud system. This mitigates the risk of mud/fluid loss into cavernous sections of the CLA



RISK IDENTIFICATION														
RISK IDENTIFICATION				CONSEQUENCES	POTENTIAL EXPOSURE	CONSEQUENCE CATEGORY			EXISTING CONTROLS		RA			COMMENT
Risk ID	Risk Title There is a chance that...	Phase of Works	Risk Causes Because...	Consequences (This will mean ...)	Assumptions	Community	Environment	Legal	Control Title	Control Type	Consequence	Likelihood	Assessed Level of Risk	
5	Cross flow of groundwater from a utilised aquifer to another formation results in drawdown of water levels	Exploration DFIT Hydraulic Fracturing Development Abandonment	1) Wellbore failure due to incomplete cement placement or casing failure during operation or post abandonment 2) Breach of aquitard by hydraulic fracture propagation	1) Pastoral groundwater bores suffer impaired capacity (i.e. reduced bore yields) 2) Reduced environmental flows in connected springs/rivers	- Lack of zonal isolation extends continuously between zones - Differential pressure between zones	1 - Minor	1 - Minor		1) Drilling Program Design (NT-2050-35-TR-0001) 2) Beetaloo DFIT Campaign Project Overview 3) Stimulation Design	Preventative	3 - Serious	1 - Remote	LOW	Highly dependant on relative permeability of formations and pressure difference between formations. Any drawdown response is likely to be very localised and not affect existing users/environmental dependencies
6	Cross flow of groundwater between shallow aquifers results in deterioration of water quality in utilised aquifer	Exploration Development/production Abandonment	Incomplete cementing and casing of shallow aquifers provides pathway for cross formational flow	Deterioration in water quality in aquifer may impact existing groundwater users and environmental dependencies	- Multiple shallow aquifers at drill site - Aquifers have contrasting water quality - Differential pressure between aquifers enables migration of groundwater from poorer quality to better quality aquifer	2 - Moderate	2 - Moderate	3 - Serious	Drilling Program Design (NT-2050-35-TR-0001)		3 - Serious	5 - Likely	HIGH	Failure to isolate separate aquifers will breach water act regulations. This is considered highly likely in the centre and south of basin where there are multiple shallow aquifers (Cretaceous/Anthony Lagoon Beds/Gum Ridge) which are proposed in well design to be sealed by a single run of cemented surface casing.
7	Cross-formational flow of water/hydrocarbons/gas from deeper formations to utilised aquifer results in contamination of utilised aquifer	Exploration DFIT Hydraulic Fracturing Development/production Abandonment	1) Wellbore failure due to incomplete cement placement or casing failure during operation or post abandonment	Deterioration in water quality in utilised aquifer impacts existing groundwater users and affects environmental dependencies (springs, ecosystems).	- Lack of zonal isolation extends continuously between formations - Differential pressure between formations - Abandoned exploration bore has compromised construction - Intersected faults extend through aquitard	3 - Serious	2 - Moderate		Drilling Program Design (NT-2050-35-TR-0001)	Preventative	3 - Serious	3 - Unlikely	MEDIUM	Risk mitigated by well design, utilised aquifers isolated from producing formations by triple barrier of cemented casing (surface casing, intermediate casing and production casing)
			2) Blow out during drilling causes annular leakage			3 - Serious	2 - Moderate		1) Drilling Program Design (NT-2050-35-TR-0001) 2) Blow out protectors/flare pits	Preventative	3 - Serious	1 - Remote	LOW	Uncontrolled flow into shallow aquifer considered highly unlikely as utilised aquifers will be isolated by surface casing before gas bearing formations are drilled
			3) Breach of aquitard by hydraulic fracture propagation			3 - Serious	2 - Moderate		1) Beetaloo DFIT Campaign Project Overview 2) Stimulation design	Preventative	3 - Serious	1 - Remote	LOW	Aquitards separating utilised aquifers from fracture targets are of significant thickness (100s metres) in Beetaloo basin. Thickness of aquitards significantly exceeds extent of recorded frcture propagation
			4) Hydraulic fracturing opens pathway through abandoned exploration well			3 - Serious	2 - Moderate		1) Beetaloo DFIT Campaign Project Overview 2) Stimulation design	Preventative	3 - Serious	1 - Remote	LOW	Very few abandoned wells in the Beetaloo Basin and none in the immediate vicinity of Origins planned works
			5) Leakage along faults intersected by drilling or induced fracturing			3 - Serious	2 - Moderate		1) Drilling Program Design (NT-2050-35-TR-0001) 2) Beetaloo DFIT Campaign Project Overview 3) Stimulation design	Preventative	3 - Serious	3 - Unlikely	MEDIUM	Fault intersections are identified during fracture stimulation by leak-off and stage of fracturing will be abandoned ceasing fracture propagation
8	Induced seismicity leads to greater connection between deeper formations and utilised aquifers	DFIT Hydraulic Fracturing	Hydraulic fracturing induces local seismicity	Change in flowpaths and aquifer inerconnection leads to flow of groundwater between formations and results in contamination of utilised aquifer and impacts on existing pastoral use and environmental dependencies	- Lack of zonal isolation extends continuously between zones - Differential pressure between zones - High permeability in deeper zone - Poorer water quality in deeper zones	3 - Serious	3 - Serious		1) Beetaloo DFIT Campaign Project Overview 2) Stimulation Design	Preventative	3 - Serious	1 - Remote	LOW	Seismic event of magnitude sufficient to deform existing geology structures/pathways and induced by hydraulic frcturing is unprecedented and likelihood is considered extremely remote
9	Loss of radioactive source in utilised aquifer during logging results in contamination of aquifer	Exploration Development	Logging tool becomes stuck in hole Logging cable breaks	Localised contamination of utilised aquifer with radioactive source impacts ability of existing groundwater users to exploit the resource	- Radioactive source on the logging string when the tool becomes stuck	2 - Moderate	2 - Moderate		1) Well Design (NT-2050-35-TR-0001) 2) Logging procedure	Preventative	2 - Moderate	1 - Remote	LOW	Utilised aquifers will be isolated with casing before wire-line logging is undertaken, in the event of cable breakage any radioactive source will most likely be lost in deeper, non-potable formations which are the target for logging operations.



## Appendix C Construction water supply drawdown risk assessment

### C.1 Background

#### C.1.1 Objective

The objectives of the drawdown assessment are to:

- Assess the likely magnitude and extent of groundwater level drawdown in the water table aquifer resulting from extraction at construction supply bores located near each of Origin's proposed exploration well sites; and
- Identify bores that may be impacted by the groundwater abstraction.

#### C.1.2 Scope

The scope of the drawdown modelling exercise was confined to the following tasks:

- Determine the likely range of hydraulic parameters in the vicinity of the three proposed exploration wells;
- Determine the volume and duration of pumping based on the supplied information for three bores;
- Estimate the drawdown versus distance from the pumping well at selected times for the range of hydraulic parameters; and
- Identify any landholder bores that fall within the zone of influence of the construction supply bores.

To demonstrate the effects of the groundwater abstraction outputs from the modelling will include:

- Distance drawdown graphs displaying the minimum and maximum expected drawdown scenario and radial distance from the production bore.
- Local scale water level drawdown maps showing the modelled cone of depression (minimum and maximum) around each supply well at the end of development year 1 (2015) and year 2 (2016).
- The water level drawdown maps will also identify any landholder bores that fall within the zone of influence of the construction supply bores.

#### C.1.3 Assumptions and limitations

- The assessment assumes a continuous pumping rate based on the average water demand;

- The drawdown analysis will not consider the cumulative drawdown resulting from the operation of landholder bores or interference resulting from the simultaneous pumping of multiple construction supply bores.

#### C.1.4 Model confidence level classification

The groundwater model presented is deemed to be Class 1 using the classification presented by Barnett et al (2012). A Class 1 model is suitable for understanding groundwater flow processes under various hypothetical conditions and developing coarse relationships between groundwater extraction locations, rates and associated impacts.

Based on the objectives of the modelling study a Class 1 confidence level is considered appropriate.

## C.2 Methodology

The drawdown modelling was undertaken using analytical methods based on conventional pumping test solutions (i.e. Theis solution). The modelled scenarios are appropriate for all five 2015/2016 exploration well sites and assume that a maximum of one supply bore is required for each exploration well.

The permeability and storage parameters were sourced from the baseline hydrogeological assessment (Fulton and Knapton, 2015). There is a reasonable level of uncertainty in the range of hydraulic parameters due to the limited number of studies on the aquifers in the Gum Ridge and Anthony Lagoon Beds. The hydraulic parameters of these formations are poorly constrained and a probabilistic approach using Monte Carlo simulation methods has been applied to characterise the likely range of drawdowns.

### C.2.1 Monte Carlo simulations

Monte Carlo simulation is a versatile method for analysing the behavior of an activity, plan or process that involves uncertainty. Its core idea is to use random samples of parameters or inputs to explore the behavior of a complex system or process.

In groundwater modelling, Monte Carlo simulation is typically used to describe a method for propagating (translating) uncertainties in model inputs into uncertainties in model outputs (results). Hence, it is a type of simulation that explicitly and quantitatively represents uncertainties. Monte Carlo simulation relies on the process of explicitly representing uncertainties by specifying inputs as probability distributions. If the inputs describing a system are uncertain, the prediction of future performance is necessarily uncertain. That is, the result of any analysis based on inputs represented by probability distributions is itself a probability distribution.

In Monte Carlo simulation, the entire system is simulated a large number of times (e.g., 10000). Each simulation is equally likely, referred to as a realization of the system. For each realization, all of the uncertain parameters are sampled (i.e. a single random value is selected from the specified distribution describing each parameter). The system is then simulated through time (given the particular set of input parameters) such that the performance of the system can be computed. This

results in a large number of separate and independent results, each representing a possible “future” for the system (i.e. one possible path the system may follow through time). The results of the independent system realizations are assembled into probability distributions of possible outcomes. As a result, the outputs are not single values, but probability distributions.

## C.2.2 Analytical model

The Monte Carlo analysis was conducted using the Theis equation (Theis, 1935). The solution is for a confined aquifer enabling the drawdown to be estimated using the pumping rate  $Q$ , transmissivity  $T$  and the storage coefficient  $S$  of the aquifer.

$$s = \frac{Q}{4\pi KD} \int_u^{\infty} \frac{e^{-y} dy}{y} = \frac{Q}{4\pi KD} W(u)$$

$$u = \frac{r^2 S}{4KDt}$$

where

$s$  = the drawdown in m measured in a piezometer

$r$  = the distance of a piezometer from the well in metres

$Q$  = the constant well discharge in  $\text{m}^3/\text{d}$

$KD$  = the transmissivity ( $T$ ) of the aquifer in  $\text{m}^2/\text{d}$

$S$  = the dimensionless storage coefficient of the aquifer

$t$  = the time in days since pumping started

$W(u)$  = is the Theis well function and is approximated by:

$$W(u) = -0.5772 - \ln u + u - \frac{u^2}{2 \cdot 2!} + \frac{u^3}{3 \cdot 3!} - \frac{u^4}{4 \cdot 4!} + \dots$$

The Theis equation was coded into an executable that generated multiple realisations using the probability distributions detailed in section C.3.4. The results were output in the form of a text file suitable for analysis in Excel and displayed using Grapher 11 (Golden Software, 2015).

## C.3 Site characteristics

### C.3.1 Bore locations

Origin plans to drill four bores at five potential sites to provide water supply for drilling and construction of the proposed 2015/2016 exploration wells. The coordinates of the proposed exploration wells are tabulated below in Table C—1 and presented above in Figure 1. It is assumed that the location of the construction water supply bores will be in close proximity to each of the exploration wells.

**Table C—1 Proposed locations of the exploration wells.**

Well ID	Easting	Northing	Nearest bore	Distance*(metres)
Amungee NW-1	380808	8192693	RN005844	4000
Beetaloo W-1	368312	8106695	RN004882	6600
Kalala S-1	351740	8198029	RN005942	1000
Kalala NE-1	370770	8226075	RN031635	1900
Nutwood Downs SW-1	369184	8225743	RN031635	3500

Datum = GDA94, Projection = MGA Zone 53

Distance\* refers to separation distance between exploration well and nearest water bore used for groundwater abstraction.

### C.3.2 Pumping schedule and water demand

It is expected that groundwater extraction bores will be constructed at each site to produce sufficient quantities of water for drilling of the exploration well, camp operations and civil construction: (AECOM, 2015). The anticipated volumes of water for each component are:

- 0.5 ML per exploration well for drilling (AECOM, 2015);
- 0.6 ML per site for camp operations based on 200L/person/day @ 60 days (AECOM, 2015);
- 10 ML max per site is expected for civil works (A Moser 2014, pers comm., 3 Dec);

This equates to approximately 11.1 ML per site. Assuming a 60 day timeframe for each well, this is equivalent to a continuous rate of 2 l/s.

If hydraulic fracturing is undertaken then:

- A maximum of 4.8 ML per site is required for fracture stimulation (A Moser 2014, pers comm., 3 Dec).

This gives a total demand of approximately 15.9 ML per site. Assuming a 60 day timeframe for the drilling and construction of each well, this is equivalent to a continuous rate of 3 l/s.

### C.3.3 Hydraulic parameters

The location of the water bores proposed covers a large area and the hydraulic properties of the aquifer are expected to vary between sites.

#### C.3.3.1 Transmissivity

Transmissivity values determined from available pumping tests are relatively sparse throughout the Beetaloo Basin. Pumping tests are available for seven bores along the Carpentaria Highway, four of these tests were conducted on bores in the vicinity of the northern sites (Amungee NW-1, Kalala S-1, Kalala NE-1, Nutwood Downs SW-1). The estimated transmissivities range from 300 to 3400 m<sup>2</sup>/d.

A pumping test was conducted near the southern site (Beetaloo W-1) at Jingaloo Outstation (Karp, 1985) and three pumping tests have been conducted approximately 50 km to the south of the proposed site. The estimated transmissivities are greater than 300 m<sup>2</sup>/d and generally greater than 1000 m<sup>2</sup>/d. More recently a slug test was completed by Origin Energy personnel on the water supply bore adjacent to the Amungee NW-1 well site, the resulting transmissivity was estimated at 925 m<sup>2</sup>/d (R. Morris 2016, pers. comm., 09 Mar.).

This would suggest transmissivity is relatively high with minimum likely value of around 300 m<sup>2</sup>/d, maximum greater than 3000 m<sup>2</sup>/d and a median value of around 1000 m<sup>2</sup>/d.

### C.3.3.2 Storage coefficient

Previous water balance methods and groundwater modelling of the Cambrian Limestone Aquifer (CLA) system indicate the system behaves regionally as an unconfined system with specific yields of approximately 0.01 to 0.04 (Jolly, 2002; Jolly et al., 2004; Knappton, 2006). However, available pumping test data for the CLA within the study area suggests that, over the shorter timeframe of the pumping tests, the local system behaves as a confined to semi-confined system. Assuming confined to semi-confined conditions exist will result in an over estimate of the final drawdown calculated at each site.

The range, mean and expected standard deviation for the log transformed transmissivity and storage coefficients are presented below in Table C—2.

**Table C—2 Hydraulic parameter probability distribution properties.**

SITE	Log T			S		
	Range	Mean	Std Dev.	Range	Mean	Std Dev.
1	2 - 4	2.8	0.25	1e-03 – 1e-05	2e-04	5e-04
2	2 - 4	2.8	0.25	1e-03 – 1e-05	2e-04	5e-04
3	2 - 4	2.8	0.25	1e-03 – 1e-05	2e-04	5e-04
4	2 - 4	2.8	0.25	1e-03 – 1e-05	2e-04	5e-04
5	2 - 4	2.8	0.25	1e-03 – 1e-05	2e-04	5e-04

### C.3.4 Hydraulic parameter uncertainty

The hydraulic parameters that are to be changed during the analysis (i.e. transmissivity and storage coefficient) are assumed to be either normally or log-normally distributed.

Material properties that are directly related to hydraulic conductivity appear to have a log-normal distribution (Neuman, 1982) and this is true of transmissivities. On the other hand, the distribution of porosities is usually regarded to exhibit a normal distribution. Assuming that hydraulic conductivity is an exponential function of porosity as suggested by some empirical formulas, then a

normal distribution of porosities implies that the distribution of hydraulic conductivities must be log-normal (Neuman, 1982).

#### C.3.4.1 Transmissivity

The average transmissivity has been assigned a value of 600 m<sup>2</sup>/d, which is lower than the likely T of around 1000 m<sup>2</sup>/d as suggested from available pumping test data and is therefore considered a conservative estimate. The probabilistic approach to the modelling does investigate the higher transmissivity values.

#### C.3.4.2 Storage coefficient

Based on the discussion above the storage coefficient has been assumed to be normally distributed with a mean of 0.0002 and a standard deviation of 0.0005 this provides a distribution that spans the observed values where p5 is approximately 0.00005 and p95 is approximately 0.001, which is considered to be representative of the confined / semi-confined CLA.

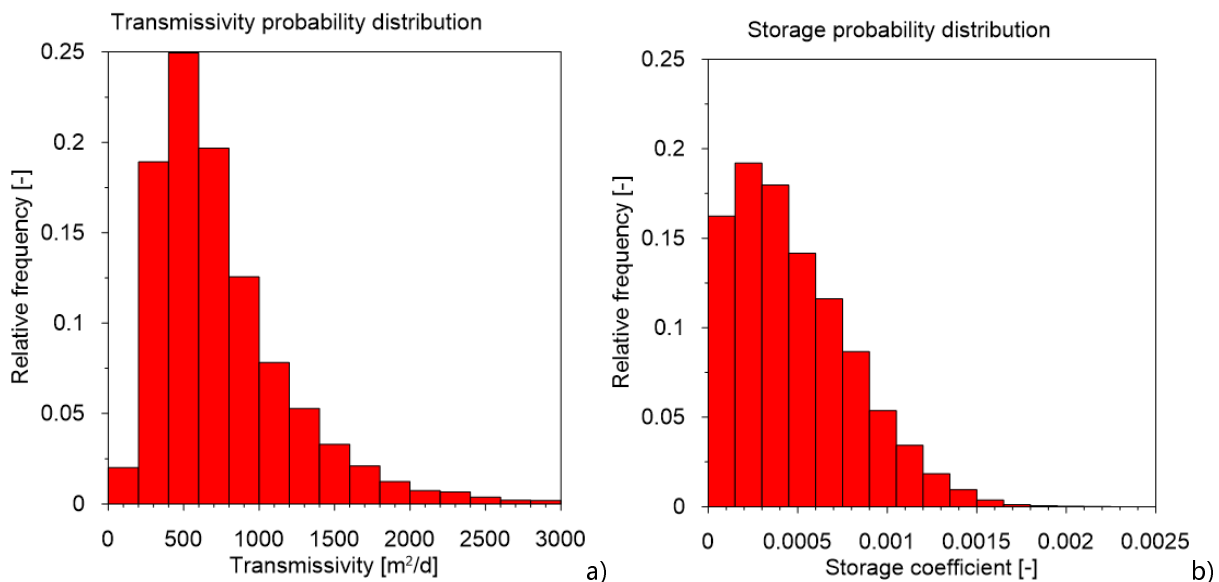


Figure 4 Probability distribution for a) transmissivity and b) storage coefficient.

### C.4 Predicted drawdowns

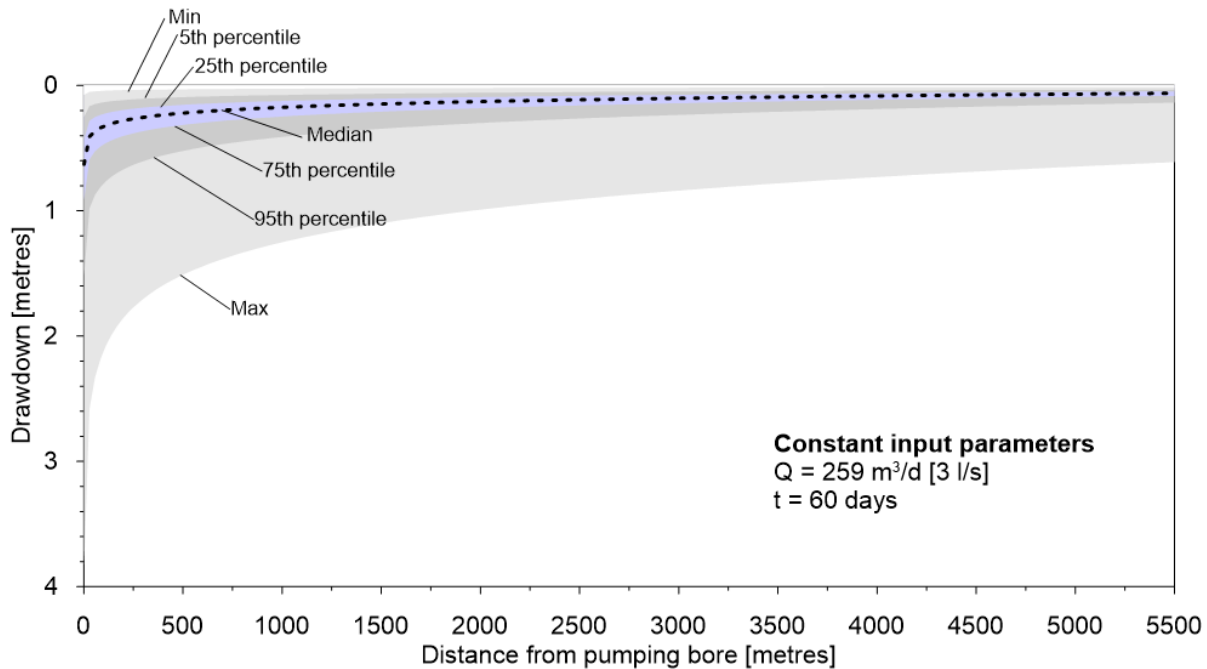
#### C.4.1 Predicted drawdown from the proposed drilling schedule timeframe and water demand

Using the information from the construction timetable and expected water demands the predicted drawdowns were calculated for 10000 realisations and are presented as percentiles at increasing distances from the pumping bore.

The pale grey bands indicate the extreme values (5<sup>th</sup> / 95<sup>th</sup> percentile of the drawdown data), the dark grey bands are defined the lower and upper quartiles, and the dashed centre-line is the median.

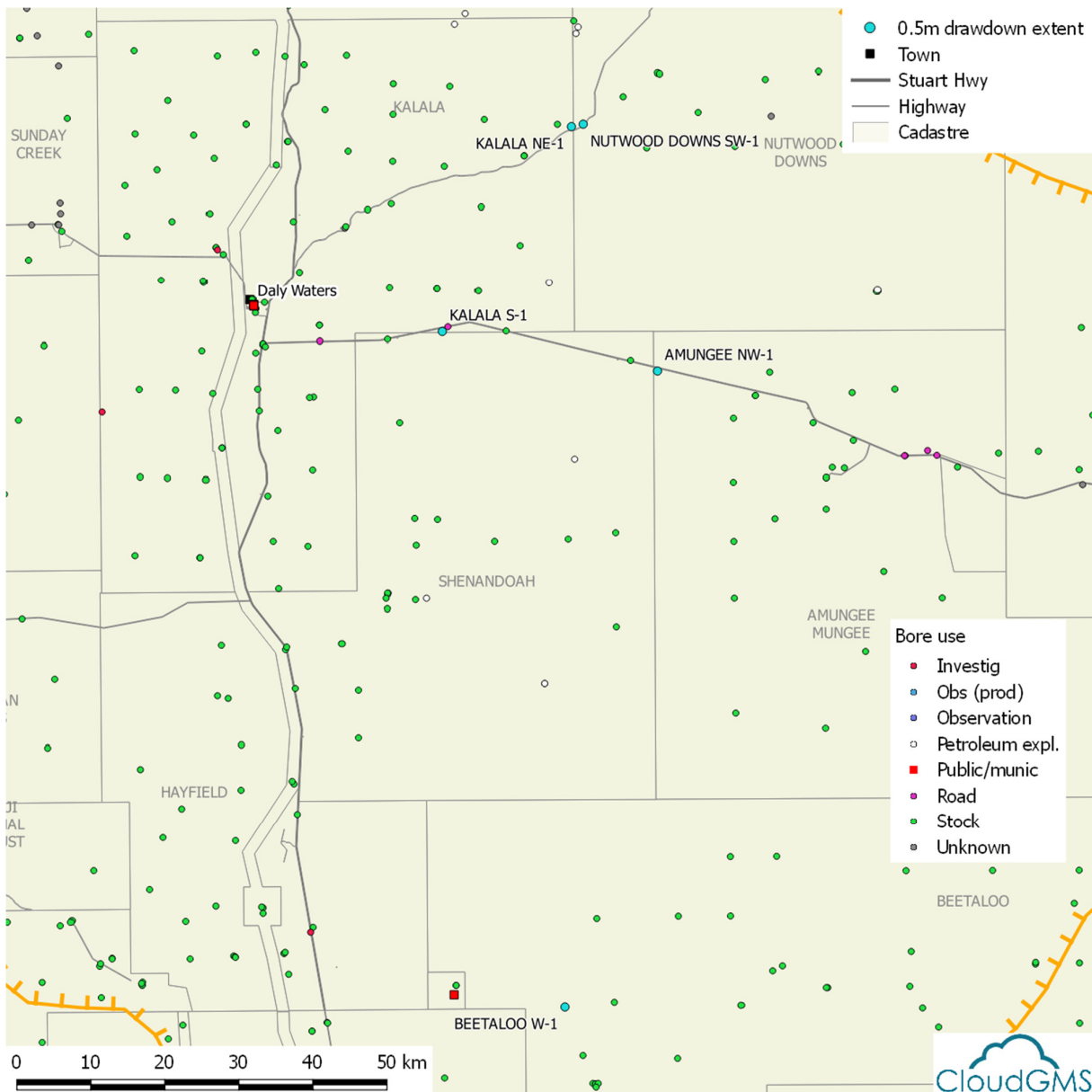
The most likely response represented by the median suggests that the impact away at a distance greater than 500 metres from the pumping bore is less than 0.3 metres and that for 95% of the realisations an impact of less than 0.5 metres can be expected.

This suggests that the impacts due to interference at any bores within the vicinity of the water supply well would be 2 – 3 times less than the expected drawdown in the bore being pumped.



**Figure 5 Percentiles of drawdown vs distance from the pumping bore based on 10000 realisations using the input hydraulic parameters from Table 1 and discharge  $Q = 259 \text{ m}^3/\text{d}$  (3 l/s) and time  $t = 60$  days. Note the vertical scale is 0 – 4 metres.**

The 95<sup>th</sup> percentile 0.5 metre drawdown contours at each site are presented in plan view to provide an appreciation of the lateral extent of the drawdown cone. A drawdown of 0.5 metres is considered the extent that a response would be measurable using manual methods such as a dipper and allowing for errors such as variations in atmospheric pressure. Table C—3 presents the expected drawdown at the closest existing bore identified for each of the proposed exploration wells.

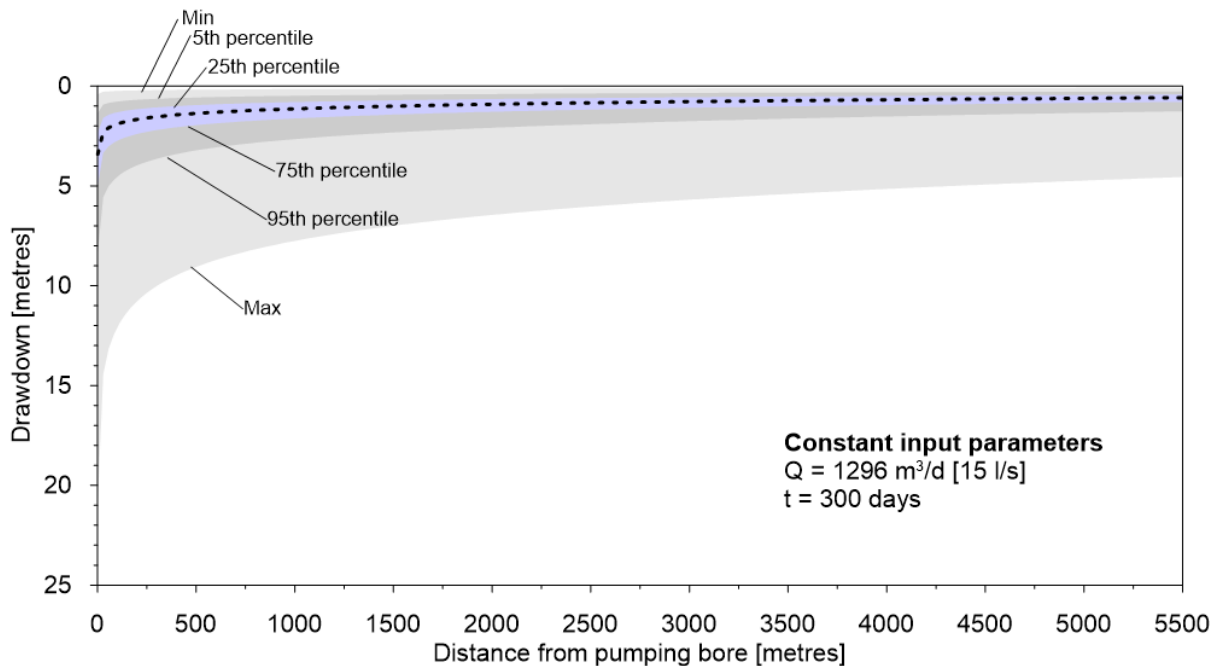


**Figure 6 Predicted 95% probability 0.5 metre drawdown extent (radius ~500-600 m) at the five potential exploration well sites using discharge  $Q = 259 \text{ m}^3/\text{d}$  (3 l/s) and time  $t = 60$  days.**

#### C.4.2 Predicted drawdown assuming a fivefold increase in drilling schedule timeframe and water demand

An additional analysis was conducted to investigate the impacts if the discharge and timeframe were increased by a factor of five taking the pumping time to 300 days and the discharge to 15 l/s (1296  $\text{m}^3/\text{d}$ ), which is the maximum rate before requiring an extraction licence. Modelling results applying these parameters are presented as cross-sectional drawdown in Figure 7 (Note that the vertical scale is 0 – 25 m cf 0 – 4 m in Figure 3).





**Figure 7 Percentile drawdowns vs distance from the pumping bore based on 10000 realisations and using the input hydraulic parameters from Table 1 and discharge  $Q = 1296 \text{ m}^3/\text{d}$  (15 l/s) and time  $t = 300$  days. Dashed line is the median drawdown response. Note the vertical scale is from 0 – 25 metres.**

Table C—3 summaries the resulting range of drawdowns from the two scenarios. The 95<sup>th</sup> percentile drawdown at a distance of 1000 m for any of the five bores considered is expected to be between 2 – 3 m.

**Table C—3 Predicted 95<sup>th</sup> percentile drawdowns at bores adjacent to the proposed exploration wells assuming  $Q = 3 \text{ L/s}$  and duration of 60 days and  $Q = 15 \text{ L/s}$  and duration of 300 days.**

Well ID	Nearest bore	Distance (metres)	Drawdown ( $Q = 3 \text{ L/s}$ and $T = 60\text{d}$ )	Drawdown ( $Q = 15 \text{ L/s}$ and $T = 300 \text{ d}$ )
Amungee NW-1	RN005844	4000	< 0.5m	1 – 2m
Beetaloo W-1	RN004882	6600	< 0.5m	< 1m
Kalala S-1	RN005942	1000	< 1m	2 – 3m
Kalala NE-1	RN031635	1900	< 0.5m	2 – 3m
Nutwood Downs SW-1	RN031635	3500	< 0.5m	1 – 2m

## C.5 Conclusions

Based on the available aquifer material properties and the pumping information supplied it is unlikely that significant drawdown will result due to groundwater abstraction from the CLA system for exploration well construction and poses a low risk to other users with respect to reducing yields of adjacent pastoral bores.

## Appendix D Drilling fluid leakage risk assessment

### D.1 Background

#### D.1.1 Objective

The objectives of the drilling fluid leakage modelling are to:

- Model the leakage from the retention basins during their operational life;
- Provide guidance on the suitability of the pit construction to limit leakage with consideration to local soil and hydrogeological conditions; and
- Using the results of the mud / flare pit leakage assessment to constrain the likelihood of short term spills at the surface migrating to the groundwater.

#### D.1.2 Scope

The modelling process is guided by the Groundwater Modelling Guidelines (Barnett et al, 2012) and involves the following steps:

- A literature review to establish local hydrogeological conditions (informed by the baseline assessment, Fulton and Knapton, 2015) and the likely unsaturated hydraulic parameters;
- The unsaturated zone parameters and average water level depth will be based on the typical soils / bore logs in the area;
- Development of a conceptual model based on the flare / mud pits geometry and expected material properties based on the local hydrogeological conditions;
- Design, configure and construct a single base case transient numerical model based on the conceptual model. No calibration will be undertaken as there are no site specific observations available;
- Construct variant models using unsaturated material properties specific to each of the areas to be considered;
- Assess the leakage risk from the flare / mud pits for each variant of the base model;
- Undertake uncertainty modelling to examine seepage quantities and migration of the infiltrated fluid using different soil parameters.

The outputs from the leakage assessment modelling include:

- A time series of the 2-dimensional cross-section through the pit and the underlying unsaturated zone showing leakage rates and pressure distribution over the operational life of the retention ponds.
- The calculated cumulative seepage flux over the operational life of the basins for each case considered.

- Based on the predictive results an assessment on the suitability of the construction of the pits to limit the depth of migration of the infiltrated fluid to the unsaturated zone over their operational life.

### D.1.3 Assumptions and limitations

The leakage assessment modelling has been undertaken using the following assumptions and limitations:

- It is assumed that the flare / mud pits will be unlined;
- The model assumes a constant head level in the flare / mud pits during operation;
- No further water infiltrates into the unsaturated zone due to rainfall or overland flow following cessation of operations;
- The modelling does not consider the impact and/or fate of the leakage water if it reaches the saturated zone (water table);
- The modelling does not consider risks and impacts associated with overtopping in the mud/flare pits; and
- Solute transport modelling has not been considered.

### D.1.4 Model confidence level classification

Based on the objectives and limitations of the modelling study, the model presented herein is deemed to be Class 1 using the classifications presented by Barnett et al (2012). A Class 1 model is suitable for understanding groundwater flow processes under various hypothetical conditions; and developing coarse relationships between groundwater extraction locations and rates and associated impacts. A Class 1 confidence level is considered appropriate.

## D.2 Methodology

A seepage modelling analysis was performed to evaluate the leakage through the floor of the mud/flare pits and interaction (if any) with the groundwater. This analysis was based on likely unsaturated zone material parameters based on available lithological information and basin geometry and schedule provided by Origin.

The model development and seepage analysis was conducted using FEFLOW. FEFLOW is a commercially available computer modelling software package that is designed to analyse steady-state and transient flow under saturated and partially saturated conditions.

The analysis involved developing a single axisymmetric 2D transient numerical model based on the conceptualisation of the site. The model will be used to examine the leakage from several scenarios looking at different combinations of soil permeability and retention properties consistent with the available information.

The outcomes of the modelling will be to make quantitative predictions about seepage fluxes, compare the alternative construction techniques and identify the main governing parameters (such as presence of a liner or unsaturated zone permeability).

## D.3 Site characteristics

### D.3.1 Basin locations

The locations of the drilling mud / flare pits are adjacent to the exploration well sites. The proposed locations are listed in Table C—1 and presented above in Figure 1.

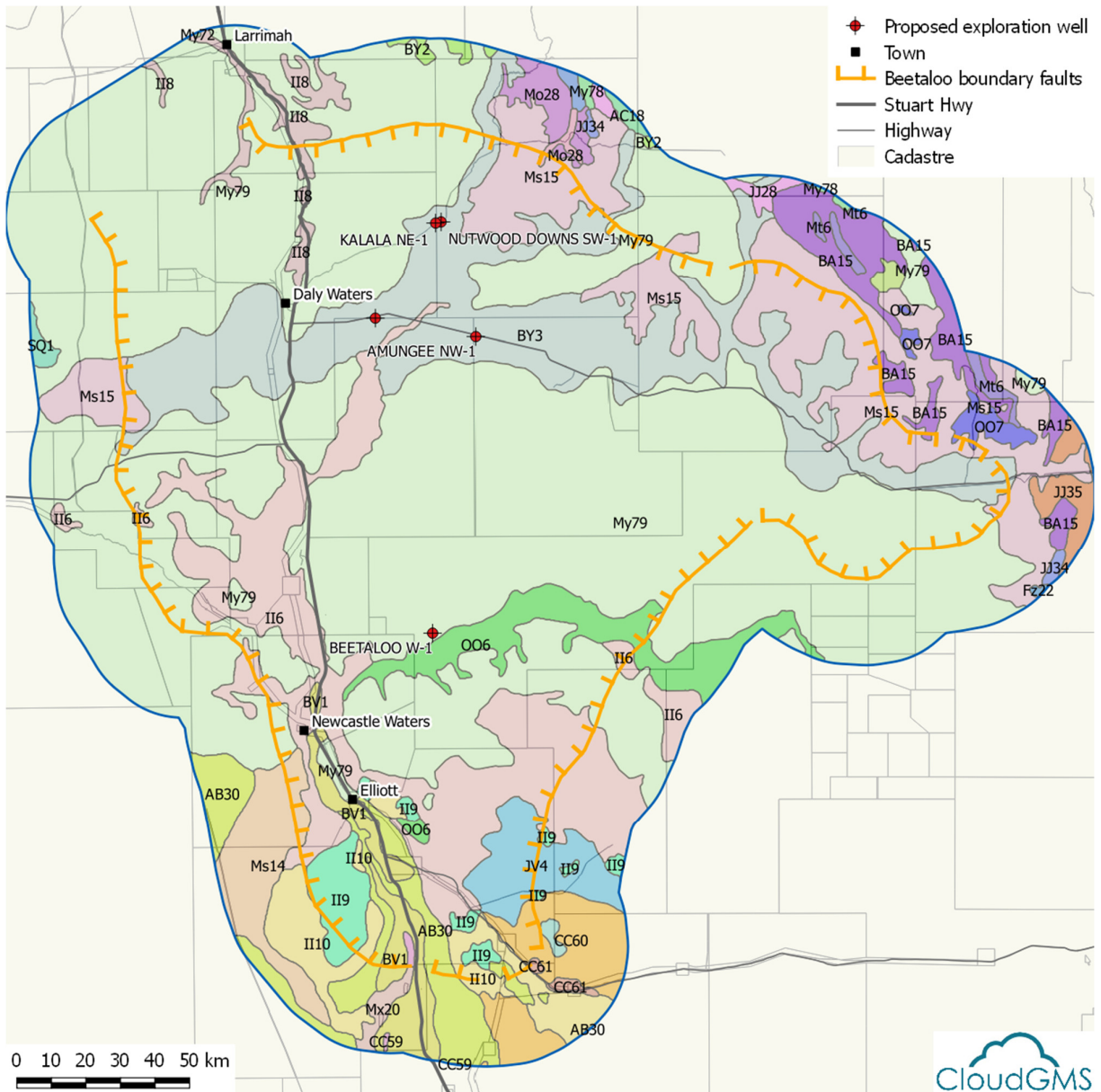
### D.3.2 Basin geometry

The geometry of the modelled pits is based on the supplied dimensions of the mud pit and flare pit which are approximately 50 x 50 metres 25 x 25 metres respectively (R. Morris pers comm., May 4, 2015). This is a combined area of 3125 m<sup>2</sup> and is equivalent to a circular area with a radius of 32 metres. The pit is assumed to be 2.5 m deep.

### D.3.3 Description of natural soils

Local soil textures have been derived from the 1991 Digital Atlas of Australian Soils after Northcote et al (1960-1968). The distribution of soil types in the study area is presented below in Figure 8.

The unsaturated properties considered for the leakage assessment, were initially based on the dominant Principal Profile Form (PPF) interpretations after McKenzie et al (2000). PPFs for each mapped soil type and the 50% percentile (median) properties of the dominant PPF. However, the saturated hydraulic conductivity designated by McKenzie et al., (2000) do not appear to be related to the texture of the soil and are expected to be overestimates. The estimates of unsaturated hydraulic parameters for the soils in this study have, therefore, been assigned based on the texture designated by McKenzie et al., (2000) and using the pedotransfer functions between soil texture and soil water characteristics in Table D—8 developed by Carsel and Parrish, (1988). These pedotransfer functions were also utilised to assign unsaturated hydraulic parameters to the unsaturated profile between the upper soil horizons and the watertable based on the lithologies specified in the available bore logs.



Map Unit	Area	PPF1	PPF2	PPF3	PPF4	PPF5
BY3	6150	K-Uc1.4	K-Uc4.1	KS-Uc1.4	KS-Uc4.1	
My79	31000	Gn2.12	Gn2.21	Gn2.22	Gn2.24	Gn2.61

**Table D—2 Two-layer soil model parameters (after McKenzie et al, 2000).**

Soil Type	PPF	A <sub>text</sub>	A <sub>thick</sub>	B <sub>text</sub>	B <sub>thick</sub>	AK <sub>sat</sub> m/d	BK <sub>sat</sub> m/d
My79	Gn2.12	Loam	0.20	Clay Loam	0.70	7.59	0.76
	Gn2.21	Loam	0.20	Clay Loam	0.70	2.40	0.76
	Gn2.22	Sandy Loams	0.20	Loam	0.60	2.40	0.76
	Gn2.24	Loam	0.30	Clay Loam	0.80	2.40	2.40
	Gn2.61	Loam	0.20	Light Clay	0.80	2.40	0.76
BY3	K-Uc1.4	Sands	0.40		0.00	7.59	
	K-Uc4.1	Sands	0.40	Sands	0.50	2.40	2.40
	KS-Uc1.4	Sandy Loams	0.40		0.00	7.59	
	KS-Uc4.1	Sands	0.40	Sands	0.50	2.40	2.40

PPF = Principal Profile Form identified in Table D—1.

### D.3.4 Description of underlying geology

The underlying geology and average groundwater level depth have been determined from mandatory drilling completion reports, referred to as the statement of bore (SOB). The lithological logs suggest that the northern sites have an unsaturated zone profile that is quite different to the southern site. The differences in the strata and the depth to water table between the two areas are discussed in the following sections. As a result of the distinct site conditions separate base models were developed for the northern sites and southern site.

#### D.3.4.1 2015 Northern sties

The Amungee NW-1 and Kalala S-1 exploration wells are located along the Carpentaria Highway. The SOBs for the three closest bores reveals a relatively consistent lithological profile and depth to groundwater (see Table D—3).

The bore logs for RN005761 and RN005764 show lateritised clay to approximately 23 metres and 6 metres respectively and unweathered clay to approximately 70 metres and 55 metres respectively. The clayey strata are interpreted to be the upper layers of the undifferentiated Cretaceous sequence and overlie a basal sandstone; the overlying lateritic clays are interpreted to be weathered undifferentiated Cretaceous or Quaternary aged sediments.

The depth to the watertable ranges between 76 and 110 mBGL across the three sites, the variation in watertable depth is controlled by differences in topography across the area.

**Table D—3 Lithological summary and depth to watertable for bores adjacent to the 2015 northern well sites.**

Bore ID	Thickness of Cretaceous	SWL (mBGL)	Date
RN005761	Lateritised clay to 23 m; Clay to 70 m; dolomite to 96.6 m (TD)	87	12/04/1967
RN005764	Lateritised clay to 6 m; Clay to 55 m; sandstone to 70 m; dolomite to 84.4 m (TD)	76	26/05/1967
RN005844	Clay to 73 m; sandstone to 124 m (TD)	109	16/09/1967

TD = total depth

The layering for the leakage model representing the northern sites is based on the available lithological information summarised in Table D—3.

The layers intervals as referenced from the top of the model domain are:

- Loam sand 0-6 m
- Clay / claystone 6-70 m
- Sandstone / limestone 70-100 m

The watertable represented by a saturation of 1 and pressure of 0 kPa was assigned at a depth of 80 m below the top of the model.

#### D.3.4.2 2016 Northern sites

The Nutwood Downs SW-1 and Kalala NE-1 exploration wells are located to the north of the Carpentaria Highway and relatively close to a recent NTG Water Resources investigation bores (RN38812). The SOB for the three closest bores reveals a relatively consistent lithological profile and depth to groundwater (see Table D—4).

The bore logs for show lateritised clay to approximately 6 m and unweathered clay to approximately 45 – 65 m. The clayey strata are interpreted to be the upper layers of the undifferentiated Cretaceous sequence and overlie a basal sandstone; the overlying lateritic clays are interpreted to be weathered undifferentiated Cretaceous or Quaternary aged sediments.

The depth to the watertable ranges between 81 and 91 mBGL across the three sites, the variation in watertable depth is controlled by differences in topography across the area.



**Table D—4 Lithological summary and depth to watertable for bores adjacent to the 2016 northern well sites.**

Bore ID	Thickness of Cretaceous	SWL (mBGL)	Date
RN031635	Sandy clays to 3 m; Clay to 45 m; no returns to 110 (TD)	81	07/12/2008
RN038812	Lateritised clay to 6 m; Clay to 65 m; no sample to 88 m; limestone to 149 m; basalt to 159 m (TD)	81	16/11/2014
RN038813	Lateritised clay to 3 m; Clay to 66 m; sandstone / sand to 90 m; limestone to 108 m; claystone to 111 m; basalt to 128 m (TD)	91	22/11/2014

TD = total depth

The simplified layering for the leakage model representing the 2016 northern sites is based on the available lithological information summarised in Table D—4.

The layers for the 2016 sites are summarised as:

- Loam sand 0-6 m
- Clay / claystone 6-65 m
- Clay and limestone 65-90 m
- Limestone 90-100 m

The layering for these sites (particularly the Cretaceous clay layer thickness) is consistent with the layering for the utilised in the 2015 northern sites model and therefore the 2015 model has been employed to assess the likelihood of leakage migration through the unsaturated zone at the 2016 sites.

#### D.3.4.3 Southern site

Three bores in the vicinity of Beetaloo W-1 provide lithological and depth to the watertable controls for the southern well site.

The bore log for RN004882 shows sand and or clay to approximately 6 metres and clay or claystone to approximately 15 – 35 metres and sandy clay to approximately 90 metres. The clayey strata encountered are interpreted to be the upper layers of the undifferentiated Cretaceous sequence

with a basal sandstone unit. The laterite is interpreted to be weathered Cretaceous or Quaternary alluvium.

The watertable depth ranges from around 64 mBGL (RN004882) to 70 mBGL (RN023794). The variation in watertable depth is considered to relate to changes in topography between the bore sites rather than a temporal water level trend.

**Table D—5 Lithological summary and depth to watertable for bores adjacent to the southern well site.**

Bore ID	Thickness of Cretaceous	SWL (mBGL)	Date
RN004882	Sand to 6 m; Claystone to 35 m; sandstone with bands of clay to 87 m;	64	03/05/1965
RN023794	Sand to 7.5 m; Clay to 25 m; Clay and sandstone to 88 m; sandstone to 103 m; limestone to 110 m (TD)	71	22/05/1985

TD = total depth

The layering for the leakage model representing the southern site is based on the available lithological information summarised in Table D—5 with particular reference to the closest bore RN023794.

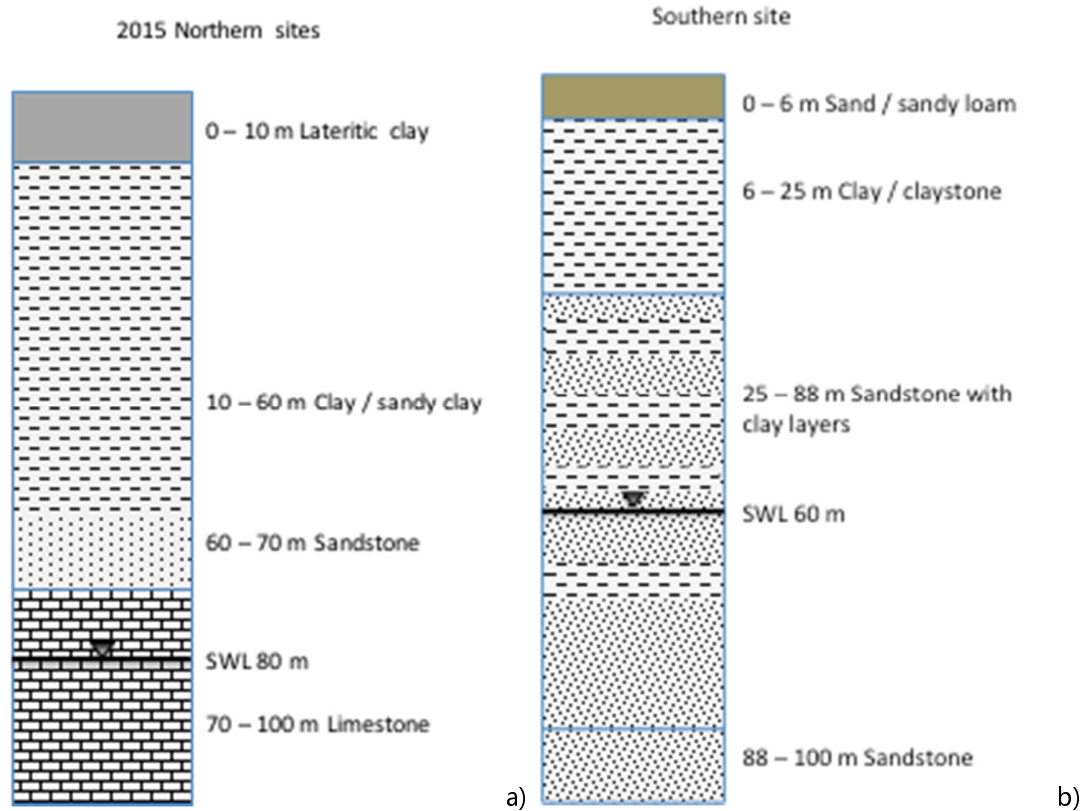
- Sand 0-6 m
- Clay / claystone 6-25 m
- Sandstone / clay bands 25-88 m
- Sandstone 88 – 100 m

The water table represented by a saturation of 1 and pressure of 0 kPa was assigned at a depth of 60 m below the top of the model.

### D.3.5 Profile conceptualisations

Based on the lithological descriptions provided above, a conceptualisation of the unsaturated zone profiles for three base case sites have been determined. The generalised profiles are presented below in Figure 9.

Unsaturated parameters for limestone, which was encounter in the northern bores, are not available and will be modelled using the parameters derived for sand.



**Figure 9 Conceptualisation of the unsaturated profiles for the three base case models based on available lithological data a) 2015 northern sites and 2016 northern sites and b) 2015 southern site.**

### D.3.6 Unsaturated zone hydraulic parameters

Unsaturated flow parameters are difficult to obtain from sub-surface samples, therefore, the soil texture has been used as a proxy to determine unsaturated flow parameters. Several catalogues of soil texture to water retention parameters are available in the literature (Rawls et al., 1982; Carsel and Parrish, 1988; Schaap, 2000; Schaap et al., 2001). The unsaturated model HYDRUS 1D utilises the soil texture classes and the corresponding average van Genuchten parameters determined by Carsel and Parrish, (1988). The averaged parameters (refer Table D—8) are employed in this study as estimates for the soils / lithologies identified in the bore logs.

Twelve soil texture classifications are defined by the USDA. Soil textures are classified by the fractions of each soil separate (i.e. sand, silt, and clay) present in a soil. Classifications are typically named for the primary constituent particle size or a combination of the most abundant particles sizes, e.g. "sandy clay" or "silty clay." A fourth term, loam, is used to describe a roughly equal concentration of sand, silt, and clay, and lends to the naming of even more classifications, e.g. "clay loam" or "silt loam".

## D.4 Numerical model description

### D.4.1 Problem summary

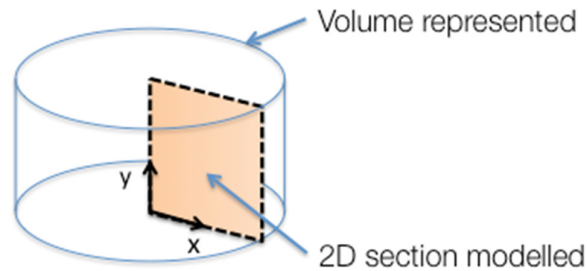
The leakage assessment has been conducted using the finite element method, with the model(s) being constructed and analysed using the FEFLOW code. The problem class, settings and mesh details for the base model are presented below in Table D—6.

**Table D—6 FEFLOW problem summary details**

Problem class	
Property	Setting
Description	Separate flow process
Type	Unsaturated
Projection	Vertical axisymmetric
Time Class	Transient flow
Time Stepping	Forward Euler/Backward Euler (FE/BE) predictor-corrector
Upwinding	No upwinding
Mesh	
Domain dimensions	100 x 100 m
Number of dimensions	2
Element type	Triangle
Mesh elements	35881
Mesh nodes	18260

### D.4.2 Vertical 2D axisymmetric model domain

Vertical 2D axisymmetric (or radially symmetric) models (refer Figure 10), where the axis of rotation corresponds to the y-axis (i.e. the x-coordinate is zero) offer an efficient alternative to full 3D models with considerable computational gains. This is provided the assumption of axial symmetry can be justified. In this case the system is assumed to be centered in the middle of a retention pond and parameters are radially homogeneous.



**Figure 10 Conceptualisation of the axisymmetric model domain.**

### D.4.3 FEFLOW settings

The various settings for unsaturated flow modelling used in this study are presented in Table D—7.

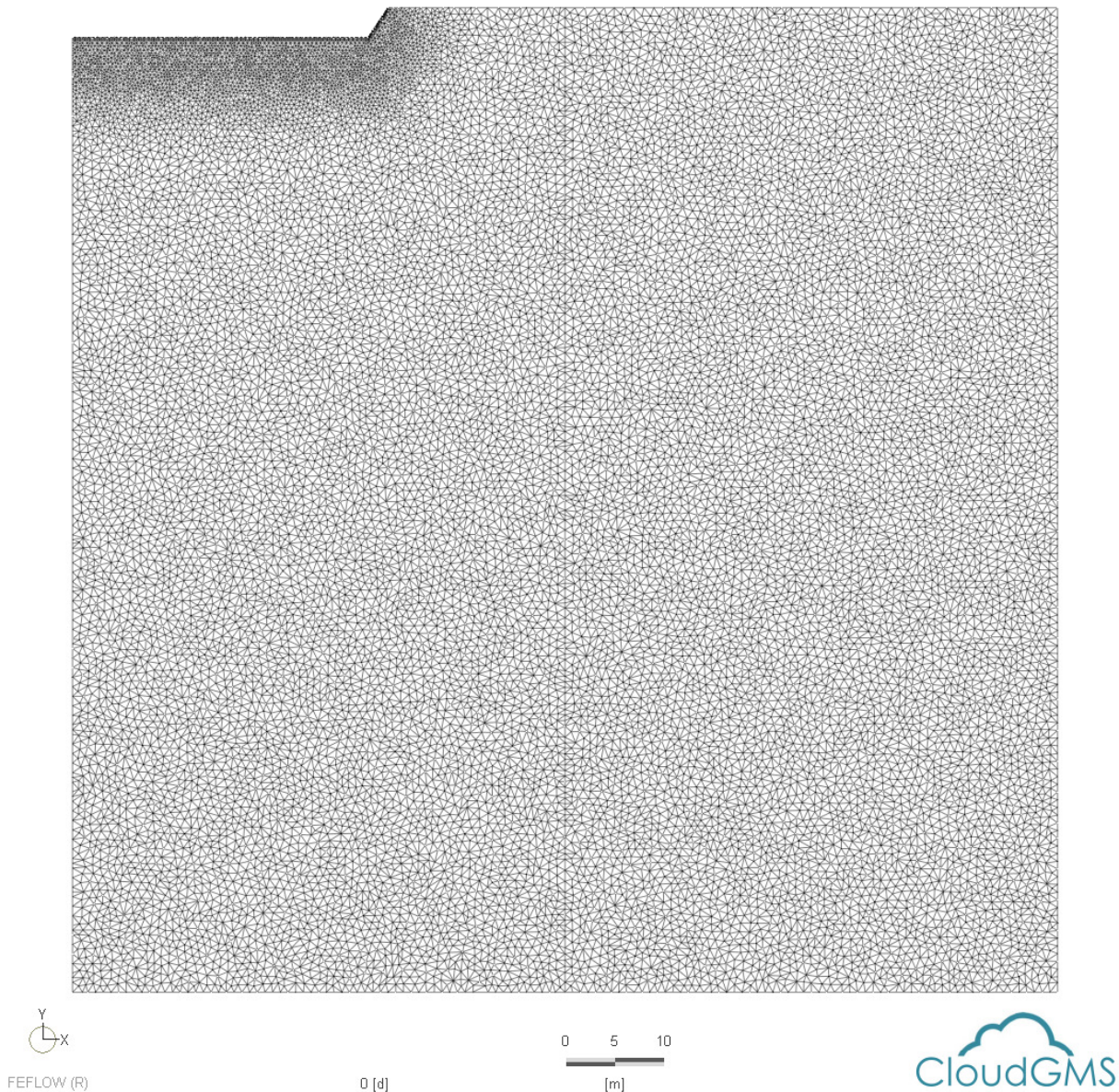
**Table D—7 Unsaturated flow solution settings**

Property	Setting	Comment
Richards' equation formulation	Head based (standard form)	This is the default solution and is based on hydraulic head and represents the standard form and is applicable for larger and moderate capillary pressure heads (e.g., Psi > -10 m or -1000 kPa).
Error checking	Predicted pressure-head and saturation values	Error checks for pressure head and saturation values can be performed in addition to checking hydraulic-head values. The computed error is used to determine the time-step length in simulations with an automatic time-stepping scheme.
Spatial integration of hydraulic conductivity	Upstream weighting correction	By default, the average of the relative conductivity at the centroids of elements is used (central-weighting method). Alternatively, an upstream-weighting can be applied where the relative conductivity in an element is then moved upstream. In case of spurious local minima and maxima at coarse mesh sizes upstream-weighting may smoothen the results.
Numeric solver	SAMG multigrid solver	SAMG internally switching between multigrid and CG method depending on the matrix properties it can also be a very good option for many transient models with more homogeneous element sizes.
Error tolerance	Euclidian L2 integral (RMS) norm (default)	The Error tolerance (unit: $10^{-3}$ ) is defined as the averaged absolute error (change in the primary variable) divided by the maximum value occurring in initial or boundary conditions.
Error criterion	$10^{-3}$ (default)	The dimensionless error criterion is used for the automatic time-stepping process.

## D.4.4 Model development

### D.4.4.1 Model domain

The model domain used to investigate the leakage from the mud and flare pits at the exploration well sites consists of a 100 x 100 m domain with a 2.5 m deep basin centred on  $x = 0$  m and extending to  $x = 32$  m (physically representing a circular pond of radius 32 metres). The 2D section showing the finite element mesh is presented below in Figure 11.



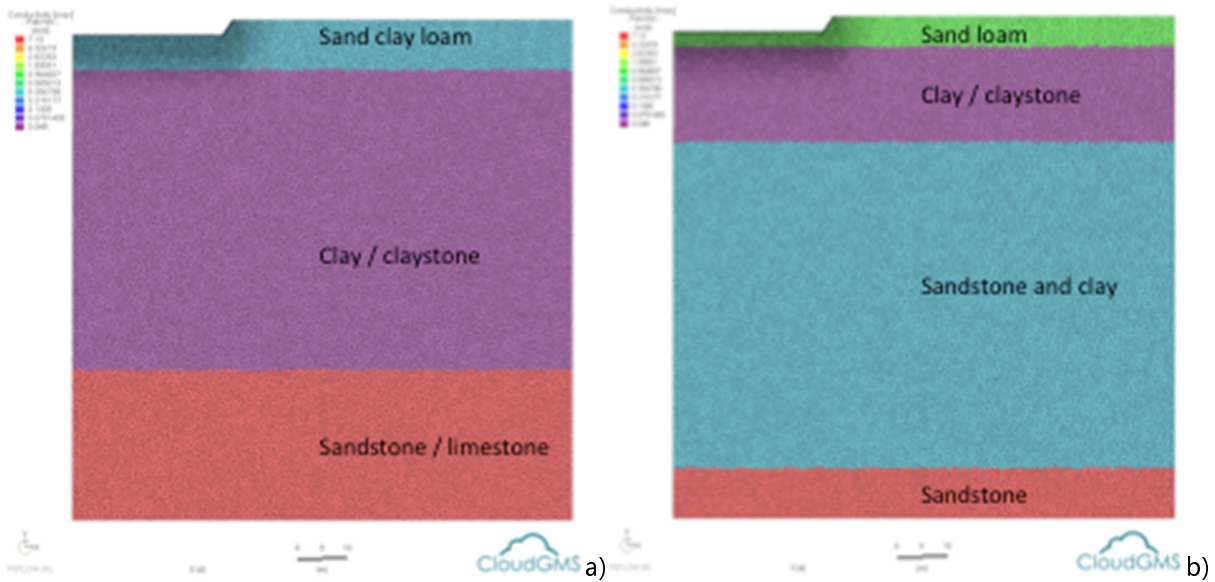
**Figure 11 Leakage assessment model domain and finite element mesh.**

### D.4.4.2 Model layering

The layering of material properties within the model was based on the lithological information presented in sections D.3.4 and the profile conceptualisations presented in section D.3.5. The



layering within the model and the differences between the two sites is demonstrated using the hydraulic conductivity distributions, which are presented below in Figure 12.



**Figure 12 Saturated hydraulic conductivity (Ksat) distribution showing the layering for the a) 2015 northern unsaturated profile and 2016 northern unsaturated profile and b) southern unsaturated profile.**

#### D.4.4.3 Material parameters

The same parameters have been used for the lithologies identified in the conceptualised unsaturated profiles, that is sand, loam sand, sandy clay loam and clay. The unsaturated zone parameters for each of the soil classes are presented in Table D—8.

**Table D—8 van Genuchten unsaturated soil parameters converted to FEFLOW units (after Carsel and Parish, 1988). Highlighted records are used in the current modelling study.**

Soil texture	Porosity	Sr	Ss	A	n	Ksat
Units	(m <sup>3</sup> /m <sup>3</sup> )	(-)	(-)	(1/m)	(-)	(m/d)
Silty Clay	0.36	0.194	1	0.500	1.090	0.005
Silty Clay Loam	0.43	0.207	1	1.000	1.230	0.017
Sandy Clay	0.38	0.263	1	2.700	1.230	0.029
Clay	0.38	0.179	1	0.800	1.090	0.048
Silt	0.46	0.074	1	1.600	1.370	0.060
Clay Loam	0.41	0.195	1	1.900	1.310	0.062
Silt Loam	0.45	0.149	1	2.000	1.410	0.108
Loam	0.43	0.181	1	3.600	1.560	0.250
Sandy Clay Loam	0.39	0.256	1	5.900	1.480	0.314
Sandy Loam	0.41	0.159	1	7.500	1.890	1.061
Loamy Sand	0.41	0.139	1	12.400	2.280	3.502
Sand	0.43	0.105	1	14.500	2.680	7.128

Sr = residual saturation

Ss = maximum saturation

A = van Genuchten fitting coefficient

n = van Genuchten fitting parameter

#### D.4.4.4 Anisotropy

It is expected that the hydraulic parameters associated with the claystone and sandstone strata will exhibit some degree of anisotropy, resulting in differing vertical and horizontal hydraulic conductivity values. A typical ratio of anisotropy between horizontal hydraulic conductivity and vertical hydraulic conductivity is 10:1. In the absence of any other information this anisotropy ratio (10:1) will be employed for this study.

#### D.4.5 Boundary conditions

No boundary conditions have been assigned to the nodes along the bottom of the model domain, along the left edge at  $x = 0$ , along the right edge at  $x = 100$  and along the top of the model domain outside of the retention basin. This results in no-flow across these boundaries.

The nodes located within the basin are designated a constant head equivalent to 2 metres above the floor of the basin (i.e. hydraulic head = 99 m).



#### D.4.6 Initial conditions

The moisture content distribution within the unsaturated profile was determined by assigning a constant pressure of -100 kPa (approximately -10 m head) to the profile above the water table. This is not an unreasonable assumption given that other studies in semi-arid areas show matric potentials considerably lower than this (Allison et al., 1990; Cossens et al., 2007). This resulted in initial moisture content of 0.08 in the sandy loam strata in the top 6-10 m and initial moisture content of 0.32 in the clayey strata above the water table.

The clay and sandstone layers in the southern unsaturated profile have been assigned the parameters for sandy clay loam and the initial moisture content of this layer is 0.08. The different initial water contents for each layer is due to the different moisture retention characteristics of each of the soils used to represent the profile.

### D.5 Leakage assessment

The results of the leakage assessment are presented as cross-sectional views of pressure for the 2015 northern, 2016 northern sites and southern site presented below in Figure 13 through Figure 14 respectively. The depth that the wetting front reaches after 60 days (taken as the 0 kPa value) is 20 m below ground level for the northern sites and 16 m below ground level for the southern site.

The migration of the water infiltrated into the unsaturated zone becomes relatively static once the basin is emptied and no more fluid infiltrates into the ground. This is primarily due to the retention characteristics of the clay / claystone layer.

The results are consistent with the amount of recharge expected in areas where the upper sequence of the Cretaceous sediments is present.

The major constraining factor determining the depth of flow beneath each of the basins is the hydraulic conductivity and retention characteristics of the clay / claystone layer.

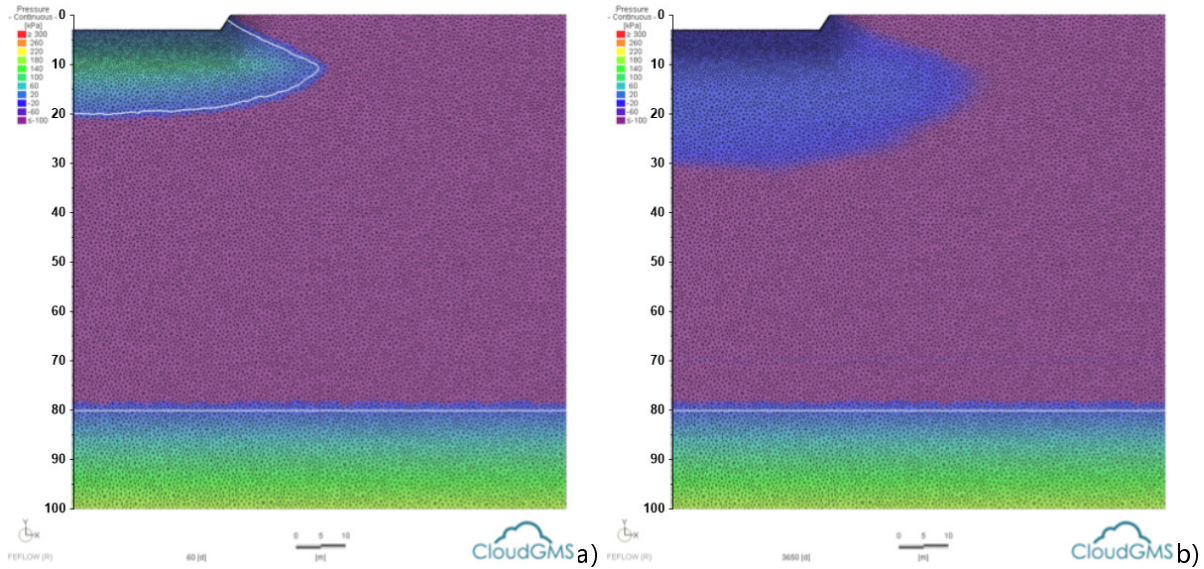


Figure 13 Unsaturated profile pressure distribution for the 2015 northern sites after a) 60 days and b) 3650 days or 10 years. The white line represents 0 kPa or fully saturated media.

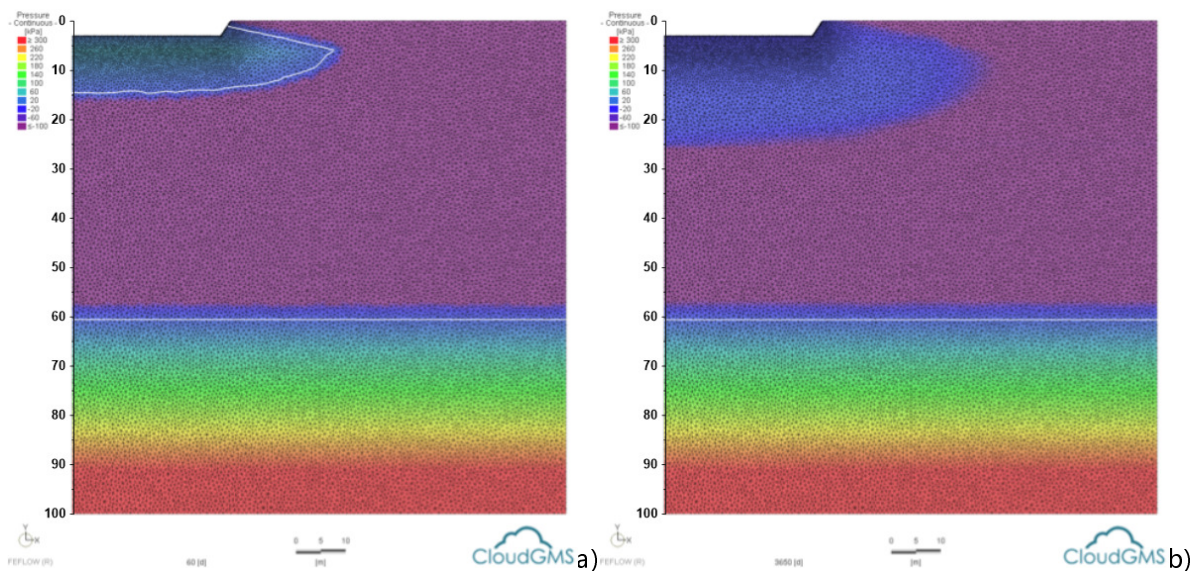
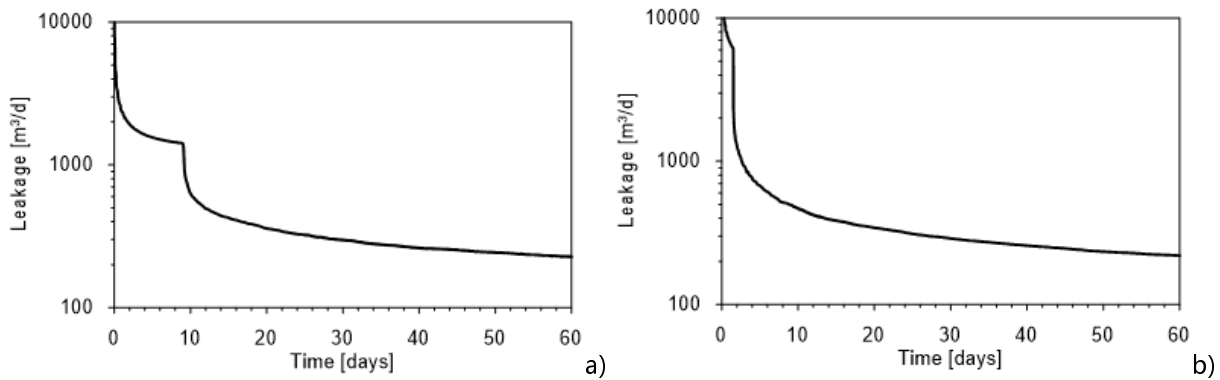


Figure 14 Unsaturated profile pressure distribution for the southern site after a) 60 days and b) 3650 days or 10 years. The white line represents 0 kPa or fully saturated media.

### D.5.1 Leakage rates

The expected leakage through the floor of each modelled retention basin has been determined and the time series rates are presented below in Figure 15.



**Figure 15 Expected leakage rates for the retention basins for the 2015 northern sites a), 2016 northern site and southern site c).**

It can be seen that for the first 10 days the leakage rates are quite different, however, after this point the rates are similar and coincide with the wetting front intercepting the clay layer which occurs at approximately 10 metres at the northern sites and 6 metres at the southern site. The final leakage rate at both sites is approximately 200 m<sup>3</sup>/d, which equates to 2.3 l/s.

The total volume required to meet the leakage through the basin floor was approximately 30-35 ML.

## D.5.2 Uncertainty analysis

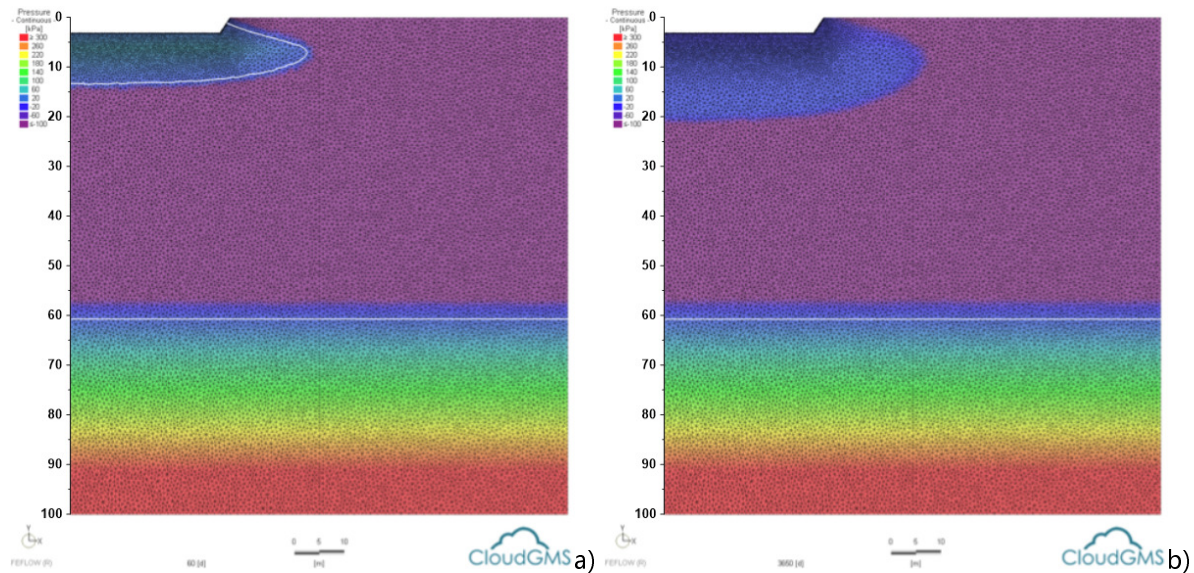
There is uncertainty regarding the exact hydraulic parameters to assign to the various lithologies expected at the sites. However, this does not mean that the range of values are completely unknown, based on the lithological description and the associated pedo-transfer functions there could be expected an order of magnitude change to the assigned parameters such as hydraulic conductivity, due to an incorrect assignment of texture to any particular lithology. For example if the clay / claystone is actually more of a sandy clay loam the hydraulic conductivity would increase from 0.048 m/d to 0.314 m/d.

The preceding scenarios indicate that the constraining factor on the leakage beneath the basins is the unsaturated hydraulic properties of the clay / claystone layer. To investigate the likely impact on the depth that the saturated wetting front that an incorrect lithology has been identified in the bore logs or that the parameters used were not appropriate, the unsaturated parameters used to describe the clay / claystone were adjusted to reflect a more sandy strata (sandy clay loam and sandy loam) using the southern site to compare the outcomes.

### D.5.2.1 Case 1 Sand clay loam

The unsaturated parameters for a sand clay loam soil were used to replace the parameters describing the clay / claystone layer resulting in a continuous profile to the water table. The lighter textured sand loam clay has a higher hydraulic conductivity, however, the available moisture content (assuming an initial pressure of -100 kPa) is 0.24 compared with 0.06 for the clay / claystone. Therefore the available storage volume is approximately four times that of the clay / claystone resulting in a reduced migration of fluid beneath the basin to 14 m below ground level despite the

increased leakage rate and total volume infiltrated of 50 ML. The results of this scenario are present below in Figure 16.

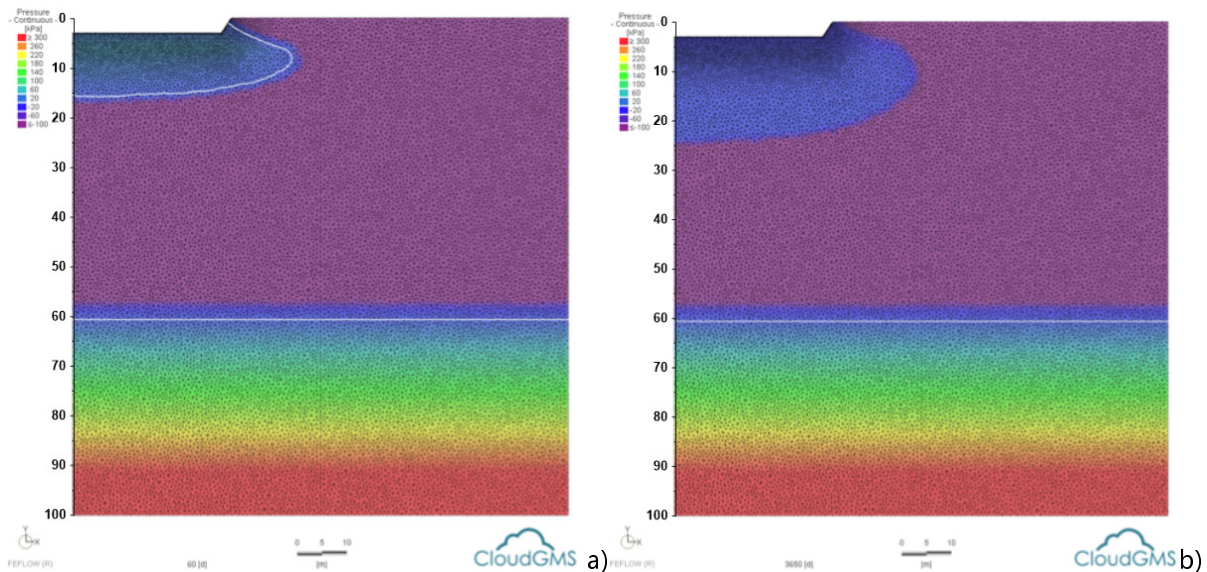


**Figure 16 Unsaturation profile pressure distribution for the southern site after a) 60 days of infiltration and b) 3650 days or 10 years.**

#### D.5.2.2 Case 2 Sandy loam

The lighter textured sandy loam has a higher hydraulic conductivity, however, the available moisture content (assuming an initial pressure of -100 kPa) is 0.33 compared with 0.24 for the sandy clay loam and 0.06 for the clay / claystone. Therefore the available storage volume is approximately five times that of the clay / claystone resulting in migration of the fluid to only 16 m below ground level, despite the increased leakage rate and total volume infiltrated of 86 ML. The results of this scenario are present below in Figure 17.





**Figure 17 Unsaturation profile pressure distribution for the southern site after a) 60 days of infiltration and b) 3650 days or 10 years.**

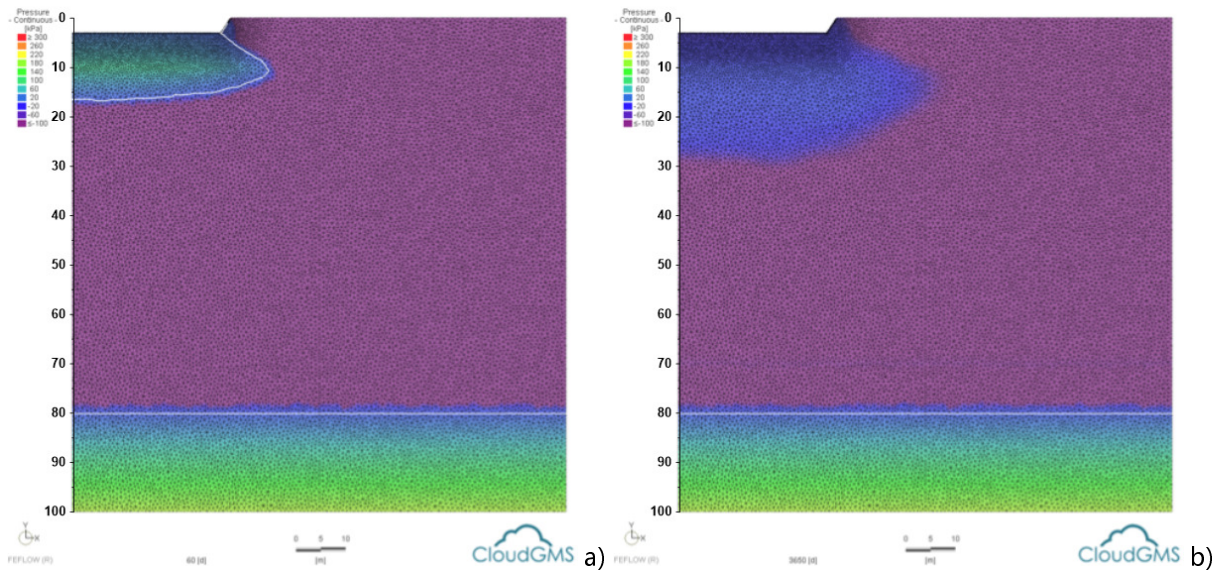
#### D.5.2.3 Filter cake

The modelling undertaken above has assumed that the basins are constructed without a liner and that the drilling fluids do not have any effect on the leakage through the basin floor as a result of a filter cake forming.

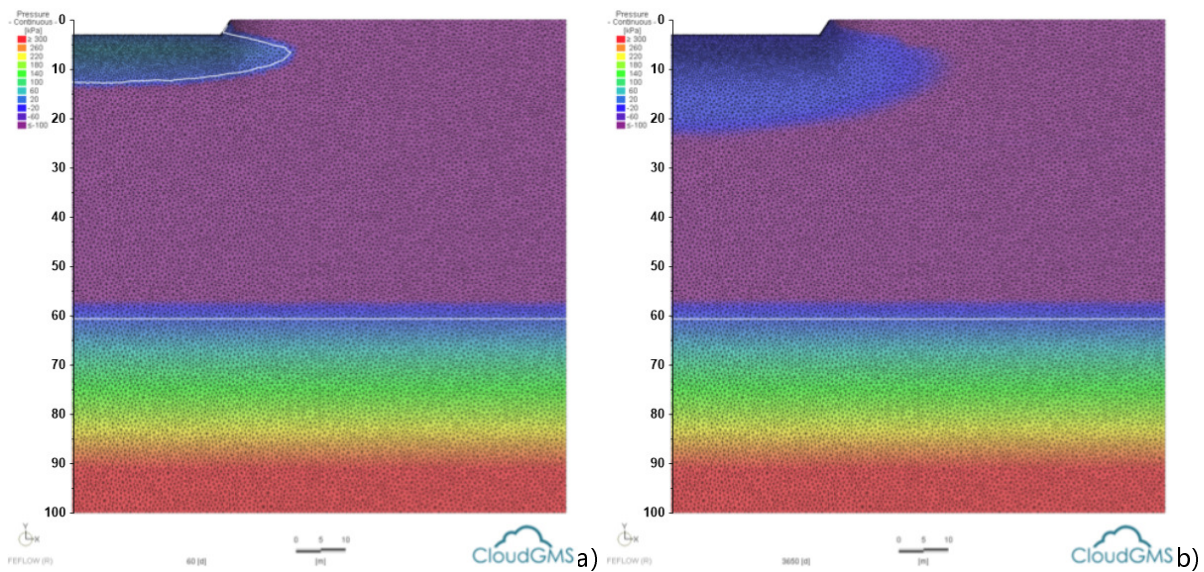
One of the main functions of drilling fluids during the drilling process is to isolate formations from drilling fluids, thus preventing fluid loss to the formation. Drilling fluid is designed to deposit a thin, low permeability filter cake to limit the invasion of drilling fluid (and suspended solids) into permeable formations and it can be expected that the same mechanism will prevent fluid loss due to leakage through the floor of the retention basin. To investigate the effects due to the formation of a filter cake a thin low hydraulic conductivity layer was applied to the floor of the basin for the southern site base case to simulate the effects of the filter-cake forming.

Testing on sand / bentonite slurries (Castelbaum and Shackelford, 2009) suggest that the expected reduction in hydraulic conductivity of sand due to a sand / bentonite filter cake, is typically four orders of magnitude and it is expected that similar reduction in hydraulic conductivity would result from the use of bio-polymers. To be conservative it was assumed that the reduction in the hydraulic conductivity due to the formation of a filter cake on the floor of the basin was approximately two orders of magnitude. The hydraulic conductivity of the soil for the southern sites is 1 m/d a reduction of two orders of magnitude results in a hydraulic conductivity of 0.01 m/d. The filter cake layer was 0.2 m thick.

The depth of migration of the wetting front after 60 days and 3650 days for the northern and southern sites are presented in Figure 18 and Figure 19 respectively.

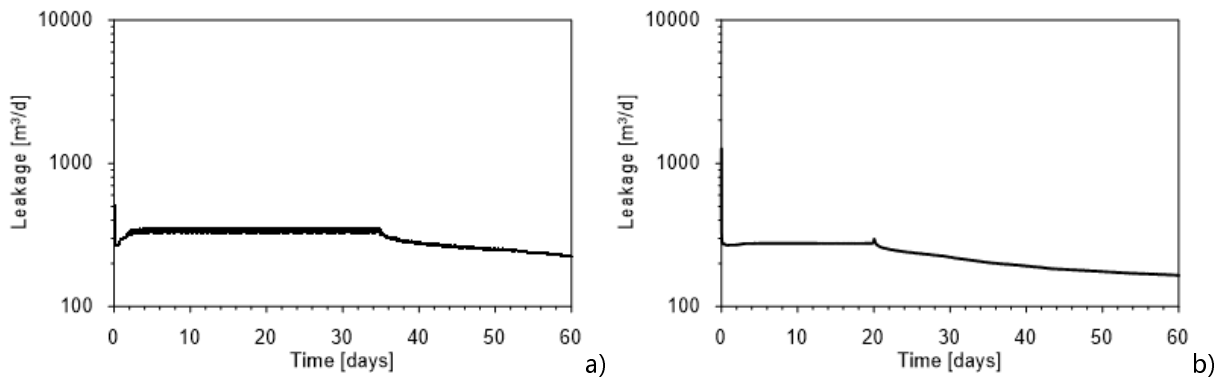


**Figure 18 Unsaturation profile pressure distribution for the 2015 and 2016 northern sites after a) 60 days of infiltration and b) 3650 days or 10 years.**



**Figure 19 Unsaturation profile pressure distribution for the southern site after a) 60 days of infiltration and b) 3650 days or 10 years.**

The final depth of the wetting front for the southern site is approximately 13 m below ground level and the total infiltrated volume is approximately 15 ML. The final depth of the wetting front for the both the northern sites is approximately 17 m below ground level and 19 ML. Although the depth of the wetting front is about 15-20% less than the case with no filter cake formation, the infiltrated volume is approximately 50% of the volume infiltrated with no filter cake formation.



**Figure 20 Expected leakage rate for the retention basin for a) the 2015 northern site, b) 2016 northern site and c) the southern site.**

### D.5.3 Discussion

#### D.5.3.1 Leakage assessment

The leakage assessment results are summarised below in Table D—9. Generally the depth of migration of the infiltrated water during the operational phase is less than 20 metres and less than 30 metres after 10 years after the end of operation, assuming no further water infiltrates into the unsaturated zone due to rainfall or overland flow events.

**Table D—9 Summary of leakage assessment results.**

Scenario	Infiltrated Vol.	Wetted depth 60d	Wetted depth 3650d
	ML	mBGL	mBGL
Base south	30-35	16	25
Base 2015 and 2016 north	30-35	20	30
Case 1	50	14	21
Case 2	86	16	25
Filter cake south	15	13	22
Filter cake 2015 and 2016 north	19	17	28

mBGL = metres below ground level

#### D.5.3.2 Likelihood of spillage migrating to groundwater

There is a risk that surface spillage of mud products/diesel/stimulation additives/flow back water during transport, storage or transfer onsite will lead to the contamination of groundwater resources.

This has the potential to impact groundwater users close to the spill site and environmental receptors.

The leakage assessment presented suggests that based on the volumes that can reasonably be expected from a spill/leakage event would be insufficient to mobilise fluid and any potential contaminant to the watertable under the expected site conditions. Based on the following assumptions:

- the maximum volume of any spill would be less than 0.001 - 0.002 times considered in the leakage assessment (based on 50000 litres maximum load of a B Double trailer); and
- the spill would be removed in less than the 60 days of the mud/flare pit operation timeframe considered in the leakage assessment.

## D.6 Conclusions

The following conclusions have been determined from the leakage assessment modelling:

- The major constraining factor determining the depth of flow beneath each of the basins is the hydraulic conductivity and retention characteristics of the clay / claystone layer which comprises the majority of the unsaturated zone above the watertable.
- Despite the relative uncertainty of the properties of the unsaturated profile beneath the basins, it is felt that the possible range of depths that the infiltrating water will migrate is relatively well constrained.
- The inclusion of a filter cake (or a clay liner) would result in a reduction in the depth of migration of the wetting front beneath the pits and a considerable reduction in the leakage rate through the floor of the pit. A reduction in the hydraulic conductivity of two orders of magnitude resulted in a reduction in the leakage by a similar magnitude.
- Although reduction in leakage through the pit floor, by utilising a liner (or drilling muds), will reduce the migration of fluid beneath the pits by between 10-20%, it is expected that a major benefit will be a reduction in the operational volumes by between 40-50% from the base case.
- Based on the scenarios considered the likelihood of surface spillage migrating to the watertable is low when taking into consideration the water table depth (>60 m), spill volumes, timeframe for spill containment / remediation and existing controls.



## Appendix C – Protected Matters Searches



# EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information is available about [Environment Assessments](#) and the EPBC Act including significance guidelines, forms and application process details.

Report created: 19/08/14 13:54:50

[Summary](#)

[Details](#)

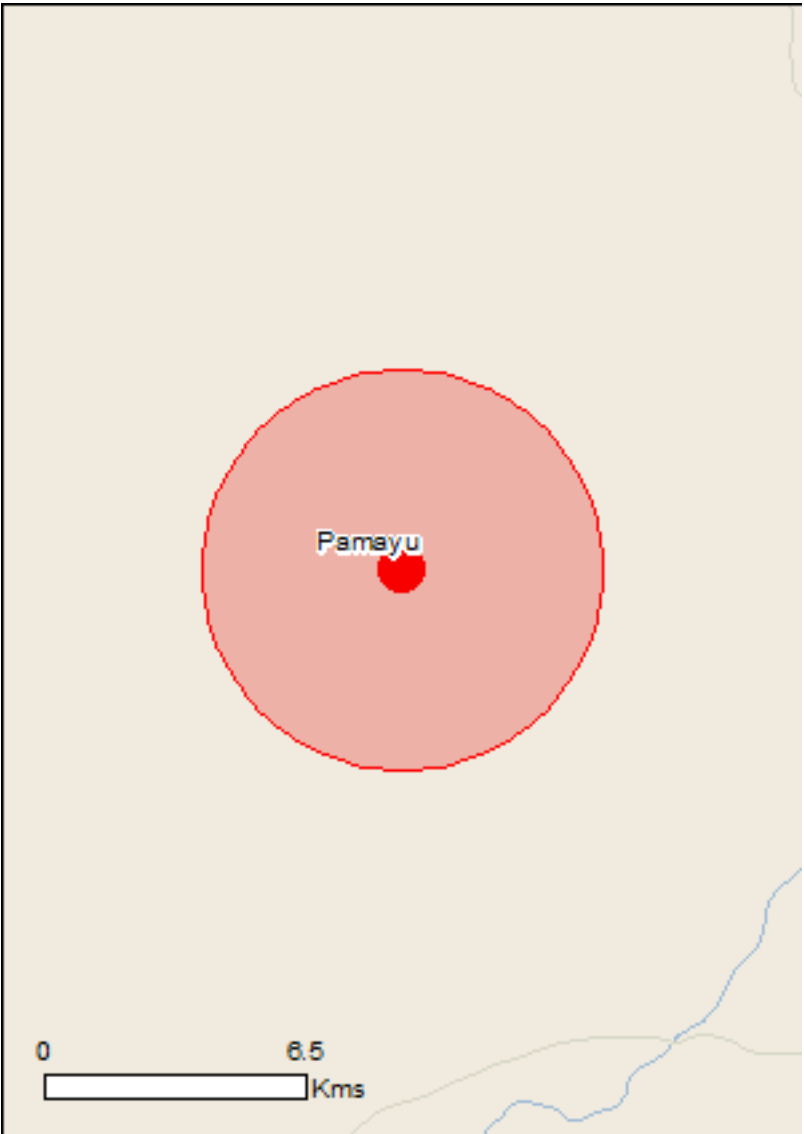
[Matters of NES](#)

[Other Matters Protected by the EPBC Act](#)

[Extra Information](#)

[Caveat](#)

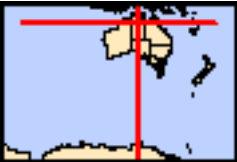
[Acknowledgements](#)



This map may contain data which are  
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[Coordinates](#)

Buffer: 5.0Km



# Summary

## Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the [Administrative Guidelines on Significance](#).

<a href="#">World Heritage Properties:</a>	None
<a href="#">National Heritage Places:</a>	None
<a href="#">Wetlands of International Importance:</a>	None
<a href="#">Great Barrier Reef Marine Park:</a>	None
<a href="#">Commonwealth Marine Areas:</a>	None
<a href="#">Listed Threatened Ecological Communities:</a>	None
<a href="#">Listed Threatened Species:</a>	5
<a href="#">Listed Migratory Species:</a>	8

## Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As [heritage values](#) of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place and the heritage values of a place on the Register of the National Estate.

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

A [permit](#) may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

<a href="#">Commonwealth Land:</a>	None
<a href="#">Commonwealth Heritage Places:</a>	None
<a href="#">Listed Marine Species:</a>	9
<a href="#">Whales and Other Cetaceans:</a>	None
<a href="#">Critical Habitats:</a>	None
<a href="#">Commonwealth Reserves Terrestrial:</a>	None
<a href="#">Commonwealth Reserves Marine</a>	None

## Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

<a href="#">Place on the RNE:</a>	None
<a href="#">State and Territory Reserves:</a>	None
<a href="#">Regional Forest Agreements:</a>	None
<a href="#">Invasive Species:</a>	7
<a href="#">Nationally Important Wetlands:</a>	None
<a href="#">Key Ecological Features (Marine)</a>	None

## Details

### Matters of National Environmental Significance

Listed Threatened Species		[ Resource Information ]
Name	Status	Type of Presence
Birds		
<a href="#">Erythrotriorchis radiatus</a> Red Goshawk [942]	Vulnerable	Species or species habitat may occur within area
<a href="#">Erythrura gouldiae</a> Gouldian Finch [413]	Endangered	Species or species habitat may occur within area
<a href="#">Rostratula australis</a> Australian Painted Snipe [77037]	Endangered	Species or species habitat may occur within area
<a href="#">Tyto novaehollandiae kimberli</a> Masked Owl (northern) [26048]	Vulnerable	Species or species habitat may occur within area
Mammals		
<a href="#">Macrotis lagotis</a> Greater Bilby [282]	Vulnerable	Species or species habitat likely to occur within area
Listed Migratory Species		[ Resource Information ]
* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.		
Name	Threatened	Type of Presence
Migratory Marine Birds		
<a href="#">Apus pacificus</a> Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Migratory Terrestrial Species		
<a href="#">Haliaeetus leucogaster</a> White-bellied Sea-Eagle [943]		Species or species habitat may occur within area
<a href="#">Merops ornatus</a> Rainbow Bee-eater [670]		Species or species

Name	Threatened	Type of Presence
		habitat may occur within area
Migratory Wetlands Species		
<a href="#">Ardea alba</a> Great Egret, White Egret [59541]		Species or species habitat likely to occur within area
<a href="#">Ardea ibis</a> Cattle Egret [59542]		Species or species habitat may occur within area
<a href="#">Charadrius veredus</a> Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area
<a href="#">Glareola maldivarum</a> Oriental Pratincole [840]		Species or species habitat may occur within area
<a href="#">Rostratula benghalensis (sensu lato)</a> Painted Snipe [889]		Species or species habitat may occur within area

Other Matters Protected by the EPBC Act

Listed Marine Species		[ <a href="#">Resource Information</a> ]
* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.		
Name	Threatened	Type of Presence
Birds		
<a href="#">Anseranas semipalmata</a> Magpie Goose [978]		Species or species habitat may occur within area
<a href="#">Apus pacificus</a> Fork-tailed Swift [678]		Species or species habitat likely to occur within area
<a href="#">Ardea alba</a> Great Egret, White Egret [59541]		Species or species habitat likely to occur within area
<a href="#">Ardea ibis</a> Cattle Egret [59542]		Species or species habitat may occur within area
<a href="#">Charadrius veredus</a> Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area
<a href="#">Glareola maldivarum</a> Oriental Pratincole [840]		Species or species habitat may occur within area
<a href="#">Haliaeetus leucogaster</a> White-bellied Sea-Eagle [943]		Species or species habitat may occur within area
<a href="#">Merops ornatus</a> Rainbow Bee-eater [670]		Species or species habitat may occur within area
<a href="#">Rostratula benghalensis (sensu lato)</a> Painted Snipe [889]	Endangered*	Species or species habitat may occur within area

Extra Information

Invasive Species

[ Resource Information ]

Weeds reported here are the 20 species of national significance (WoNS), along with other introduced plants that are considered by the States and Territories to pose a particularly significant threat to biodiversity. The following feral animals are reported: Goat, Red Fox, Cat, Rabbit, Pig, Water Buffalo and Cane Toad. Maps from Landscape Health Project, National Land and Water Resouces Audit, 2001.

Name	Status	Type of Presence
Mammals		
<a href="#">Bos taurus</a> Domestic Cattle [16]		Species or species habitat likely to occur within area
<a href="#">Camelus dromedarius</a> Dromedary, Camel [7]		Species or species habitat likely to occur within area
<a href="#">Canis lupus familiaris</a> Domestic Dog [82654]		Species or species habitat likely to occur within area
<a href="#">Felis catus</a> Cat, House Cat, Domestic Cat [19]		Species or species habitat likely to occur within area
<a href="#">Sus scrofa</a> Pig [6]		Species or species habitat likely to occur within area
Plants		
<a href="#">Cenchrus ciliaris</a> Buffel-grass, Black Buffel-grass [20213]		Species or species habitat likely to occur within area
<a href="#">Parkinsonia aculeata</a> Parkinsonia, Jerusalem Thorn, Jelly Bean Tree, Horse Bean [12301]		Species or species habitat likely to occur within area

# Coordinates

-17.01035 133.85943

## Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World Heritage and Register of National Estate properties, Wetlands of International Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

For species where the distributions are well known, maps are digitised from sources such as recovery plans and detailed habitat studies. Where appropriate, core breeding, foraging and roosting areas are indicated under 'type of presence'. For species whose distributions are less well known, point locations are collated from government wildlife authorities, museums, and non-government organisations; bioclimatic distribution models are generated and these validated by experts. In some cases, the distribution maps are based solely on expert knowledge.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.



# Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

- [Department of Environment, Climate Change and Water, New South Wales](#)
- [Department of Sustainability and Environment, Victoria](#)
- [Department of Primary Industries, Parks, Water and Environment, Tasmania](#)
- [Department of Environment and Natural Resources, South Australia](#)
- [Parks and Wildlife Service NT, NT Dept of Natural Resources, Environment and the Arts](#)
- [Environmental and Resource Management, Queensland](#)
- [Department of Environment and Conservation, Western Australia](#)
- [Department of the Environment, Climate Change, Energy and Water](#)
- [Birds Australia](#)
- [Australian Bird and Bat Banding Scheme](#)
- [Australian National Wildlife Collection](#)
- Natural history museums of Australia
- [Museum Victoria](#)
- [Australian Museum](#)
- [SA Museum](#)
- [Queensland Museum](#)
- [Online Zoological Collections of Australian Museums](#)
- [Queensland Herbarium](#)
- [National Herbarium of NSW](#)
- [Royal Botanic Gardens and National Herbarium of Victoria](#)
- [Tasmanian Herbarium](#)
- [State Herbarium of South Australia](#)
- [Northern Territory Herbarium](#)
- [Western Australian Herbarium](#)
- [Australian National Herbarium, Atherton and Canberra](#)
- [University of New England](#)
- [Ocean Biogeographic Information System](#)
- [Australian Government, Department of Defence](#)
- [State Forests of NSW](#)
- [Geoscience Australia](#)
- [CSIRO](#)
- Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the [Contact Us](#) page.





# EPBC Act Protected Matters Report

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Information is available about [Environment Assessments](#) and the EPBC Act including significance guidelines, forms and application process details.

Report created: 22/02/16 11:55:42

[Summary](#)

[Details](#)

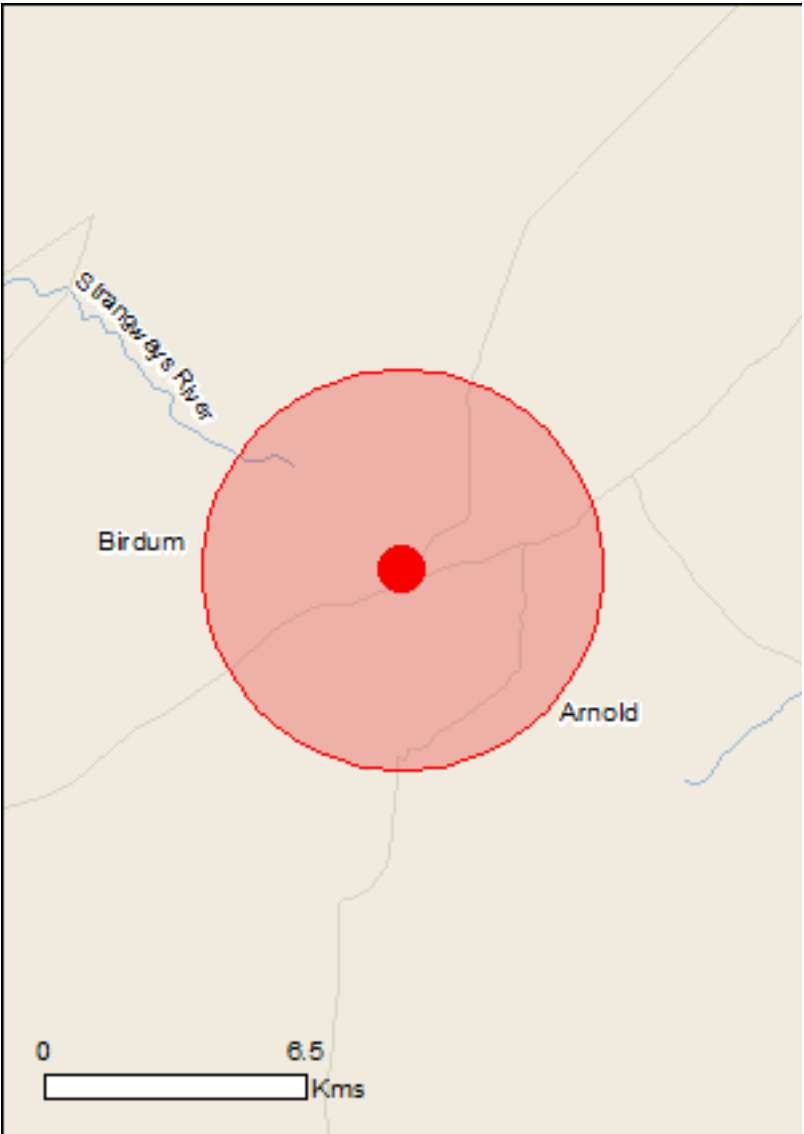
[Matters of NES](#)

[Other Matters Protected by the EPBC Act](#)

[Extra Information](#)

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[Buffer: 5.0Km](#)



# Summary

## Matters of National Environmental Significance

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<a href="#">World Heritage Properties:</a>	None
<a href="#">National Heritage Places:</a>	None
<a href="#">Wetlands of International Importance:</a>	None
<a href="#">Great Barrier Reef Marine Park:</a>	None
<a href="#">Commonwealth Marine Area:</a>	None
<a href="#">Listed Threatened Ecological Communities:</a>	None
<a href="#">Listed Threatened Species:</a>	9
<a href="#">Listed Migratory Species:</a>	11

## Other Matters Protected by the EPBC Act

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A [permit](#) may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

<a href="#">Commonwealth Land:</a>	None
<a href="#">Commonwealth Heritage Places:</a>	None
<a href="#">Listed Marine Species:</a>	15
<a href="#">Whales and Other Cetaceans:</a>	None
<a href="#">Critical Habitats:</a>	None
<a href="#">Commonwealth Reserves Terrestrial:</a>	None
<a href="#">Commonwealth Reserves Marine:</a>	None

## Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

<a href="#">State and Territory Reserves:</a>	None
<a href="#">Regional Forest Agreements:</a>	None
<a href="#">Invasive Species:</a>	8
<a href="#">Nationally Important Wetlands:</a>	None
<a href="#">Key Ecological Features (Marine)</a>	None

# Details

## Matters of National Environmental Significance

Listed Threatened Species		[ Resource Information ]
Name	Status	Type of Presence
Birds		
<a href="#">Erythroriorchis radiatus</a> Red Goshawk [942]	Vulnerable	Species or species habitat may occur within area
<a href="#">Erythrura gouldiae</a> Gouldian Finch [413]	Endangered	Species or species habitat likely to occur within area
<a href="#">Falcunculus frontatus whitei</a> Crested Shrike-tit (northern), Northern Shrike-tit [26013]	Vulnerable	Species or species habitat likely to occur within area
<a href="#">Rostratula australis</a> Australian Painted Snipe [77037]	Endangered	Species or species habitat may occur within area
<a href="#">Tyto novaehollandiae kimberli</a> Masked Owl (northern) [26048]	Vulnerable	Species or species habitat may occur within area
Mammals		
<a href="#">Dasyurus hallucatus</a> Northern Quoll [331]	Endangered	Species or species habitat may occur within area
<a href="#">Macrotis lagotis</a> Greater Bilby [282]	Vulnerable	Species or species habitat may occur within area
<a href="#">Saccolaimus saccolaimus nudicluniatus</a> Bare-rumped Sheathtail Bat (Qld) [66889]	Critically Endangered	Species or species habitat may occur within area
Reptiles		
<a href="#">Elseya lavarackorum</a> Gulf Snapping Turtle [67197]	Endangered	Species or species habitat may occur within area
Listed Migratory Species		[ Resource Information ]
* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.		
Name	Threatened	Type of Presence
Migratory Marine Birds		
<a href="#">Apus pacificus</a> Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Migratory Terrestrial Species		

Name	Threatened	Type of Presence
<a href="#">Cecropis daurica</a> Red-rumped Swallow [80610]		Species or species habitat may occur within area
<a href="#">Cuculus optatus</a> Oriental Cuckoo, Horsfield's Cuckoo [86651]		Species or species habitat may occur within area
<a href="#">Hirundo rustica</a> Barn Swallow [662]		Species or species habitat may occur within area
<a href="#">Merops ornatus</a> Rainbow Bee-eater [670]		Species or species habitat may occur within area
<a href="#">Motacilla cinerea</a> Grey Wagtail [642]		Species or species habitat may occur within area
<a href="#">Motacilla flava</a> Yellow Wagtail [644]		Species or species habitat may occur within area

Migratory Wetlands Species		
<a href="#">Ardea alba</a> Great Egret, White Egret [59541]		Species or species habitat likely to occur within area
<a href="#">Ardea ibis</a> Cattle Egret [59542]		Species or species habitat may occur within area
<a href="#">Charadrius veredus</a> Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area
<a href="#">Glareola maldivarum</a> Oriental Pratincole [840]		Species or species habitat may occur within area

Other Matters Protected by the EPBC Act

Listed Marine Species	[ <u>Resource Information</u> ]	
* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.		
Name	Threatened	Type of Presence
Birds		
<a href="#">Anseranas semipalmata</a> Magpie Goose [978]		Species or species habitat may occur within area
<a href="#">Apus pacificus</a> Fork-tailed Swift [678]		Species or species habitat likely to occur within area
<a href="#">Ardea alba</a> Great Egret, White Egret [59541]		Species or species habitat likely to occur within area
<a href="#">Ardea ibis</a> Cattle Egret [59542]		Species or species habitat may occur within area
<a href="#">Charadrius veredus</a> Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
<a href="#">Cuculus saturatus</a> Oriental Cuckoo, Himalayan Cuckoo [710]		Species or species habitat may occur within area
<a href="#">Glareola maldivarum</a> Oriental Pratincole [840]		Species or species habitat may occur within area
<a href="#">Haliaeetus leucogaster</a> White-bellied Sea-Eagle [943]		Species or species habitat may occur within area
<a href="#">Hirundo daurica</a> Red-rumped Swallow [59480]		Species or species habitat may occur within area
<a href="#">Hirundo rustica</a> Barn Swallow [662]		Species or species habitat may occur within area
<a href="#">Merops ornatus</a> Rainbow Bee-eater [670]		Species or species habitat may occur within area
<a href="#">Motacilla cinerea</a> Grey Wagtail [642]		Species or species habitat may occur within area
<a href="#">Motacilla flava</a> Yellow Wagtail [644]		Species or species habitat may occur within area
<a href="#">Rostratula benghalensis (sensu lato)</a> Painted Snipe [889]	Endangered*	Species or species habitat may occur within area

Reptiles	
<a href="#">Crocodylus johnstoni</a>	
Freshwater Crocodile, Johnston's Crocodile, Johnston's River Crocodile [1773]	Species or species habitat may occur within area

## Extra Information

Invasive Species	[ Resource Information ]
Weeds reported here are the 20 species of national significance (WoNS), along with other introduced plants that are considered by the States and Territories to pose a particularly significant threat to biodiversity. The following feral animals are reported: Goat, Red Fox, Cat, Rabbit, Pig, Water Buffalo and Cane Toad. Maps from Landscape Health Project, National Land and Water Resouces Audit, 2001.	

Name	Status	Type of Presence
Frogs		
Rhinella marina Cane Toad [83218]		Species or species habitat likely to occur within area
Mammals		
Bos taurus Domestic Cattle [16]		Species or species

Name	Status	Type of Presence
		habitat likely to occur within area
Bubalus bubalis Water Buffalo, Swamp Buffalo [1]		Species or species habitat likely to occur within area
Canis lupus familiaris Domestic Dog [82654]		Species or species habitat likely to occur within area
Felis catus Cat, House Cat, Domestic Cat [19]		Species or species habitat likely to occur within area
Rattus rattus Black Rat, Ship Rat [84]		Species or species habitat likely to occur within area
Sus scrofa Pig [6]		Species or species habitat likely to occur within area
Plants		
Cenchrus ciliaris Buffel-grass, Black Buffel-grass [20213]		Species or species habitat likely to occur within area

## Appendix D – Heritage Reports



13 November 2014

Dylan Stringer  
Senior Drilling Engineer  
Origin Energy Resources Limited  
339 Coronation Drive  
Milton QLD 4064

Dear Dylan

## **Aboriginal & Historic Heritage Assessment**

### **1.0 Introduction**

AECOM Australia Pty Ltd (AECOM) was commissioned by Origin Energy Resources Limited (Origin) on behalf of the Beetaloo Joint Venture (Beetaloo JV) to conduct a heritage assessment of four proposed exploratory drill locations (Kalala S-1, Amungee NW-1, Beetaloo W-1 and Beetaloo C-1) within the Beetaloo Basin covering exploration permit areas EP98 and EP117 west of Daly Waters, Northern Territory.

The assessment involved a desktop review of existing heritage data from the Australian Heritage database, the NT Heritage Branch and the Aboriginal Areas Protection Authority as well as archaeological survey reports, consultation with traditional owners of the study area and a field inspection for the area of proposed works (study area).

### **2.0 Proposed Activities**

The proposed exploration activities for the 2015 drilling program consist of:

- upgrade and/or widening of an existing access track in EP117 on the Beetaloo pastoral lease for moving equipment (e.g. drilling rigs, trucks, etc.) and people
- development of the three nominated drill sites (Kalala S-1, Beetaloo W-1 and Amungee NW-1) including:
  - construction and maintenance of a well pad and associated pits, as required, to facilitate the drilling activity. A rig is yet to be contracted but the lease area is likely to be between 1 and 2 hectares
  - drilling of the vertical wells targeting the Velkerri Formation, with total depths of approximately 2,200 mTVD to 2,600 mTVD
  - construction and maintenance of water bores and bore water storage pits for drilling and civil activities.
  - Clearing areas for a drilling rig camp, onsite offices and lay down yard.
  - temporary on-site offices and living accommodation for 24 hour operations and activities (within the well pad)
- rehabilitation work as consistent with the requirements of DME.

A fourth drill site, Beetaloo C-1 was surveyed for this assessment but may not be included in the 2015 drilling program (Table 1).

**Table 1 Coordinates of Centroid of Proposed Drill Site Locations**

Exploration Permit	Drilling Program Year	Well Name	GDA94 Zone	Easting	Northing
EP98	2015	Kalala S-1	53	350931	8198360
EP98	2015	Amungee NW-1	53	391676	8190013
EP117	2015	Beetaloo W-1	53	368312	8106695
EP117	TBA	Beetaloo C-1	53	378594	8118946

### **3.0 Existing Data Sources**

Information on the location of heritage sites within the study area was obtained from:

- a review of Native Title claims and Indigenous Land Use Agreements over the proposed activity areas



- a review of existing Northern Territory Heritage Register managed by the NT Heritage Branch
- a review of the Sacred Sites Register maintained by the Aboriginal Areas Protection Authority
- a review of past archaeological survey reports and assessments undertaken within the local area.

### 3.1 Native Title

Three Native Title determinations and one Indigenous Land Use Agreement (ILUA) are current over the permit areas (see Table 2):

**Table 2 Native Title & ILUA Agreements Current for the Permit Areas**

Type	Name	Summary
Native Title	NTD21/2010 Shenandoah Pastoral Lease	Native Title exists in parts of the determination area and is held by the Kinbininggu and Bamarrnganja groups
	NTD27/2010 Beetaloo Pastoral Lease	Native Title exists in parts of the determination area and is held by the Karranjini group; the Bamarrnganja group; the Warranangku group; the Pinda (OT Downs) group; and the Lija/Muwartpi group
	NTD17/2010 Amungee Mungee Pastoral Lease	Native title exists in parts of the determination area and is held by The Karranjini group; the Bamarrnganja group
Indigenous Land Use Agreement	D12004/014 Jingaloo CLA ILUA	Registered for Community Living Area and Tenure resolution

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

### 3.2 Australian Heritage Database

A search of the Australia Heritage Database identified that no statutory listed heritage places within the proposed impact areas. Three sites listed on the now non-statutory Register of the National Estate are located within a 125 km x 125 km search area that encompasses the full Proposal area. None of these heritage places are located within 10 km of the proposed impacts.

### 3.3 NT Heritage Register

A search of the Northern Territory Heritage Register identified 41 Aboriginal archaeological sites and 7 historic heritage sites within a 125 km x 125 km area that encompasses the full Proposal area. None of the proposed exploratory drill locations will impact previously identified heritage sites, with the closest recorded archaeological site being located over 15 km away. However, two artefact scatters located adjacent to the Stuart Highway, Goochegoochena Creek Site 1 and Goochegoochena Creek Site 2, are recorded within 600 m and 350 m respectively of the proposed access track entrance to the Beetaloo C-1 and Beetaloo W-1 exploratory well sites. These sites will not be directly affected by the proposed works.

### 3.4 Aboriginal Areas Protection Authority

AAPA clearance surveys were conducted in September 2014 for the for the 2015 drill sites, however the AAPA clearance report are still to be finalised. The following Sacred Sites were previously identified during Falcon Oil and Gas clearances in 2012. The sacred sites were previously recorded on the Beetaloo access track:

- 5563-57 – Waterhole
- 5563-14 – Waterhole
- 5563-58 – Waterhole
- 5563-45 – Open country surrounded by dense vegetation on the road to Jingaloo
- 5563-44 – Jingaloo waterhole and community.

On receipt of the clearance survey from AAPA, this information will be updated.

### 3.5 Previous Archaeological Investigations

The majority of archaeological investigations near the study area have been predominately associated with either linear infrastructure in an alignment parallel to the Stuart Highway or natural gas exploration activities associated with the Beetaloo Basin. Of the assessments of relevance to the study area, the majority of sites identified are artefact scatters composed of raw material commonly found in the immediate area (quartz, silcrete and quartzite). One stone arrangement has also been recorded. No assessments have been conducted within the boundaries of the current proposed impact areas. Table 3 provides a summary of previous archaeological investigations undertaken in the local area.

**Table 3 Previous Archaeological Assessments in the Local Area**

Researchers	Assessment Type	Locality	Key Findings
Smith 1986	Excavation	Lake Woods	Insitu artefacts dated to 6000 years
Museum and Art Galleries of the Northern Territory 1986	Survey	Amadeus Basin to Katherine	Large scale survey for a proposed natural gas pipeline targeting areas of major cultural sensitivity from Daly Waters to Katherine. 32 sites were identified with the majority being artefact scatters associated with watercourses.
Quaternary Archaeological Surveys 1998	Survey	Stuart Highway to Mataranka Homestead	Large scale survey for a fibre optic cable corridor. Three isolated artefacts and one historic heritage site identified.
Heritage Surveys 1999	Survey	Daly Waters to McArthur River	Nine archaeological sites identified including rockshelters and artefact scatters
HLA Envirosciences 2006 – 2007	Survey	Beetaloo Basin	Several archaeological sites identified across the exploration permits including artefact scatters, isolated artefacts and stone cairns. Assessments developed a preliminary predictive model based on random site modelling and landform.
AECOM 2011-2012	Survey	Beetaloo Basin	Several archaeological sites identified as part of seismic line clearance including large artefact scatters (>1km), quarry sites and isolated artefacts. Predictive model refined and used in the field to identify 'hot spots' of Indigenous archaeological significance with success.

### 4.0 Heritage Assessment

A heritage assessment involving field survey was undertaken by AECOM archaeologist, Luke Kirkwood for the proposal area from 26 to 28 August 2014 assisted by representatives of the traditional owners (Pompey Raymond, Marcus Raymond, Lennie Raymond and Raymond Raymond) and the Northern Land Council (Kevin Talbott). The archaeological inspection involved a combination of both pedestrian and vehicular survey of all exploration drill pads and access tracks. During the inspection notes were taken on landform, ground surface visibility and areas of exposure. The aim of the inspection was to identify any surface expressions of Aboriginal archaeological and cultural heritage values within the proposal area. Photographic records were taken at each proposed drill location.

Results of the inspection are provided in **Table 4. Appendix A** provides details on ground surface visibility classes and subsurface archaeological potential assessment.

**Table 4 Exploration Well Inspection Results**

Well Name	MGA E	MGA N	Ground Surface Visibility (GSV) %	Ground Surface Integrity (GSI)	Surface Archaeology	Subsurface Archaeological Potential	Impact Potential
Kalala S-1	350931	8198360	Fair	High	No surface archaeology identified	Low	Low to No Impact
Amungee NW-1	391676	8190013	Good	High	No surface archaeology identified	Low	Low to No Impact
Beetaloo W-1	368312	8106695	Fair	High	No surface archaeology identified	Low	Low to No Impact
Beetaloo C-1	378594	8118946	Poor	Moderate	No surface archaeology identified	Low	Low to No Impact



**Figure 1 Kalala S-1 general context shot looking south**

**Figure 2 Kalala S-1 ground cover context shot showing surface visibility**



**Figure 3 Amungee NW-1 general context shot looking south**

**Figure 4 Amungee NW-1 ground cover context shot showing surface visibility**





**Figure 5** Beetaloo W-1 general context shot looking north

**Figure 6** Beetaloo W-1 ground cover context shot showing surface visibility



**Figure 7** Beetaloo C-1 general context shot looking south

**Figure 8** Beetaloo C-1 ground cover context shot showing extensive grass cover. Ground surface was partly modified through land clearance and cattle.

## 5.0 Identified Heritage

### 5.1 Traditional Knowledge

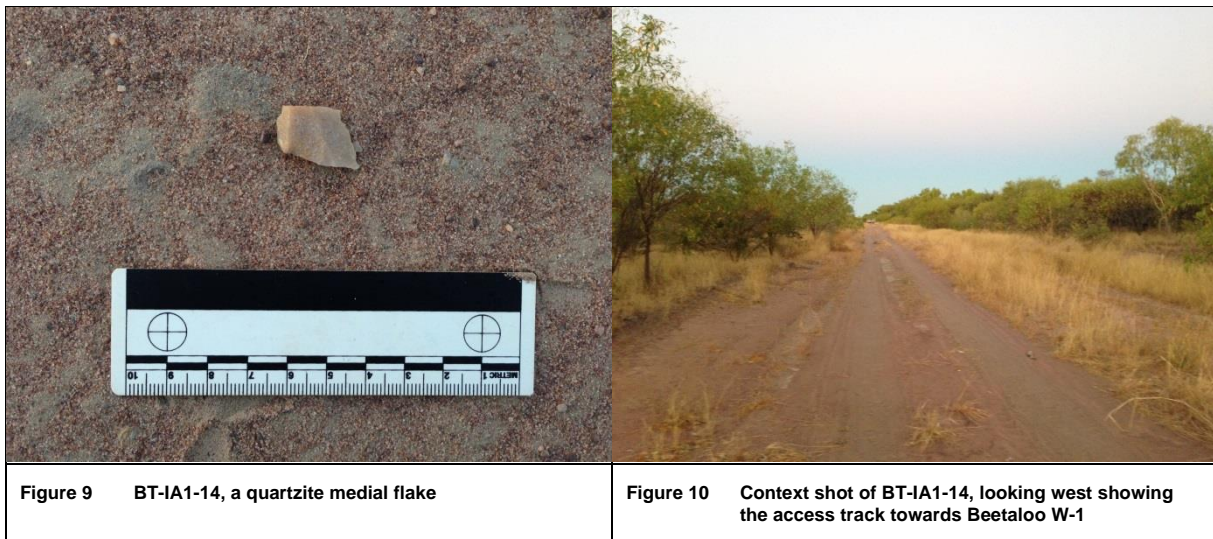
No culturally sensitive landforms were identified during the survey; however, representatives for the traditional owners identified a number of important traditional foods and medicine throughout the survey that are common in the area.

Scientific Name	Common Name	Usage
<i>Grewia retusifolia</i>	dogs balls	Fruit eaten Leaves can be boiled and body bathed in the liquid for sickness and sores
<i>Marsdenia australis</i>	bush banana	Young fruit eaten whole, when older only the inside eaten
<i>Pterocaulon sp.</i>		Small soft hairy and fragrant herb used for treating the flu
<i>Acacia sp.</i>	sticky acacia	Leaves boiled and used to treat the flu
<i>Acacia holosericea</i>	Soapbush	Leaves used for washing
	Termite mound	Pulverised and mixed with water, used to treat diarrhoea

## 5.2 Archaeological Heritage

One Aboriginal archaeological site (BT-IA1-14) was identified during the field survey on the previously disturbed Beetaloo access track 5.3 km to the west of exploration drill site Beetaloo W-1. BT-IA1-14 is an isolated quartzite medial flake. The isolated quartzite medial flake identified was not insitu and has likely been redeposited as the result of low level fluvial agency across this area. It was determined to be of low scientific value.

Discussions with the field representatives of the traditional owners agreed that the site was located in a previously disturbed area associated with a farming track and has likely washed in from somewhere else. It was identified that an appropriate management approach prior to works, would be to relocate this artefact and conduct a follow up clearance of 100 metres either side of this artefact to confirm no further heritage sites exist in this location. Following clearance, the artefact could be moved off the road to prevent further impact.



## 6.0 Key Findings and Recommendations

The key findings of this heritage assessment are:

- A review of existing heritage data and reports for the study area indicate that no previously recorded heritage sites will be impacted by the proposed works.
- No Aboriginal or historic heritage sites were located during field survey within the proposed drilling locations.
- Numerous traditional foods and medicines are located throughout the study area. However due to their distribution across the wider landscape and the nature of the proposed impacts to these traditional resources the risk will be minimal and managed under previous land clearance protocols.
- One isolated artefact, BT-IA1-14, was identified on the Beetaloo access track. This artefact is not insitu and has likely been moved by hydrological processes common across this area during the wet season. Management recommendations for the isolated artefact, BT-IA1-14, were developed in consultation with representatives of the traditional owners and the Northern Land Council.
- AAPA clearance surveys have been carried out for the drill sites, however the AAPA clearance report is still to be finalised. Based on previous studies carried out in the permit areas, the following Sacred Sites have been recorded on the Beetaloo access track:
  - 5563-57 – Waterhole
  - 5563-14 – Waterhole
  - 5563-58 – Waterhole
  - 5563-45 – Open country surrounded by dense vegetation on the road to Jingaloo
  - 5563-44 – Jingaloo waterhole and community.

On the basis of the above findings, the following recommendations are made:

- Prior to works and with the involvement of traditional owners:
  - BT-IA1-14 is to be relocated approximately 50 metres perpendicular off the access track from where it was originally located and a 100 metre buffer around the original location of the artefact is again to be cleared to confirm that no additional artefacts are present within the general area that have been exposed since the original survey.
  - A clearance form signed by traditional owner field representatives is to be provided to Origin for internal documentation stating that the clearance has been undertaken according to the above conditions.
  - An unexpected heritage finds stop works procedure is to be implemented for the duration of the project.
  - Induction of staff on site is to include reference to the wider area having Indigenous heritage values and the stop works procedure.

Yours faithfully

**Luke Kirkwood**

Principal Archaeologist

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## **7.0 References**

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

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

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

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.

HLA-Envirosciences Pty Limited (2006) *Beetaloo Basin: Cooe Hill and 80 Metre Tower Archaeological Assessment*, unpublished report for Sweetpea Petroleum.

HLA-Envirosciences Pty Limited (2006) *Beetaloo Basin: Newcastle Creek Archaeological Assessment*, unpublished report for Sweetpea Petroleum.

HLA-Envirosciences Pty Limited (2006) *Beetaloo Basin: Yaroo, South Martyr's Tree and Dunmarra Archaeological Assessment*, unpublished report for Sweetpea Petroleum.

HLA-Envirosciences Pty Limited (2007) *Beetaloo Basin: Newcastle Creek (Seismic Line 13A) Archaeological Assessment*, unpublished report for Sweetpea Petroleum.

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

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



## Appendix A - Legislation

### Commonwealth Legislation

#### Environment Protection and Biodiversity Conservation Act

The Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) took effect on the 16 July 2000 (NSW Department of Urban Affairs and Planning, 2000). Under section 26 of the EPBC Act it is stated that:

*A person must not take on Commonwealth land an action that has, will have or is likely to have a significant impact on the environment.*

Under section 28 of the EPBC Act it is stated that:

*The Commonwealth or a Commonwealth agency must not take inside or outside the Australian jurisdiction an action that has, will have or is likely to have a significant impact on the environment inside or outside the Australian jurisdiction.*

An action is defined as a project, development, undertaking, activity, series of activities, or alteration. An action will also require approval if:

*It is undertaken on Commonwealth land and will have or is likely to have a significant impact;*

*It is undertaken outside Commonwealth land and will have or is likely to have a significant impact on the environment on Commonwealth land; and*

*It is undertaken by the Commonwealth and will have or is likely to have a significant impact.*

The EPBC Act defines 'environment' as both natural and cultural environments and therefore includes Aboriginal and historic heritage items. Under the Act, protected heritage items are listed on the National Heritage List (items of significance to the nation) or the Commonwealth Heritage List (items belonging to the Commonwealth or its agencies). These two lists replaced the Register of the National Estate (RNE) which is no longer a statutory list.

It is a requirement of the Department of Defence that a HMP must meet the requirements of Schedule 7A of the EPBC Regulations 2003. As RAAF TDL and the archaeological sites it contains are not listed in the Commonwealth Heritage List (CHL) or on the National Heritage List (NHL) Schedule 7A is not a legislative requirement, however the principles it outlines have been utilised in this HMP while the HMP itself has been structured in accordance with the Defence Heritage Toolkit (Department of Defence, n.d.-a).

#### Aboriginal and Torres Strait Islander Heritage Protection Act 1984

The *Aboriginal and Torres Strait Islander Heritage Protection Act 1984* (the ATSIHP Act) provides for the preservation and protection of places, areas and objects of particular significance to Indigenous Australians. The stated purpose of the ATSIHP Act is the 'preservation and protection from injury or desecration of areas and objects in Australia and in Australian waters, being areas and objects that are of particular significance to Aboriginals in accordance with Aboriginal tradition' (section 4).

Under the Act, 'Aboriginal tradition' is defined as "the body of traditions, observances, customs and beliefs of Aboriginals generally or of a particular community or group of Aboriginals, and includes any such traditions, observances, customs or beliefs relating to particular persons, areas, objects or relationships" (Section 3). A 'significant Aboriginal area' is an area of land or water in Australia that is of 'particular significance to Aboriginals in accordance with Aboriginal tradition' (Section 3). A 'significant Aboriginal object', on the other hand, refers to an object (including Aboriginal remains) of like significance.

For the purposes of the Act, an area or object is considered to be injured or desecrated if:

- In the case of an area:
  - it is used or treated in a manner inconsistent with Aboriginal tradition;
  - the use or significance of the area in accordance with Aboriginal tradition is adversely affected;
  - passage through, or over, or entry upon, the area by any person occurs in a manner inconsistent with Aboriginal tradition;



- in the case of an object:
  - it is used or treated in a manner inconsistent with Aboriginal tradition.

The ATSIHP Act can override state and territory laws in situations where a state or territory has approved an activity, but the Commonwealth Minister prevents the activity from occurring by making a declaration to protect an area or object. However, the Minister can only make a decision after receiving a legally valid application under the ATSIHP Act and, in the case of long term protection, after considering a report on the matter. Before making a declaration to protect an area or object in a state or territory, the Commonwealth Minister must consult the appropriate Minister of that state or territory (section 13).

## Appendix B – Archaeological Assessment Criteria

**Table B1 Ground Surface Visibility (GSV) Rating Scheme**

GSV rating	Percentage GSV
No ground surface visible	0%
Very poor	1-10%
Poor	11-30%
Fair	31-50%
Good	51-70%
Very good	71-90%
Excellent	91-100%

**Table B2 Ground Surface Integrity (GSI) Rating Scheme**

GSI rating	Definition
Low	Ground surface has been subjected to significant disturbance (e.g. earthworks, excavation). Little to no integrity remains.
Moderate	Ground surface has been subject to moderate disturbance (e.g. native vegetation clearance) but retains a reasonable degree of integrity.
High	An unmodified or minimally modified ground surface.

**Table B3 Definitions for Subsurface Archaeological Potential**

Subsurface Archaeological Potential	Definition
Low	Areas in which subsurface archaeological materials are unlikely to occur. This may be due to unfavourable environmental conditions and/or prior disturbance(s).
Moderate	Areas in which subsurface archaeological materials may occur. Reasonable environmental conditions exist though high artefact counts/densities are unlikely. Subsurface evidence likely to be the product of random discard events as opposed to repeated or extensive activity by Aboriginal people in antiquity.
High	Areas known or highly likely to contain subsurface archaeological materials. Presence of archaeological materials typically reflects optimal environmental conditions and little to no prior landscape disturbance. High artefact counts/densities are likely.

**Table B4 Impact Potential Ranking for Aboriginal Objects**

Impact Potential	Definition	Management Action
No Impact	Aboriginal objects will not be affected by the proposed activity.	No action required
Low Impact	The proposed activity is unlikely to disturb, destroy, damage or deface an Aboriginal object or objects.	No action required
Moderate Impact	The proposed activity has <i>reasonable</i> potential to disturb, destroy, damage or deface an Aboriginal object or objects.	Avoid area if possible. If avoidance not an option, test excavate area to determine nature and extent of potential archaeological deposits

Impact Potential	Definition	Management Action
High Impact	The proposed activity will, or is highly likely to, disturb, destroy, damage or deface an Aboriginal object or objects.	Avoid area if possible. If avoidance not an option, test excavate area to determine nature and extent of potential archaeological deposits

## Appendix C – Listed Heritage Sites

**Table C1 NT Heritage Register – Aboriginal Heritage Sites**

Site Name	Easting	Northing	Site Type
Amungee Mungee 1	409212	8154884	Stone artefact scatter; grindstone portable
Amungee Mungee 2	411012	8167284	Stone artefact scatter
Amungee Mungee 3	411312	8165084	Stone artefact scatter
Amungee Mungee 4	411812	8160984	Stone artefact scatter
Amungee Mungee 5	411912	8159184	Stone artefact scatter
Amungee Mungee 6	409012	8154584	Stone artefact scatter
Amungee Mungee 7	397912	8144284	Stone artefact scatter
Amungee Mungee 8	401312	8147984	Stone artefact scatter
CHT 1	398967	8171452	Stone artefact scatter
Daly Waters Creek Site 1	327912	8178184	Stone artefact scatter
Dunmara Site 1 - flaked telegraph insulator	330912	8154584	Isolated nonstone artefact
Dunmarra 1	319785	8144995	Isolated stone artefact
Goochegoochena Creek Site 1	335612	8107484	Stone artefact scatter
Goochegoochena Creek Site 10	337412	8096184	Isolated stone artefact
Goochegoochena Creek Site 11	337412	8096084	Isolated stone artefact
Goochegoochena Creek Site 12	337412	8095884	Isolated stone artefact
Goochegoochena Creek Site 2	335812	8106684	Stone artefact scatter
Goochegoochena Creek Site 3	336412	8104084	Stone artefact scatter
Goochegoochena Creek Site 4	336512	8103384	Isolated stone artefact
Goochegoochena Creek Site 5	336612	8102384	Isolated stone artefact
Goochegoochena Creek Site 6	336612	8102384	Stone artefact scatter
Goochegoochena Creek Site 7	336712	8101484	Stone artefact scatter
Goochegoochena Creek Site 8	336712	8101184	Isolated stone artefact
Goochegoochena Creek Site 9	337012	8098984	Stone artefact scatter
Johnson Lagoon Site 1	332412	8137184	Isolated stone artefact
Johnson Lagoon Site 2	332412	8136384	Stone artefact scatter
Kalala Stat. 5	318912	8209584	Stone artefact scatter
Kalala Stat. 6	318912	8207984	Isolated stone artefact
Kalala Stat. 7	318112	8192684	Isolated stone artefact
Kalala Stat. 8	320812	8175184	Stone artefact scatter
Kalala Stat. 9	323912	8202984	isolated stone artefact
Newcastle Waters Creek Site 1	335712	8090484	Stone artefact scatter
Newcastle Waters Site 1	336012	8091684	Isolated stone artefact
Oodjuongari Waterhole	404212	8150784	Stone artefact scatter

Site Name	Easting	Northing	Site Type
Stuart Swamp [Daly Waters to McArthur R. Pipeline]	327912	8205484	Stone artefact scatter; historic object/place; grindstone portable
Yaroo 1	436844	8158463	Stone artefact scatter
Yaroo 2	436748	8158820	Stone artefact scatter
Yaroo 3	324035	8157085	isolated stone artefact
Yaroo 3a	324065	8156827	isolated stone artefact
Yaroo 3b	322622	8164699	isolated stone artefact
Yaroo 4	407464	8098625	Stone artefact scatter

**Table C2 NT Heritage Register – Historic Heritage Sites**

Place Name	Easting	Northing	Status
Flying Fox; Daly Waters	326330	8201570	Declared
Frew Ponds Overland Telegraph Poles (northern end)	330400	8130710	Declared
Frew Ponds Overland Telegraph Poles (southern end)	330340	8126260	Declared
Daly Waters Aviation Complex	326710	8201220	Declared
Daly Waters Aviation Complex	326560	8201281	Declared
Daly Waters Aviation Complex	326360	8201190	Declared
Daly Waters Aviation Complex	326510	8201350	Declared

## Appendix D – Lithic Data

Archaeological Site	Artefact Type	Raw Material	Length (mm)	Width (mm)	Breadth (mm)
BT-IA1-14	Medial Flake	Quartzite	15 mm	20 mm	5 mm

13 May 2016

Jason Ridley  
Senior Project Engineer  
Origin Energy Resources Limited  
339 Coronation Drive  
Milton QLD 4064

Dear Jason

**Nutwood Downs - Aboriginal & Historic Heritage Assessment****1.0 Introduction**

AECOM Australia Pty Ltd (AECOM) was commissioned by Origin Energy Resources Limited (Origin) on behalf of the Beetaloo Joint Venture (Beetaloo JV) to conduct a heritage assessment of two proposed exploratory drill locations (Nutwood Downs SW-1 and Kalala NE-1) within the Beetaloo Basin covering exploration permit area EP98 west of Daly Waters, Northern Territory.

The assessment involved a desktop review of existing heritage data from the Australian Heritage database, the NT Heritage Branch and the Aboriginal Areas Protection Authority as well as archaeological survey reports, consultation with traditional owners of the study area and a field inspection for the area of proposed works (study area).

**2.0 Proposed Activities**

The proposed exploration activities for the 2016 drilling program consist of:

- development of one of the two nominated drill sites (Nutwood Downs SW-1 and Kalala NE-1) including:
  - construction and maintenance of a well pad and associated pits, as required, to facilitate the drilling activity. A rig is yet to be contracted but the entire lease area is likely to be around 4 to 6 hectares
  - drilling of the vertical wells
  - construction and maintenance of water bores and bore water storage pits for drilling and civil activities.
  - clearing areas for a drilling rig camp, onsite offices and lay down yard.
  - temporary on-site offices and living accommodation for 24 hour operations and activities
- rehabilitation work as consistent with the requirements of DME.

Table 1 Coordinates of Centroid of Proposed Drill Site Locations

Exploration Permit	Drilling Program Year	Well Name	GDA94 Zone	Easting	Northing
EP98	2017	Nutwood Downs SW-1	53	370770	8226075
EP98	2017	Kalala NE-1	53	369184	8225743

**3.0 Existing Data Sources**

Information on the location of heritage sites within the study area was obtained from:

- a review of Native Title claims and Indigenous Land Use Agreements over the proposed activity areas
- a review of existing Northern Territory Heritage Register managed by the NT Heritage Branch
- a review of the Sacred Sites Register maintained by the Aboriginal Areas Protection Authority
- a review of past archaeological survey reports and assessments undertaken within the local area.

### 3.1 Native Title

Six Native Title determinations have been made over the permit area EP98 (see Table 2). No Indigenous Land Use Agreements (ILUA) are current over the permit area.

**Table 2 Native Title Determinations for the Permit Area**

Type	Name	Summary
Accepted	NTD17/2010	Native title exists in parts of the determination area
	NTD21/2010	Native title exists in parts of the determination area
	NTD24/2010	Native title exists in parts of the determination area
	NTD26/2010	Native title exists in parts of the determination area
Not Accepted	NTD33/2012	Not accepted for registration
	NTD20/2013	Not accepted for registration

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

### 3.2 Australian Heritage Database

A search of the Australia Heritage Database identified that no statutory listed heritage places within the proposed impact areas. Three sites listed on the now non-statutory Register of the National Estate are located within a 125 km x 125 km search area that encompasses the full EP98 permit area. None of these heritage places are located within 10 km of the proposed impacts.

### 3.3 NT Heritage Register

A search of the Northern Territory Heritage Register identified 41 Aboriginal archaeological sites and 7 historic heritage sites within a 125 km x 125 km area that encompasses the full EP98 permit area (Appendix C). Neither of the proposed exploratory drill locations will impact previously identified heritage sites, with the closest recorded archaeological site being located over 15 km away.

### 3.4 Aboriginal Areas Protection Authority

AAPA clearance surveys were originally conducted in September 2014 for a previous program of exploration drilling. This was updated in April 2016 to account for the changes in location made for the proposed 2017 drill sites, however the 2016 AAPA clearance report is still to be finalised. The following sacred sites were previously identified in certificate issued in 2015 for EP98 on the Nutwood Downs Road include:

- AAPA #5565-1 – a soak
- AAPA #5665-6 – a small rock hole
- AAPA #5665-5 – a waterhole
- AAPA #5665-4 – a waterhole
- AAPA #5665-2 – two waterholes, a swamp and trees.

On receipt of the 2016 clearance report from AAPA, this information may be updated.

### 3.5 Previous Archaeological Investigations

The majority of archaeological investigations near the study area have been predominately associated with either linear infrastructure in an alignment parallel to the Stuart Highway or natural gas exploration activities associated with the Beetaloo Basin. Of the assessments of relevance to the study area, the majority of sites identified are artefact scatters composed of raw material commonly found in the immediate area (quartz, silcrete and quartzite).



One stone arrangement has also been recorded. No assessments have been conducted within the boundaries of the current proposed impact areas. Table 3 provides a summary of previous archaeological investigations undertaken in the local area.

**Table 3 Previous Archaeological Assessments in the Local Area**

Researchers	Assessment Type	Locality	Key Findings
Smith, 1986	Excavation	Lake Woods	Insitu artefacts dated to 6000 years.
Hermes, 1986	Survey	Amadeus Basin to Katherine	Large scale survey for a proposed natural gas pipeline targeting areas of major cultural sensitivity from Daly Waters to Katherine. 32 sites were identified with the majority being artefact scatters associated with watercourses.
Quaternary Archaeological Surveys, 1998	Survey	Stuart Highway to Mataranka Homestead	Large scale survey for a fibre optic cable corridor. Three isolated artefacts and one historic heritage site identified.
Heritage Surveys, 1999	Survey	Daly Waters to McArthur River	Nine archaeological sites identified including rockshelters and artefact scatters.
HLA-Envirosciences Pty Ltd, 2006a, 2006b, 2006c, 2006d, 2007	Survey	Beetaloo Basin	Several archaeological sites identified across the exploration permits including artefact scatters, isolated artefacts and stone cairns.
AECOM Australia Pty Ltd, n.d., 2011, 2012a, 2012b	Survey	Beetaloo Basin	Several archaeological sites identified as part of seismic line clearance including large artefact scatters (>1km), quarry sites and isolated artefacts.
AECOM Australia Pty Ltd, 2014	Survey	Beetaloo Basin	One isolated artefact identified as part of an exploration drilling program clearance.

#### 4.0 Heritage Assessment

A heritage assessment involving field survey was undertaken by AECOM archaeologist, Elspeth Mackenzie for the proposal area from 19 to 20 April 2016 assisted by representatives of the traditional owners (Pompey Raymond, Marcus Raymond, Lennie Raymond and Raymond Raymond) and the Northern Land Council (Matthew Dmitrieff and Kevin Neade). The archaeological inspection involved pedestrian survey of all exploration drill pads, campsites and access tracks. During the inspection notes were taken on landform, ground surface visibility and areas of exposure. The aim of the inspection was to identify any surface expressions of Aboriginal archaeological and cultural heritage values within the proposal area. Photographic records were taken at each proposed drill and camp location.

Results of the inspection are provided in Table 4. Appendix A provides details on ground surface visibility classes and subsurface archaeological potential assessment.

**Table 4 Exploration Well Inspection Results**

Location	Zone	MGA E	MGA N	GSV	GSI	Surface Archaeology	Subsurface Archaeological Potential	Impact Potential
Nutwood Downs SW-1 well	53	370770	8226075	Good	High	None identified	Low	Low to No Impact
Nutwood Downs SW-1 camp	53	370427	8225871	Fair	High	None identified	Low	Low to No Impact
Kalala NE-1 well	53	369184	8225743	Poor	High	None identified	Low	Low to No Impact
Kalala NE-1 camp	53	369269	8225353	Very Poor	High	None identified	Low	Low to No Impact

GSV = Ground Surface Visibility, GSI = Ground Surface Integrity



**Plate 1** Nutwood Downs SW-1 well centre general context shot facing west



**Plate 2** Nutwood Downs SW-1 well centre ground cover context shot showing surface visibility







**Plate 3** Nutwood Downs SW-1 camp centre general context shot facing south



**Plate 4** Nutwood Downs SW-1 camp centre ground cover context shot showing surface visibility



	
<p><b>Plate 5</b>      <b>Kalala NE-1 well centre general context shot facing east</b></p>	<p><b>Plate 6</b>      <b>Kalala NE-1 well centre ground cover context shot showing surface visibility</b></p>
	
<p><b>Plate 7</b>      <b>Kalala NE-1 camp centre general context shot facing south</b></p>	<p><b>Plate 8</b>      <b>Kalala NE-1 camp centre ground cover context shot showing surface visibility</b></p>

## 5.0 Identified Heritage

No Aboriginal archaeological sites or culturally sensitive landforms were identified during the survey. It is noted however that ground surface visibility was highly variable across the exploration lease areas.

Representatives for the traditional owners identified that a previously registered sacred site (AAPA #5665-2) was in the vicinity of the proposed works and would need to be treated with due care and respect during any exploration activities. This sacred site is located just off Nutwood Downs Road and the site complex consists of two waterholes, a swamp and trees. It is recorded as a location through which the kangaroo, barramundi, sugar bag and witchetty grub travelled as they headed to their resting places.

This access point to the sacred site on Nutwood Downs Road is located approximately 1.5 kilometres from the access point to Nutwood Downs SW-1 and 300 metres from the access point to Kalala NE-1.

## 6.0 Key Findings and Recommendations

The key findings of this heritage assessment are:

- A review of existing heritage data and reports for the study area indicate that no previously recorded heritage sites will be impacted by the proposed works.
- No Aboriginal or historic heritage sites were located during field survey within the proposed drilling locations.
- AAPA clearance surveys have been carried out for the drill sites, however the 2016 AAPA clearance report is still to be finalised. Based on previous studies carried out in the permit areas, the following Sacred Sites have been recorded on the Nutwood Downs Road:

- AAPA #5565-1 – a soak
- AAPA #5665-6 – a small rock hole
- AAPA #5665-5 – a waterhole
- AAPA #5665-4 – a waterhole
- AAPA #5665-2 – two waterholes, a swamp and trees.

On the basis of the above findings, the following recommendations are made:

- The access point to the closest sacred site (AAPA #5665-2) is to be clearly marked and signed with “No Access Permitted” to prevent any unintentional disturbance.
- An unexpected heritage finds stop works procedure is to be implemented for the duration of the project.
- Induction of staff on site is to include reference to the wider area having Indigenous heritage values and the stop works procedure.

## 7.0 References

AECOM Australia Pty Ltd. (2011). *Archaeological Assessment – Drill Sites and Access Roads*. Unpublished report for Falcon Oil and Gas Australia.

AECOM Australia Pty Ltd. (2012a). *EP99 Archaeological Survey, Beetaloo Basin*. Unpublished report for Falcon Oil and Gas Australia.

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

AECOM Australia Pty Ltd. (2014). *Aboriginal & Historic Heritage Assessment*. Unpublished report for Origin Energy Resources Limited.

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 the NT Museums and Art Galleries.

HLA-Envirosciences Pty Ltd. (2006a). *Archaeological Assessment 2006 for the Sweetpea Petroleum Seismic Program, Beetaloo Basin, Northern Territory, 2006*. Unpublished report for Sweetpea Petroleum Pty Ltd.

HLA-Envirosciences Pty Ltd. (2006b). *Beetaloo Basin: Cooee Hill and 80 Metre Tower Archaeological Assessment*. Unpublished report for Sweetpea Petroleum Pty Ltd.

HLA-Envirosciences Pty Ltd. (2006c). *Beetaloo Basin: Newcastle Creek Archaeological Assessment*. Unpublished report for Sweetpea Petroleum Pty Ltd.

HLA-Envirosciences Pty Ltd. (2006d). *Beetaloo Basin: Yaroo, South Martyr's Tree and Dunmarra Archaeological Assessment*. Unpublished report for Sweetpea Petroleum Pty Ltd.

HLA-Envirosciences Pty Ltd. (2007). *Beetaloo Basin: Newcastle Creek (Seismic Line 13A) Archaeological Assessment*. Unpublished report for Sweetpea Petroleum Pty Ltd.

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

Smith, M. A. (1986). An Investigation of Possible Pleistocene Occupation at Lake Woods, Northern Territory. *Australian Archaeology*, 22, 60–74.

Yours faithfully

A handwritten signature in black ink, appearing to read 'Luke Kirkwood', written in a cursive style.

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## Appendix A - Legislation

### Commonwealth Legislation

#### Environment Protection and Biodiversity Conservation Act

The Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) took effect on the 16 July 2000 (NSW Department of Urban Affairs and Planning, 2000). Under section 26 of the EPBC Act it is stated that:

*A person must not take on Commonwealth land an action that has, will have or is likely to have a significant impact on the environment.*

Under section 28 of the EPBC Act it is stated that:

*The Commonwealth or a Commonwealth agency must not take inside or outside the Australian jurisdiction an action that has, will have or is likely to have a significant impact on the environment inside or outside the Australian jurisdiction.*

An action is defined as a project, development, undertaking, activity, series of activities, or alteration. An action will also require approval if:

*It is undertaken on Commonwealth land and will have or is likely to have a significant impact;*

*It is undertaken outside Commonwealth land and will have or is likely to have a significant impact on the environment on Commonwealth land; and*

*It is undertaken by the Commonwealth and will have or is likely to have a significant impact.*

The EPBC Act defines 'environment' as both natural and cultural environments and therefore includes Aboriginal and historic heritage items. Under the Act, protected heritage items are listed on the National Heritage List (items of significance to the nation) or the Commonwealth Heritage List (items belonging to the Commonwealth or its agencies). These two lists replaced the Register of the National Estate (RNE) which is no longer a statutory list.

#### Aboriginal and Torres Strait Islander Heritage Protection Act 1984

The Aboriginal and Torres Strait Islander Heritage Protection Act 1984 (the ATSIHP Act) provides for the preservation and protection of places, areas and objects of particular significance to Indigenous Australians. The stated purpose of the ATSIHP Act is the 'preservation and protection from injury or desecration of areas and objects in Australia and in Australian waters, being areas and objects that are of particular significance to Aboriginals in accordance with Aboriginal tradition' (section 4).

Under the Act, 'Aboriginal tradition' is defined as "the body of traditions, observances, customs and beliefs of Aboriginals generally or of a particular community or group of Aboriginals, and includes any such traditions, observances, customs or beliefs relating to particular persons, areas, objects or relationships" (Section 3). A 'significant Aboriginal area' is an area of land or water in Australia that is of 'particular significance to Aboriginals in accordance with Aboriginal tradition' (Section 3). A 'significant Aboriginal object', on the other hand, refers to an object (including Aboriginal remains) of like significance.

For the purposes of the Act, an area or object is considered to be injured or desecrated if:

- In the case of an area:
  - it is used or treated in a manner inconsistent with Aboriginal tradition;
  - the use or significance of the area in accordance with Aboriginal tradition is adversely affected;
  - passage through, or over, or entry upon, the area by any person occurs in a manner inconsistent with Aboriginal tradition;
- In the case of an object:
  - it is used or treated in a manner inconsistent with Aboriginal tradition.

The ATSIHP Act can override state and territory laws in situations where a state or territory has approved an activity, but the Commonwealth Minister prevents the activity from occurring by making a declaration to protect an area or object. However, the Minister can only make a decision after receiving a legally valid application under the

ATSIHP Act and, in the case of long term protection, after considering a report on the matter. Before making a declaration to protect an area or object in a state or territory, the Commonwealth Minister must consult the appropriate Minister of that state or territory (section 13).

## Appendix B – Archaeological Assessment Criteria

**Table B1 Ground Surface Visibility (GSV) Rating Scheme**

GSV rating	Percentage GSV
No ground surface visibility	0%
Very poor	1-10%
Poor	11-30%
Fair	31-50%
Good	51-70%
Very good	71-90%
Excellent	91-100%

**Table B2 Ground Surface Integrity (GSI) Rating Scheme**

GSI rating	Definition
Low	Ground surface has been subjected to significant disturbance (e.g. earthworks, excavation). Little to no integrity remains.
Moderate	Ground surface has been subject to moderate disturbance (e.g. native vegetation clearance) but retains a reasonable degree of integrity.
High	An unmodified or minimally modified ground surface.

**Table B3 Definitions for Subsurface Archaeological Potential**

Subsurface Archaeological Potential	Definition
Low	Areas in which subsurface archaeological materials are unlikely to occur. This may be due to unfavourable environmental conditions and/or prior disturbance(s).
Moderate	Areas in which subsurface archaeological materials may occur. Reasonable environmental conditions exist though high artefact counts/densities are unlikely. Subsurface evidence likely to be the product of random discard events as opposed to repeated or extensive activity by Aboriginal people in antiquity.
High	Areas known or highly likely to contain subsurface archaeological materials. Presence of archaeological materials typically reflects optimal environmental conditions and little to no prior landscape disturbance. High artefact counts/densities are likely.

**Table B4 Impact Potential Ranking for Aboriginal Objects**

Impact Potential	Definition	Management Action
No Impact	Aboriginal objects will not be affected by the proposed activity.	No action required
Low Impact	The proposed activity is unlikely to disturb, destroy, damage or deface an Aboriginal object or objects.	No action required
Moderate Impact	The proposed activity has reasonable potential to disturb, destroy, damage or deface an Aboriginal object or objects.	Avoid area if possible. If avoidance not an option, test excavate area to determine nature and extent of potential archaeological deposits
High Impact	The proposed activity will, or is highly likely to, disturb, destroy, damage or deface an Aboriginal object or objects.	Avoid area if possible. If avoidance not an option, test excavate area to determine nature and extent of potential archaeological deposits



## Appendix C – Listed Heritage Sites

Table C1 NT Heritage Register - Aboriginal Heritage Sites

Site Name	Easting	Northing	Site Type
Amungee Mungee 1	409212	8164884	Stone artefact scatter; grindstone portable
Amungee Mungee 2	411012	8167284	Stone artefact scatter
Amungee Mungee 3	411312	8165084	Stone artefact scatter
Amungee Mungee 4	411812	8160984	Stone artefact scatter
Amungee Mungee 5	411912	8159184	Stone artefact scatter
Amungee Mungee 6	409012	8154584	Stone artefact scatter
Amungee Mungee 7	397912	8144284	Stone artefact scatter
Amungee Mungee 8	401312	8147984	Stone artefact scatter
CHT 1	398967	8171452	Stone artefact scatter
Daly Waters Creek Site 1	327912	8178184	Stone artefact scatter
Dunmara Site 1 - flaked telegraph insulator	330912	8154584	Isolated non-stone artefact
Dunmarra 1	319785	8144995	Isolated stone artefact
Goochegoochena Creek Site 1	335612	8107484	Stone artefact scatter
Goochegoochena Creek Site 2	335812	8106684	Stone artefact scatter
Goochegoochena Creek Site 3	336412	8104084	Stone artefact scatter
Goochegoochena Creek Site 4	336512	8103384	Isolated stone artefact
Goochegoochena Creek Site 5	336612	8102384	Isolated stone artefact
Goochegoochena Creek Site 6	336612	8102384	Stone artefact scatter
Goochegoochena Creek Site 7	336712	8101484	Stone artefact scatter
Goochegoochena Creek Site 8	336712	8101184	Isolated stone artefact
Goochegoochena Creek Site 9	337012	8098984	Stone artefact scatter
Goochegoochena Creek Site 10	337412	8096184	Isolated stone artefact
Goochegoochena Creek Site 11	337412	8096084	Isolated stone artefact
Goochegoochena Creek Site 12	337412	8095884	Isolated stone artefact
Johnson Lagoon Site 1	332412	8137184	Isolated stone artefact
Johnson Lagoon Site 2	332412	8136384	Stone artefact scatter
Kalala Stat. 5	318912	8209584	Stone artefact scatter
Kalala Stat. 6	318912	8207984	Isolated stone artefact
Kalala Stat. 7	318112	8192684	Isolated stone artefact
Kalala Stat. 8	320812	8175184	Stone artefact scatter
Kalala Stat. 9	323912	8202984	Isolated stone artefact
Newcastle Waters Creek Site 1	335712	8090484	Stone artefact scatter
Newcastle Waters Site 1	336012	8091684	Isolated stone artefact
Oodjuongari Waterhole	404212	8150784	Stone artefact scatter

Site Name	Easting	Northing	Site Type
Stuart Swamp [Daly Waters to McArthur R. Pipeline]	327912	8205484	Stone artefact scatter; historic object/place; grindstone portable
Yaroo 1	436844	8158463	Stone artefact scatter
Yaroo 2	436748	8158820	Stone artefact scatter
Yaroo 3	324035	8157085	Isolated stone artefact
Yaroo 3a	324065	8156827	Isolated stone artefact
Yaroo 3b	322622	8164699	Isolated stone artefact
Yaroo 4	407464	8098625	Stone artefact scatter

**Table C2 NT Heritage Register - Historic Heritage Sites**

Place Name	Easting	Northing	Status
Flying Fox; Daly Waters	326330	8201570	Declared
Frew Ponds Overland Telegraph Poles (northern end)	330400	8130710	Declared
Frew Ponds Overland Telegraph Poles (southern end)	330340	8126260	Declared
Daly Waters Aviation Complex	326710	8201220	Declared
Daly Waters Aviation Complex	326560	8201281	Declared
Daly Waters Aviation Complex	326360	8201190	Declared
Daly Waters Aviation Complex	326510	8201350	Declared

## Appendix E – Risk Assessment

Note that groundwater risks are contained in the Appendix B – Cloud GMS Report

Risk Ref	Activity	Aspect	Location	Impact	Impact Description	Pre Mitigation Risk Assessment						Mitigation Measure  (Note preliminary mitigation, full mitigation presented in Section 5.0 Potential Impacts and Management)	Post Mitigation Risk Assessment															Risk Band						
						Impact to Origin or Contracting Personnel	Natural Environment	Community Damage / Impact / social / cultural	Financial Impact (e.g. due to loss of revenue, business interruption)	Damage to reputation, services	Breach of Law or Criminal Prosecution or civil action		Natural Environment			Community Damage / impact / social /cultural heritage	Financial Impact (e.g. due to loss of revenue, business interruptions, commodity, trading, asset)			Damage to reputation, services interruption, customer interruption			Breach of Law or Criminal Prosecution or civil action (e.g. OHS, environment, industrial)											
						Consequence	Consequence	Consequence	Consequence	Consequence	Consequence		Consequence	Likelihood	Risk Level	Consequence	Likelihood	Risk Level	Consequence	Likelihood	Risk Level	Consequence	Likelihood	Risk Level	Consequence	Likelihood	Risk Level		Consequence	Likelihood	Risk Level			
4	Camp and Drilling Operations	Management of Land - Soil and Erosion	All Sites	Dust impacts on built-up areas (camp site), vegetation and amenity as a result of exploration activities.	Vehicles traversing across the site and access tracks have the potential to cause dust impacts on surrounding environment. Bull dust generation may be an issue on areas of disturbed soil, primarily the grassland areas. Observations showed that bull dust formed in places where the surface crust had been disturbed and then subjected to repeated ground disturbance.		2	1			1	- Restrict speed limit on unsealed roads, in particular the camp site. - Ensure site environmental inductions for all site personnel and contractors include air quality management and protective measures to Control or report air emissions. - Monitor road conditions to Ensure deterioration with possible increase in Dust creation, does not occur and undertake road rehabilitation If required. - use water truck where applicable to manage Dust emissions from vehicle movement or drilling operations on the site.				1	1	Low	1	1	Low							1	1	Low	Low			
9	Camp Operations	Management of Water - Surface Water	All Sites	Contamination or pollution of surface waters through waste or waste water impact	Inappropriate management of ablution and camp kitchen waste could impact on Site personnel and environment from contamination concerns and odours.	2	3	1			2	- Grey water from kitchen and showering facilities should be directed to earth drains designed to prevent discharge, as per specifications in Part 6 of the DoH Code of Practice for Small On-site Sewage and Sullage Treatment Systems and the Disposal or Reuse of Sewage Effluent, 2014. - Toilet facilities should consist of pit or chemical systems, as described in Part 4 of the DoH Code of Practice for Small On-site Sewage and Sullage Treatment Systems and the Disposal or Reuse of Sewage Effluent, 2014. For chemical systems, the contents should be disposed of off-site. If pit toilets are necessary, the pit should be covered with at least a metre of fill. - The site assessment criteria provided in the DoH Code of Practice for Small On-site Sewage and Sullage Treatment Systems and the Disposal or Reuse of Sewage Effluent, 2014 (Section 7.2) should be reviewed when determining siting of effluent disposal systems, including consideration of soil depth, proximity to drainage lines or areas prone to flooding, proximity to water bores or wells and ground slope. - It is noted that the DoH would need to be consulted in relation to management of waste water.	1	1	Low	1	2	Low	1	1	Low										1	1	Low	Low
13	Camp Operations	Groundwater	All Sites	Extraction of groundwater for the use during camp operations impacting on groundwater supply for exploration operations and the wider area.	Pastoral groundwater bores suffer reduced groundwater yields  Note: Groundwater is the primary water source for the Barkly Region.		2	2			3	- Where a groundwater water supply bore is required ensure appropriate licences are obtained prior to works and that planned abstraction is sustainable. - Baseline groundwater quality sampling is available for the permit areas. If additional base line samples are required for the installation of water bores and the well bore to ensure that a pre-operational reference for the water quality is undertaken to provide a water quality tracking tool and future rehabilitation criteria. These samples will be analysed in an appropriately accredited National Association of Testing Authorities (NATA) laboratory with an initial broad spectrum of analytes consistent with DME Groundwater Sampling Advisory Note - AA7-024 Ground Water Sampling Methodology (2011). - Operational period testing for the water bores may be required during camp operations to determine any potential changes in aquifer and well properties such as excessive draw down or change in aquifer water composition. Operational testing will comprise the measurement of field parameters (e.g. pH, Electrical Conductivity (EC) and Standing Water Level (SWL)). - Operational period testing for the water bores may be required during camp operations to determine any potential changes in aquifer and well properties such as excessive draw down or change in aquifer water composition. Operational testing will comprise the measurement of field parameters (e.g. pH, Electrical Conductivity (EC) and Standing Water Level (SWL)).				1	1	Low	1	1	Low										1	1	Low	Low
17	Camp and Drilling Operations	Waste	All sites	Contamination of soil or water through generation of or use of hazardous materials, domestic, industrial and drilling wastes and sewage			2				1	- Allow for waste storage and handling provisions onsite for offsite disposal. - Allow for removal and disposal of hazardous wastes, including local licensed landfills and noting that limited facilities exist in the Northern Territory to handle hazardous waste, in which case transport requirements would need to be considered.	1	1	Low	1	1	Low	1	1	Low	1	1	Low	1	1	Low	1	1	Low	Low			

Risk Ref	Activity	Aspect	Location	Impact	Impact Description	Pre Mitigation Risk Assessment						Mitigation Measure  (Note preliminary mitigation, full mitigation presented in Section 5.0 Potential Impacts and Management)	Post Mitigation Risk Assessment															Risk Band			
						Impact to Origin or Contracting Personnel	Natural Environment	Community Damage / Impact to social / cultural	Financial Impact (e.g. due to loss of revenue, business interruptions)	Reputation / services	Criminal Prosecution or civil litigation		Impact to Origin or Contracting Personnel	Natural Environment			Community Damage / impact / social /cultural heritage	Financial Impact (e.g. due to loss of revenue, business interruptions, commodity, trading, asset)			Damage to reputation, services interruption, customer interruption			Breach of Law or Criminal Prosecution or civil action (e.g. OHS, environment, industrial)							
						Consequence	Consequence	Consequence	Consequence	Consequence	Consequence		Consequence	Likelihood	Risk Level	Consequence	Likelihood	Risk Level	Consequence	Likelihood	Risk Level	Consequence	Likelihood	Risk Level	Consequence	Likelihood	Risk Level				
18	Camp Operations	Waste	All sites	Encouragement of pest species to waste sites.	Incorrectly managing waste on site could potentially attract pest species.		2				1	- Segregate and safely store and label chemical packaging, lube oils, batteries, tyres, maintenance and other industrial wastes for proper disposal to recycling and approved landfill facilities. • All waste material introduced to site will be removed from the lease area and disposed of, e.g. discarded drilling equipment, oil drums, machinery, engine debris, food and drink packaging etc.. • All sample bags, waste materials and contaminants must be removed from site and disposed of in an appropriate manner, following the completion of the drilling program. • Drill cuttings that are acidic, radioactive or of a substantially different colour to the surface soil should be backfilled in the drill hole, sump or other excavation. All other cuttings should be dispersed around the site or raked over.	1	1	Low	1	1	Low	1	1	Low	1	1	Low	1	1	Low	1	1	Low	Low
19	All activities	Air Quality and Emissions	All sites	Potential for an increase in dust during site preparation (clearing of access tracks, drill sites and camp areas) and resulting from vehicular traffic	Dust - The road network within the permit area is almost entirely unsealed and dust is generated as a result of vehicle movements upon these roads during the dry season. Dust generation also occurs on other areas of the permits where vehicles are used off		1				1	- Ensure site environmental inductions for all site personnel and contractors include air quality management and protective measures to control or report air emissions. - all vehicles and equipment used on site will be well maintained with mufflers fitted. - Monitor road conditions to Ensure deterioration with possible increase in Dust creation, does not occur and undertake road rehabilitation If required. - use water truck where applicable to manage Dust emissions from vehicle movement or drilling operations on the site.				1	3	Low									1	1	Low	Low	
20	All activities	Air Quality and Emissions	All sites	Potential for an increase in exhaust emissions from contractors' vehicles and generators resulting in localised effect on air quality and global contribution to greenhouse gases.	Vehicle Emissions - Vehicle exhaust emissions are a current occurrence in the region as a whole, from users of the national highways and pastoral machinery. Portable diesel or petrol fuel generators may be used during the exploration phase and a larger		1				1				1	1	Low									1	1	Low	Low		
21	All activities	Air Quality and Emissions	All sites	Potential for dust generated to impact on health and functioning of the surrounding vegetation.	Excessive dust deposited onto plant foliage can reduce the photosynthetic performance (photosynthesis, stomata conductance, transpiration etc.), thus reducing overall health and plant growth (Hirano 1995) although the type and severity of impacts is largely unknown. On the drill site, the		1				1				1	3	Low										1	1	Low	Low	
22	All activities	Air Quality and Emissions	All sites	Potential for an increase in volatile hydrocarbons present in air surrounding drill sites, as petroleum compounds are moved to the surface	Hydrocarbon Emissions - There may be a periodic requirement to burn waste hydrocarbons in the flare pit, during the drilling process (e.g. during the drill stem test). The management of this has been discussed in the EP, but the process itself		1				1				1	1	Low										1	1	Low	Low	
44	Well stimulation	Groundwater	Frac Stimulated well sites	A surface spill of stimulation fluids /flow back water/diesel leads to the contamination of groundwater resources.	Contamination of shallow aquifers by flowback/formation water impacts existing/ potential groundwater users (landholder) and environmental dependencies. Relatively shallow groundwater occurrence. Unsaturated zone sediments are permeable and provide pathway to watertable aquifer. Likelihood of groundwater contamination resulting from surface spillage is low when taking in consideration watertable depth, spill volumes and existing controls. Community impact is related to potential		2	2				Tank integrity is tested during commissioning and prior to any flowback water being pumped in. Regular tank inspections and integrity checks. Planned groundwater monitoring activities. Ability to transfer between tanks. Spill kits and drip trays used to manage small leaks. Excess storage capacity available. Pressure tested surface lines to ensure piping connection integrity				2	2	Low	2	2	Low									Low	
45	Well stimulation	Groundwater	Frac Stimulated well sites	Leakage of frac flowback from storage vessels leads to the contamination of groundwater resources.	Contamination of shallow aquifers by flowback/formation water impacts existing groundwater users and environment.		2					Tank integrity is tested during commissioning and prior to any flowback water being pumped in. Regular tank inspections and integrity checks. Planned groundwater monitoring activities. Ability to transfer between ponds. Spill kits to manage small leaks. Excess storage capacity available.				2	1	Low												Low	
46	Well stimulation	Groundwater	Frac Stimulated well sites	Groundwater extraction required to supply water for the project results in drawdown of water levels which impacts existing groundwater users and/or the environment.	Pastoral groundwater bores suffer impaired capacity (ie. Reduced bore yields). Reduction in environmental flows in connected springs/streams.		2					CloudGMS risk assessment modelling predicts nil impacts.				1	1	Low												Low	
47	Well stimulation	Groundwater	Frac Stimulated well sites	Cross flow of groundwater from a utilised aquifer to another formation causes declining groundwater levels.	Pastoral groundwater bores suffer impaired capacity (ie. Reduced bore yields). Reduction in environmental flows in connected springs/streams.		2					OE DMS and adherence to industry best practice. Well control critical equipment and systems on rig fit for purpose, certified, maintained in good work order and tested as required. Appropriate well control training/certification for rig personnel. Well engineering design compliant with best practice and Origin standards (Casing Design and Barrier Philosophy). Pressure test verifying integrity of the string.				2	2	Low												Low	
48	Well stimulation	Groundwater	Frac Stimulated well sites	Stimulation activity enables cross formational flow between shallow aquifers in contravention of Water Act (NT) Regulations.	Deterioration in water quality in utilised aquifer impacts existing groundwater users and affects environmental dependencies (springs, ecosystems).		2	3				Programme Design. Stimulation design.				2	1	Low	3	1	Low									Low	
49	Well stimulation	Groundwater	Frac Stimulated well sites	Hydraulic fracturing induces seismicity which increases connectivity between formations and enhances the potential for cross flow of water /hydrocarbons/gas.	Change in flowpaths and aquifer interconnection leads to flow of groundwater between formations and results in contamination of utilised aquifer and impacts on existing pastoral use and environmental		3					Significant distance between target reservoir formation and aquifers Presence of natural frac barriers and high perm zones to contain fracture height growth Fracture stimulation design to contain height growth				2	1	Low												Low	

Risk Ref	Activity	Aspect	Location	Impact	Impact Description	Pre Mitigation Risk Assessment						Mitigation Measure  (Note preliminary mitigation, full mitigation presented in Section 5.0 Potential Impacts and Management)	Post Mitigation Risk Assessment															Risk Band	
						Impact to Origin or Contracting Personnel	Natural Environment	Community Damage / Impact / social / cultural	Financial Impact (e.g. due to loss of revenue, business interruptions, commodity, trading, asset)	Damage to reputation, services	Breach of Law or Criminal Prosecution or civil action (e.g. OHS, environment, industrial)		Natural Environment			Community Damage / Impact / social / cultural heritage			Financial Impact (e.g. due to loss of revenue, business interruptions, commodity, trading, asset)			Damage to reputation, services interruption, customer interruption			Breach of Law or Criminal Prosecution or civil action (e.g. OHS, environment, industrial)				
						Consequence	Consequence	Consequence	Consequence	Consequence	Consequence		Consequence	Likelihood	Risk Level	Consequence	Likelihood	Risk Level	Consequence	Likelihood	Risk Level	Consequence	Likelihood	Risk Level	Consequence	Likelihood	Risk Level		
50	Well stimulation	Natural Environment - Seismic	Frac Stimulated well sites	Hydraulic fracturing induces local seismicity and reactivates a fault.	Noticeable seismic tremor at surface. Negative Impact to perceptions regarding hydraulic fracturing.		2	1				30-40m on either side of known fault has been blanked.				2	1	Low	1	1	Low								Low
51	Well stimulation	Water	Frac Stimulated well sites	Delayed decision regarding appropriate disposal mechanism results in inadequate water disposal.	Local contamination resulting in potential environmental impact.		3					Daily pH sampling of water. Water Management Plan.				3	2	Medium											Medium
52	Well stimulation	Natural Environment - Fauna	Frac Stimulated well sites	Water storage on site negatively impacts fauna.	Fauna ingress into water storage resulting in potential fauna mortality.		3					Tanks are of sufficient height mitigating ground dwelling fauna entering tank.				3	1	Low											Low
53	Well stimulation	Natural Environment - Contamination	Frac Stimulated well sites	Radioactive elements (NORMs) in the formation are carried back by the water or in fines production.	Personnel exposure. Potential damage to ecosystem in the event of inadequate disposal.	3	3					Limited exposure time for personnel. NORMs testing will be undertaken throughout the programme. Adequate disposal of NORMs will be undertaken.	3	1	Low	3	2	Medium											Medium
54	Well stimulation	Groundwater	Frac Stimulated well sites	Loss of well integrity during frac programme.	Potential contamination of aquifer in the event of loss of integrity.		2					OE DMS and adherence to industry best practice. Well control critical equipment and systems on rig fit for purpose, certified, maintained in good work order and tested as required. Appropriate well control training/certification for rig personnel. Well engineering design compliant with best practice and Origin				2	2	Low										Low	
56	Post Drilling & completion (not activity specific)	Groundwater	All sites	Cross flow of groundwater between shallow aquifers results in deterioration of water quality in utilised aquifer.	Deterioration in water quality in utilised aquifer may impact existing groundwater users and environmental interdependencies.		3					completion design - cementing between aquifers verification of barriers - cement bond log, pressure tests (?) with failed/partial barrier flow path still restricted *** limited pressure differential (limited driver for flow)				1	2	Low										Low	

## Appendix F – Stakeholder Consultation Summary Log and Storyboards

## ORIGIN ENERGY - Origin Beetaloo Stakeholder Consultation 2014 to 2016

Status Options: Engage throughout; Inform only; Not relevant person; Don't want further info; Close

Stakeholder / Organisation	Contact Name	Date(s)	Mode	Functions, Interests, Activities of Stakeholder	Origin Overview of Engagement and Relationship	Status
HiWay Inn Daly Waters	Jack & Kim Harries	2015 to present	Emails; Direct Engagement	Landholder and community BBQ, constant accommodation to Origin employees and sub-contractors through the dry season	The HiWay Inn owners have been consulted all the way through this campaign through informing of the work program, updates on any major vehicle and personnel movements as well as utilisation of their services for accommodation and meals. Kim is the Secretary for the local Daly Waters campdraft association and through her Origin have become a major sponsor of this event. They have interests in any commercial opportunities that the project may propose and as a result our contact with them has been consistent in this regard too. They have always been supportive of the project and interested in developments as we go.	Ongoing
Daly Waters Pub	Lindsay	2015 to present	Emails; Direct Engagement	Support the business now and again with meals etc. No official functions however, we do attend the campdraft each year	Lindsay has been kept abreast of the program through a detailed update meeting where the 2016 work program was presented. Lindsay was supportive of the project based on this meeting with concerns presented as a general issue around environmental management, however, there was a high level of trust that Origin would perform within regulation and operate at the highest standards. The business does not target resource companies for work as they rely solely on the tourist trade and would rather it stay that way hence no commercial push back on us. Lindsay also oversees the airstrip and maintains it for use by different parties.	Ongoing
Dunmurra Pub	Gary Frost	2015 to present	Emails; Direct Engagement	Proposed Landholder BBQ but had to be cancelled due to LH's unable to attend at that time - mustering commitments	Gary has been kept abreast of the program through a detailed update meeting where the 2016 work program was presented. Gary was supportive of the project based on this meeting and proposed his assistance through his business should we need it i.e. accommodation, fuel, meals etc	Ongoing
Chamber of Commerce NT	Greg Bicknell Brian O'Gallagher Kaye Eade	16/03/2015 to present	Meetings; Conference Presenter and participant	Established in 1957 the Chamber of Commerce NT is the largest employer association in the Northern Territory. An independent, not-for-profit and non-government body - with membership and offices spanning across the Territory. CoCNT Provide Members and the Northern Territory business community with an effective platform for lobbying on the issues that impact business, whilst providing services and support to business in a number of key areas including industrial relations, training, employment, education and training advice, networking and premier business events. The Chamber of Commerce NT is governed by a Board of Directors and has both a General Council and Regional Executive Council in each region of the Northern Territory ensuring Members have direct influence and control in the lobbying platforms and policies of the Chamber.	The Chamber of Commerce NT welcomed memberships from natural gas energy operators and continues to encourage industry to deliver factual, scientific and technically relevant information to its membership and the broader community. Origin was invited as a guest presenter at both the 2015 and 2016 Regional Mining Seminars hosted by the Chamber of Commerce, Alice Springs. Each year's presentations have assisted in being able to share information about the small scale and nature of current exploration activities to a broader demographic across the NT.  Origin representatives also hosted a focus group information session with the Chamber of Commerce NT (Katherine) branch and members and share with them the results of the 2015 campaign and proposed activities for 2016 (pending receipt of regulatory and necessary approvals). All participants welcomed the factual provision of information.  <i>* No known concerns regarding Origin's exploration activities and / or the NT's onshore natural gas.</i>	Ongoing
Regional Economic Development Committee(s)	Tennant Creek Nhulunbuy	2015 to present	Direct Engagement		Origin presented an overview of 2015 activities and proposed activities for 2016. Participants were very interested in the factual and scientific information as well as understanding the current level (small) of activity. They are also interested in understanding future opportunities for their community members.  <i>* No current outstanding requests for information regarding Origin's exploration activities and / or the NT's onshore natural gas.</i>	Ongoing



Stakeholder / Organisation	Contact Name	Date(s)	Mode	Functions, Interests, Activities of Stakeholder	Origin Overview of Engagement and Relationship	Status
Katherine Town Council	Mayor CEO Aldermen	2015 to present	Emails; Direct Engagement		<p>Origin has met with the appropriate level of frequency with the Katherine Town Council Mayor, CEO and Alderman and participated in additional meetings and information sessions at their request. In November 2015 the entire Town Council were given an overview of the 2015 activities and an update on proposed activities (pending all regulatory and necessary approvals) for 2016. The Mayor and Alderman advised that fresh water use, waste water storage; and potential for water contamination were the primary topics of conversation and concern. Origin provided a full overview of these topics (as relevant for the level and type of current activities) at which Alderman were pleased and thankful for the factual information.</p> <p><i>* No current outstanding requests for information regarding Origin's exploration activities and / or the NT's onshore natural gas.</i></p>	Ongoing
Lock the Gate (and Alliance Groups)	Naomi Hogan Charmaine Roth Errol Lawson	2015 to present	Emails; Direct Engagement		<p>Origin has participated in several one-on-one meetings with Lock the Gate Alliance members in Katherine and Alice Springs. Some meetings have been particularly constructive and mutually beneficial whilst other engagements remain difficult and industry and some opponents agree to disagree.</p> <p>- Origin representatives have had regular meetings and communication with Chairmaine Roth and Errol Lawon - Origin accepted an invitation to the Speaker of the House to participate in a Lock the Gate panel discussion (industry not represented on the panel) at Parliament House in November 2015</p>	Ongoing
Media	Katherine Times (Editor, Lyndon Keane)	2015 to present	Emails; Telephone; Direct Engagement	Katherine Times - Local Newspaper		Ongoing and as required
APPEA	Malcolm Roberts Matt Doman	CEO Director NT	Emails; Telephone; Direct Engagement			Ongoing
Katherine Mining Services Association	Katherine Business Association		Emails; Telephone; Direct Engagement		<p>Origin has participated in several one-on-one and group meetings with KMSA members in Katherine. All meetings and engagements have been constructive and anchored in discussions around facts, science and potential future opportunities.</p> <p>- Origin representatives attended the KMSA Conferences held in 2015 and 2016 as well as hosting a number of smaller focus groups with community / association members.</p> <p><i>* No current outstanding requests for information regarding Origin's exploration activities and / or the NT's onshore natural gas.</i></p>	Ongoing
Industry Capability Network	Kevin Peters CEO	2015 to present	Direct Engagement; Emails and Telephone Calls		<p>The ICN has welcomed increased engagement with natural gas energy operators in the NT. Supported the industry in being able to continue to deliver factual, scientific and technically relevant information to its business members and the broader community.</p> <p><i>* No known concerns regarding Origin's exploration activities and / or the NT's onshore natural gas.</i></p>	Ongoing

Stakeholder / Organisation	Contact Name	Date(s)	Mode	Functions, Interests, Activities of Stakeholder	Origin Overview of Engagement and Relationship	Status
NT Cattlemen's Association	Tracey Hayes CEO	2015 to present	Direct Engagement; Emails and Telephone Calls	NTCA Annual Conferences 2015 & 2016	Origin attended the NTCA Annual Conference in Darwin and Alice Springs year on year. Other engagements have been at like minded events throughout the NT as well as phone contact. The NTCA have always been upfront in their wish for both industries to collaborate effectively around issues such as land access and environmental management (aquifer)	Ongoing
NT Combined Unions		2015 to present	Direct Engagement; Emails and Telephone Calls		<p>APPEANT and Origin representatives attended an information session (approximately three hours) with the NT Combined Unions. Repesentative delegates where shared results of Origin's the 2015 campaign as well as given visibility of proposed activities for 2016 (pending receipt of regulatory and necessary approvals). All participants welcomed the factual provision of information. The DAE economic benefits report was also discussed and they expressed a level of comfort with operators Origin and Santos and encouraged industry to do more engagement and dissemination of factual information.</p> <p><i>* No outstanding concerns regarding Origin's exploration activities and / or the NT's onshore natural gas.</i></p>	Ongoing
ICRG North	Dean Rioli CEO Russell Jeffrey NT Group Manager	February 2016 to present	Direct Engagement; Emails and Telephone Calls		<p>Santos and Origin representatives provided an information session (approximately three hours) with the executive of ICRG North. The indigenous owned and operated NT business welcomed receipt of factual information and have since invited Origin to share information and listen to questions from additional staff members and business associations.</p> <p><i>* No outstanding concerns regarding Origin's exploration activities and / or the NT's onshore natural gas.</i></p>	Ongoing
Nova Peris (Senator for NT) Retired July 2016	Nova Peris	February 2016 to present	Direct Engagement; Emails and Telephone Calls		<p>Santos and Origin representatives provided an information session (approximately three hours) with the Senator who appreciated and welcomed receipt of factual information and facilitated additional meetings with indigenous Territory Labor Candidates (Costa, Uboi)</p> <p><i>* No outstanding concerns regarding Origin's exploration activities and/ or the NT's onshore natural gas.</i></p> <p><i>* No outstanding requests for information.</i></p>	Ongoing
Northern Territory Show Circuit		2015 and 2016	Direct Engagement		<p>Industry representatives have attended all shows across the Northern Territory including :</p> <ul style="list-style-type: none"> <li>- Freds Pass</li> <li>- Alice Springs</li> <li>- Borroloola</li> <li>- Tenant Creek</li> <li>- Katherine</li> <li>- Darwin</li> </ul>	Ongoing

# ORIGIN ENERGY - Origin Beetaloo Stakeholder Consultation 2014 to 2016

Status Options: Engage throughout; Inform only; Not relevant person; Don't want further info; Close

Stakeholder / Organisation	Contact Name	Title	Date(s)	Mode	Functions, Interests, Activities of Stakeholder	Origin Overview of Engagement and Relationship	Status
Department of Mines and Energy - NT Government	Ron Kelly Victoria Jackson Jop van Hattum	Chief Executive Senior Energy Director Snr Director Petroleum Technology & Operations	2014 to present	Meetings; Emails; and Telephone Calls		Ongoing engagement and consultation with Department of Mines and Energy to ensure compliance to legislation and regulations.	Engage throughout
Department of Transport NT	Garry Fischer	Director	11/02/2015 to present	Meetings; Emails; and Telephone Calls	The Department of Transport provides safe, efficient and sustainable transport systems to meet community and NT Government needs.  It is responsible for: - Aviation; Commercial passenger vehicle industry; Marine safety; Motor Vehicle Registry (MVR); Public transport; Road network management; Road safety; Road transport; Transport infrastructure; Transport policy; Transport safety	Ongoing engagement and consultation with Department of Transport to ensure understanding of exploration activities and use of shared infrastructure. Sought and received permission from NTG for Origin to fund and execute minor civils upgrades to the Daly Waters airstrip  <i>As at 8 July 2016 - No outstanding items or requests for additional information.</i>	Engage throughout
Department of Tourism NT	Valerie Smith	Director Planning and Policy	2015 to present	Meetings; Emails		Ongoing engagement and consultation with Department of Transport to ensure understanding of exploration activities and use of shared infrastructure - particularly the Carpentaria Highway as it is part of the Savannah Way Tourist Route. Origin has been extended an invitation for Department of Tourism to provide an information session to all department staff. Origin, Santos and APPEA will co-present at a date yet to be confirmed.  <i>As at 8 July 2016 - No outstanding items</i>	Inform and engage
Department of Lands, Planning & Environment, NT	Rod Applegate	Chief Executive Officer	07/08/2015 13/1/2016	Email; and Direct Engagement	NT Government department responsible for lands, planning & environment	The NT Government and the Chief Minister have been appropriately supportive of Origin's exploration activities as it endeavours to better understand the geology and opportunity of further developing the Northern Territory's onshore natural gas resources.  <i>* No outstanding items / concerns regarding Origin's exploration activities and / or the NT's onshore natural gas</i>	Inform and engage

Stakeholder / Organisation	Contact Name	Title	Date(s)	Mode	Functions, Interests, Activities of Stakeholder	Origin Overview of Engagement and Relationship	Status
Parliament of NT	Adam Giles	Chief Minister. Minister for Tourism; Northern and Central Australia; Economic Development and Major Projects; Indigenous Affairs	2013 to present	Email; Telephone and Direct Engagement (Meetings)	NT Chief Minister	The NT Government and the Chief Minister have been appropriately supporting of Origin's exploration activities as it endeavours to better understand the geology and opportunity of further developing the Northern Territory's onshore natural gas resources.  <i>* No outstanding items / concerns regarding Origin's exploration activities and / or the NT's onshore natural gas.</i>	Engage throughout
Parliament of NT	Willem Rudolf Westra van Holthe	Deputy Chief Minister. Minister for: Primary Industries and Fisheries; Land Resource Management; Essential Services; Public Employment; Member for Katherine			NT Government Minister	The NT Government and the Chief Minister have been appropriately supporting of Origin's exploration activities as it endeavours to better understand the geology and opportunity of further developing the Northern Territory's onshore natural gas resources.  <i>* No outstanding items / concerns regarding Origin's exploration activities and / or the NT's onshore natural gas.</i>	Engage throughout
Parliament of NT	Garry Higgins	Minister for Sport and Recreation; Environment; Arts and Museums			NT Government Minister	Discussions regarding community engagement and maintaining a social license to operate.	Engage throughout
Parliament of NT	David Tollner	Minister for Mines and Energy; Treasurer; Minister for Lands and Planning;	2013 to present	Email; Telephone and Direct Engagement (Meetings)	NT Government Minister	The Minister has been supportive of a continuing, well regulated exploration program.  <i>* No outstanding items / concerns regarding Origin's exploration activities and / or the NT's onshore natural gas.</i>	Engage throughout
Northern Territory GEOLOGICAL Survey (NTGS) and AGES	Ian Scrimmour Dorothy Close	Executive Director	2013 to present	Meetings; Conference Presenter and participant	Ongoing	Consistent and regular collaboration and enagement with the NTGS to expedite the technical understanding of the Beetaloo Sub Basin.  <i>* No known concerns regarding Origin's exploration activities and / or the NT's onshore natural gas.</i>	Engage throughout

Stakeholder / Organisation	Contact Name	Title	Date(s)	Mode	Functions, Interests, Activities of Stakeholder	Origin Overview of Engagement and Relationship	Status
Michael Gunner	Michael Gunner	Leader of the Opposition; Member for Fannie Bay	13/08/2015	Email; Telephone and Direct Engagement (Meetings)	Ongoing	<p>Consistent and regular enagement with the Opposition, Territoy Labor, to explain the exploration processes and activities relating to the Origin permits in the Beetaloo Basin.</p> <ul style="list-style-type: none"> <li>- Targetted and specific meeting with Opposition Leader and Caucus to share results of the Deloitte Access Economic Report on the economic benefits of developing the NTs onshore natural gas resources;</li> <li>- Targetted and specific meeting(s) with the Opposition Leader and Chief of Staff to discuss exploration activities and Territory Labor's moratorium policy on Hydraulic Fracture Stimulation</li> </ul> <p><i>* No known outstanding concerns regarding Origin's exploration activities and / or the NT's onshore natural gas.</i></p>	Engage throughout
Nicole Manison (Member for Leanyer)	Nicole Manison	Member for Leanyer	2015 to present	Meetings	Ongoing	<p>Consistent and regular enagement with the Opposition, Territoy Labor explain the exploration processes / activities relating to the Origin permits in the Beetaloo Sub Basin.</p> <p><i>* No known outstanding concerns regarding Origin's exploration activities and / or the NT's onshore natural gas.</i></p>	Engage throughout
Gerry McCarthy (Member for Barkly)	Gerry McCarthy	Member for Barkly	2015 to present	Meetings	Ongoing	<p>Consistent and regular enagement with the Opposition, Territoy Labor explain the exploration processes / activities relating to the Origin permits in the Beetaloo Sub Basin.</p> <p><i>* No known outstanding concerns regarding Origin's exploration activities and / or the NT's onshore natural gas.</i></p>	Engage throughout

## ORIGIN ENERGY - Origin Beetaloo Stakeholder Consultation 2014 to 2016

Status Options: Engage throughout; Inform only; Not relevant person; Don't want further info; Close

Stakeholder / Organisation	Contact Name	Title	Date(s)	Mode	Functions, Interests, Activities of Stakeholder	Origin Overview of Engagement and Relationship	Status
Northern Land Council (Jurisdiction across Origin Permit Areas)	Joe Morrison, Greg McDonald, Rhonda Yates, and Howard Smith	CEO, NLC Management and Staff	2013 to present	Email; Telephone and Direct Engagement (Meetings)	Independent statutory authority of the Commonwealth, responsible for assisting Aboriginal peoples in the Top End of the Northern Territory in securing land rights and Native Title. Also plays a role in assisting TOs in negotiations with government, mineral resource and energy companies and businesses wanting access to, and use of land	<p>Engagement with the NLC has been constructive, albeit - at times - somewhat slow though Origin suspect this relates to resourcing. Together with the NLC, Origin has participated in multiple meetings, including two On-Country meetings and numerous scouting and cultural heritage clearance surveys. TOs identified by the NLC endorsed all of Origins 2015 and 2016 activities post the completion of consultations and clearance surveys to identify Restricted Work Areas (RWAs) and provide additional reports to support AAPA Certificate applications allowing for the sacred site protection and approvals. To date Origin and TOs (supported by the NLC) have :</p> <ul style="list-style-type: none"> <li>- identified a number of RWAs which are now integrated into project planning</li> <li>- received cultural heritage clearance for approximately 10 potential well site locations</li> <li>- provided training and pre-employment opportunities to Traditional Owners (three now working with Origin sub-contractor)</li> <li>- remitted royalty payments as per Exploration Agreements with no disputes over budget and/or amounts</li> <li>- Welcome to Country scheduled to take place in mid to late July 2016</li> </ul> <p><i>* No known concerns regarding Origin's exploration activities and / or the NT's onshore natural gas.</i></p>	Engage Throughout

Stakeholder / Organisation	Contact Name	Title	Date(s)	Mode	Functions, Interests, Activities of Stakeholder	Origin Overview of Engagement and Relationship	Status
Central Land Council (no jurisdiction across Origin permit areas)	CEO and Julianne Stohles		2016 to present	Email; and Direct Engagement	Independent statutory authority of the Commonwealth, responsible for assisting Aboriginal peoples in central Northern Territory in securing land rights and Native Title. Also plays a role in assisting TOs in negotiations with government, mineral resource and energy companies and businesses wanting access to, and use of indigenous land	Engagement with the CLC has been limited to Origin's Corporate Affairs Manager (Northern Australia) meeting with CLC in her capacity as Chair of the APPEA Onshore Steering Committee. This engagement has largely been in relation to Territory Labor's moratorium policy on unconventional gas exploration and its impact on Traditional Owners, in particularly restricting their opportunity to make decisions about what projects may or may not occur on their land.  <i>* No known concerns regarding Origin's exploration activities and / or the NT's onshore natural gas.</i>	Engage Throughout
Aboriginal Areas Protection Authority (AAPA)	Dr Ben Scambray and Wendy Joan Forscutt	CEO, Registrar		Email; and Telephone	Statutory authority responsible for administering the Northern Territory Aboriginal Sacred Site Act/ Legislation		Engage Throughout

## ORIGIN ENERGY - Origin Beetaloo Stakeholder Consultation 2014 to 2016

Status Options: Engage throughout; Inform only; Not relevant person; Don't want further info; Close

Stakeholder / Organisation	Contact Name	Title	Date(s)	Mode	Functions, Interests, Activities of Stakeholder	Origin Overview of Engagement and Relationship	Status
Amungee Mungee	Adrian & Emma Brown		2015 to present	Emails; Phone; Direct Engagement - including an oilfield familiarisation tour of Origin's QLD CSG assets	Amungee Mungee Station had one (1) vertical well drilled in 2015 as well as one (1) horizontal well. During 2016, the horizontal well at Amungee Mungee has been cased and is scheduled to be fracture stimulated pending regulatory and necessary approvals.	Land access negotiations involved very detailed discussions and a very thorough land access agreement (LAA) that Origin entered into fully voluntarily prior to any regulatory requirement. The original LAA was signed in May 2015, however, there have been amendments to the agreements as required (e.g. to undertake horizontal drilling) that have been reached through amicable negotiation. Origin has covered costs of the landholder for time spent and also for external legal counsel. The primary concerns of the landholders are ground water contamination, to address these concerns the details of well integrity have been shared in multiple engagements with the landholders and the groundwater monitoring program (GMP) on Amungee Mungee has been increased (as per Origin's submission of our Beetaloo GMP). Origin has installed three monitoring bores in 2016 at substantial expense to ensure that a previously unmapped/unreported (in formal literature) shallow aquifer is monitored prior to HFS. The relationship has built up trust between the parties at a steady rate by working together to address the issues in a timely manner. Adrian has always been progressive in obtaining knowledge and understanding of our program and Origin has always acted in good faith through transparency of information - namely water monitoring, environmental management and code of conduct. LAA in place for 1 vertical well LAA in place for 1 horizontal well LAA in final stages of negotiation for 1 horizontal well fracture stimulation	Engage Throughout
Kalala	Ray & Pam Murphy		2015 to present	Emails; Phone; Direct Engagement	Kalala Station was the property that Origin drilled it first vertical well on in 2015.	Agreement to land access was reached in May 2015 with Ray and Pam Murphy. Engagements were business like, positive and constructive. The area of primary interest for the Murphys is the value add to the region and local economy including, but not limited to, opportunities to provide sub-contracting services where applicable (mainly civil construction). Origin was able to facilitate through its constructors the use of services during the construction works associated with the Kalala S-1 well. The 2015 vertical well was successfully completed and no further activities are currently forecast on Kalala. Nonetheless, Origin has maintained an appropriate level and frequency of contact and support to the landholder.	Engage Throughout



Stakeholder / Organisation	Contact Name	Title	Date(s)	Mode	Functions, Interests, Activities of Stakeholder	Origin Overview of Engagement and Relationship	Status
Beetaloo	Jane & Scotty Armstrong		2015 to present	Emails; Phone; Direct Engagement	Beetaloo Station is earmarked to have 1 vertical well drilled on their property during 2016. There is potential for that well to be fracture stimulated pending results of the well.	Land access for 1 vertical well was reached in October 2015, however, activities were deferred by agreement until 2016 given the lateness in the season and the potential risk of have a rig 'stranded' on the station during the wet season. Negotiations were extended and included external legal counsel and external land valuation advice (all funded by Origin), however, the relationship has been open and frank, and Origin representatives have made multiple trips to Beetaloo Station to address questions and concerns. The comprehensive LAA in place covers many of the principles required for development, although the scope of work is of course limited to the exploration phase of work as per our permit obligations. Their primary areas of interest have been, and remain, potential contamination risk to the aquifer through drilling and fracking procedures; and upholding the integrity of the access road that they use for livestock transporting. These areas of interest have been addressed satisfactorily to conclude the LAA. Origin will provide a substantially upgraded station road for Beetaloo Station that will be advantageous for cattle transport operations and be of direct benefit to Beetaloo Station - an excellent example of mutually beneficial outcomes / shared infrastructure from exploration activity. - LAA in place for one (1) vertical well	Engage Throughout
Newcastle Waters	Jak Andrews		2015 to present	Emails; Phone; Direct Engagement	Newcastle Waters Station is not subject to drilling activities though Origin is working with this landholder with regard to the provision of water and potentially use of their airstrip.	Negotiations for use of the NCW airstrip and water bore were productive and without conflict or concern. The relationship is strong and a well established partnership has been struck for any future engagement. - Consent and Agreement in place for water use - Alignment for use and upgrade of airstrip, though not proceeding due to time constraints to deliver material impact to the project	
Nutwood Downs	Rod & Rayna Dunbar		2015 to present	Emails; Phone; Direct Engagement	Nutwood Downs Station is earmarked to have one (1) vertical well drilled on their property during 2016. There is potential for that well to be fracture stimulated pending results of the well.	The Nutwood Downs Station landholders - the Dunbars, have been very cooperative, supportive and approached engagement from a logical and thoughtful position. It is fair and reasonable to say that they are comfortable with the industry, proposed activities on their property and the associated technical processes. Their primary areas of interest have been around any potential for a future, and long term, development of the basin in relation to their property, in particular, any impact on their infrastructure; property valuation(s) and correlating compensation for impacted productive acreage. Origin describes the relationship as open and transparent and have shared information around likely development scenarios - noting such scenarios are highly speculative given the early stages of exploration. - LAA in final stages of negotiation for 1 vertical well	

Stakeholder / Organisation	Contact Name	Title	Date(s)	Mode	Functions, Interests, Activities of Stakeholder	Origin Overview of Engagement and Relationship	Status
Hayfield	Justin & Dyer/ Brad & Lisa Inglis		2015 to present	Emails; Phone; Direct Engagement	Hayfield / Sturt Plains Stations are landholders that Origin have engaged with as there is intersection with road / access tracks between Hayfield and Beetaloo. No drilling activities presently forecast to take place on these properties.]	LAA was achieved in early 2016 which included an upgrade to an existing road through their property allowing access to Beetaloo Station and the Beetaloo W-1 well site.	



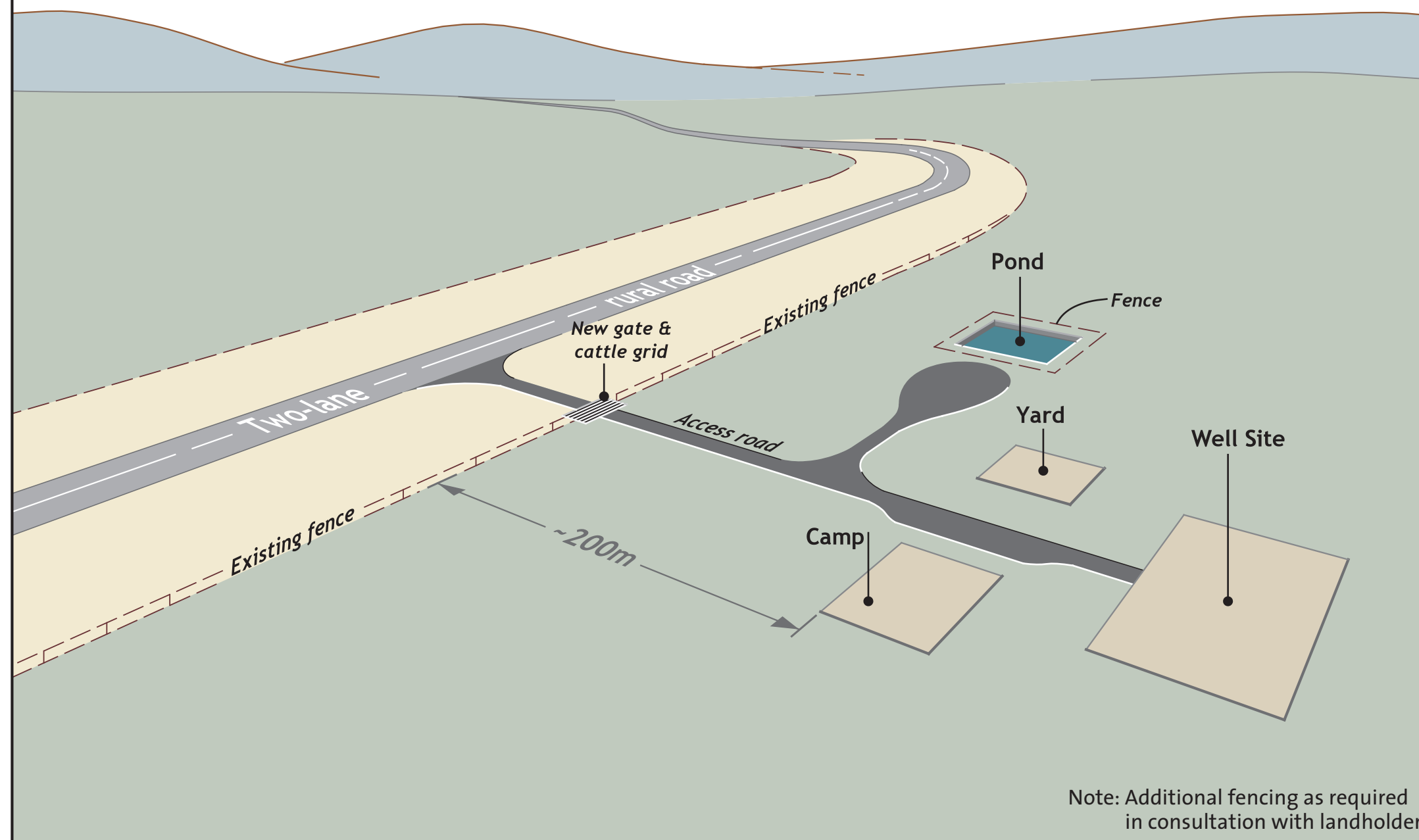
## WORK PROGRAM FOR 2016

Continue geological studies in all permits. NLC has completed sacred site clearance of an additional 6 potential well locations. The 2016 Work Program will be carried out on these locations or on the locations cleared in 2014.

**EP 98.** Drill one vertical well  
Hydraulic fracture stimulate one vertical well  
Drill and hydraulic stimulate one horizontal well

**EP 117.** Review results of studies and Beetaloo W-1 well to plan for 2017 Work Program (mainly in EP 117)

### Drilling Surface Location

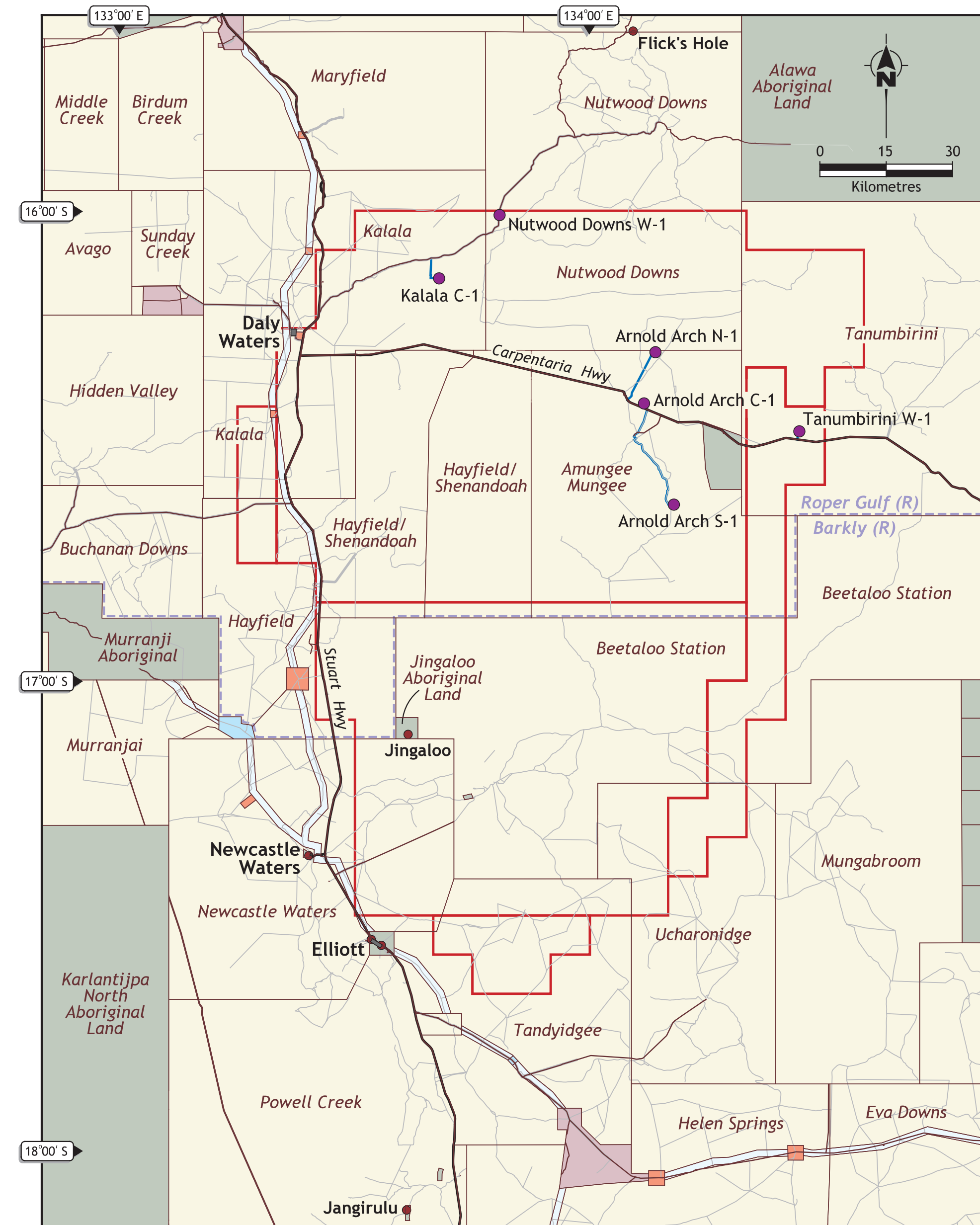


## CULTURAL HERITAGE AND NATIVE TITLE

Origin's operations will always comply with the Northern Territory Cultural Heritage Legislation and the Native Title Act.

Our approach to managing cultural heritage embodies the following principles:

- respecting indigenous people and their historic and contemporary history
- respecting the rights and interests of the communities in which Origin operates
- understanding and respecting community cultural, historical and heritage values
- avoiding, minimising and/or mitigating impacts on cultural heritage value



### Potential Well Location Map

#### Legend

Beetaloo permits	Pastoral Lease	Government	Potential well location
Sealed road	Freehold	Vacant Crown Land	Proposed access route
Unsealed road	Crown Lease	Reserve	Local Government Areas (2014)
Unsealed track	Aboriginal community	Town	



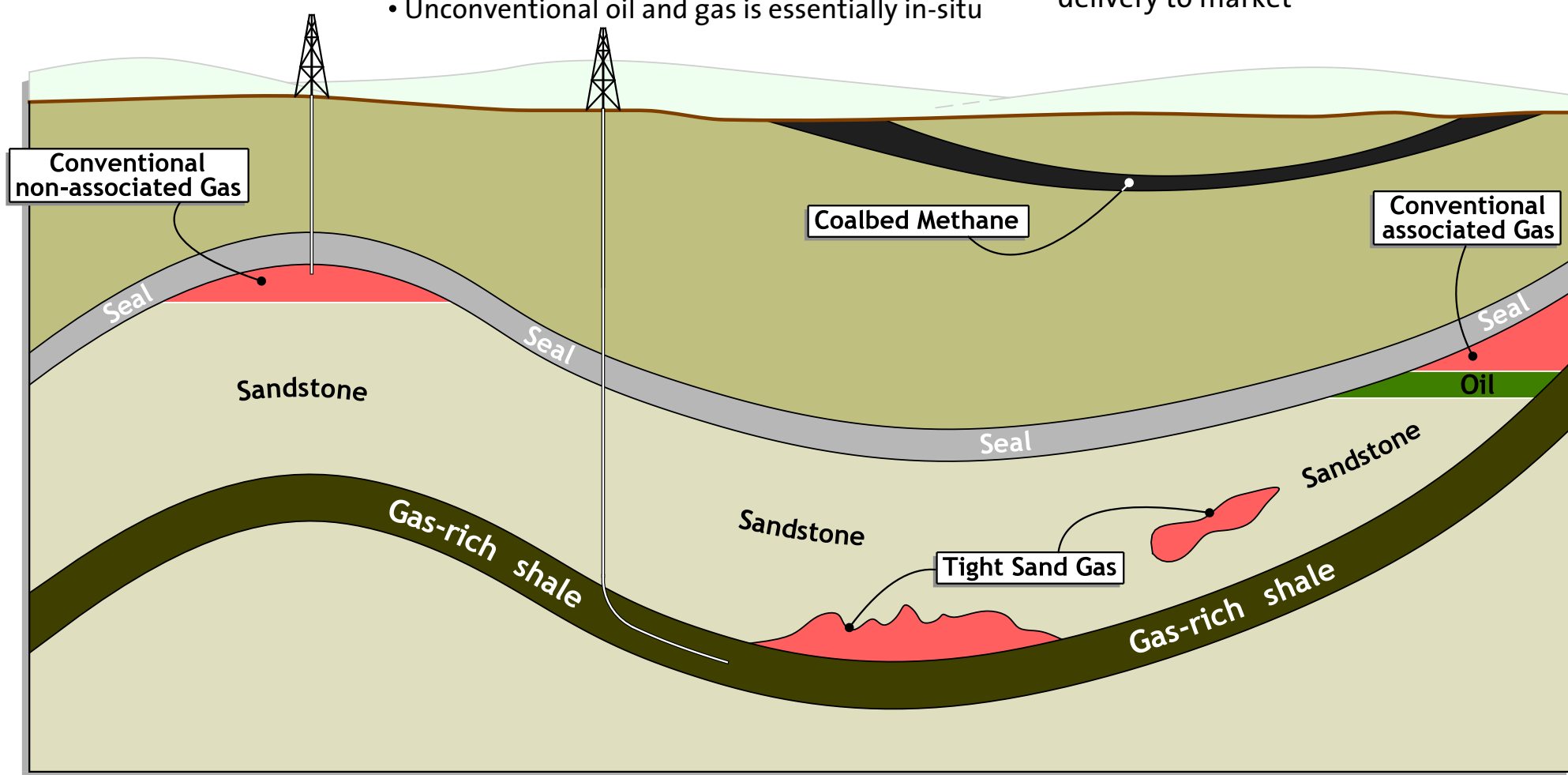


# SHALE GAS

What are unconventional hydrocarbons and 'Shale Gas'

## UNCONVENTIONAL vs CONVENTIONAL

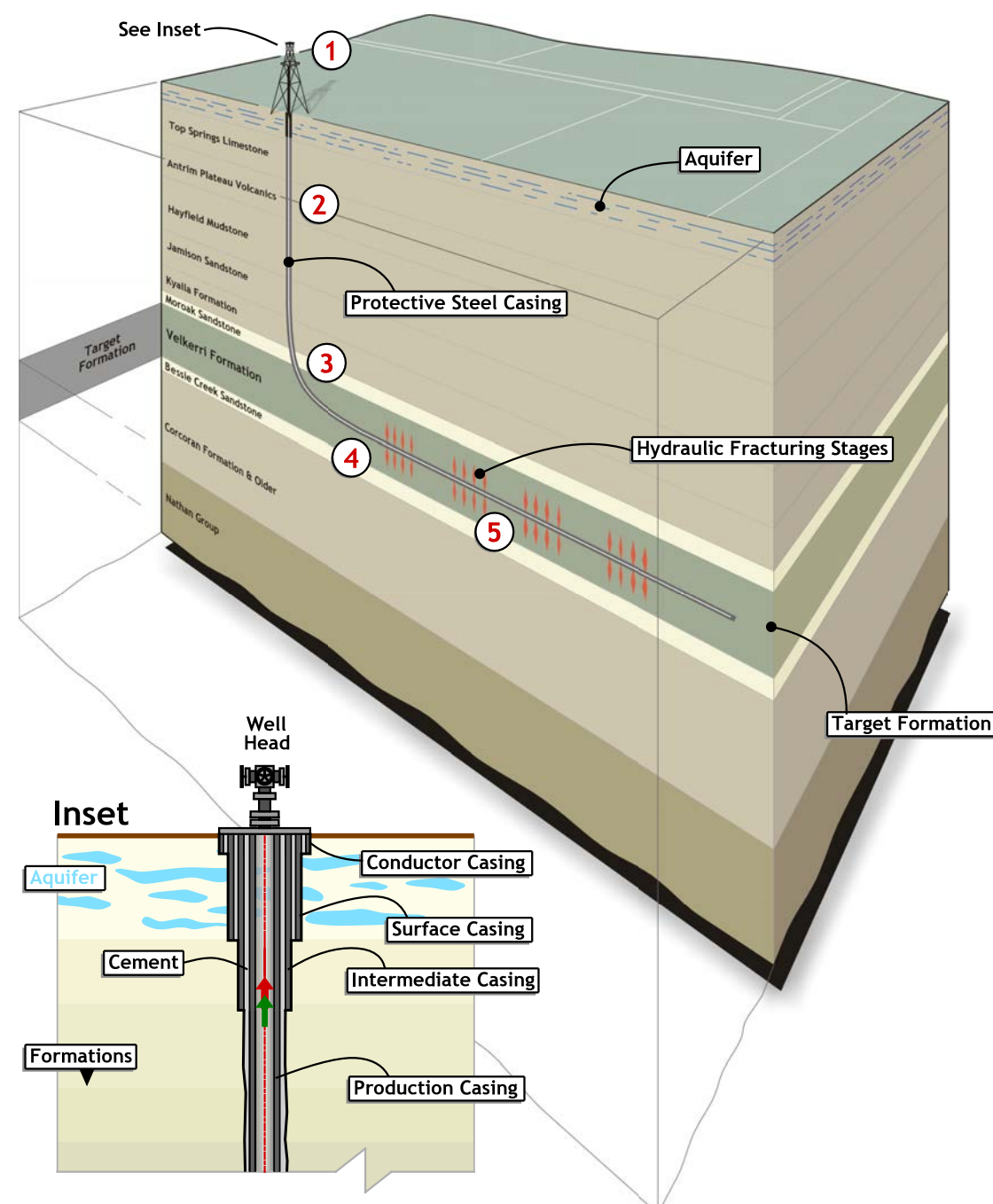
- No universally accepted definitions, though generally accepted to do with whether the hydrocarbon will flow naturally
- Fundamentally different accumulation styles:
  - Conventional oil and gas has migrated
  - Unconventional oil and gas is essentially in-situ
- Very different economic profile and drivers for commercial extraction, production and delivery to market



## LONG REACH HORIZONTAL DRILLING

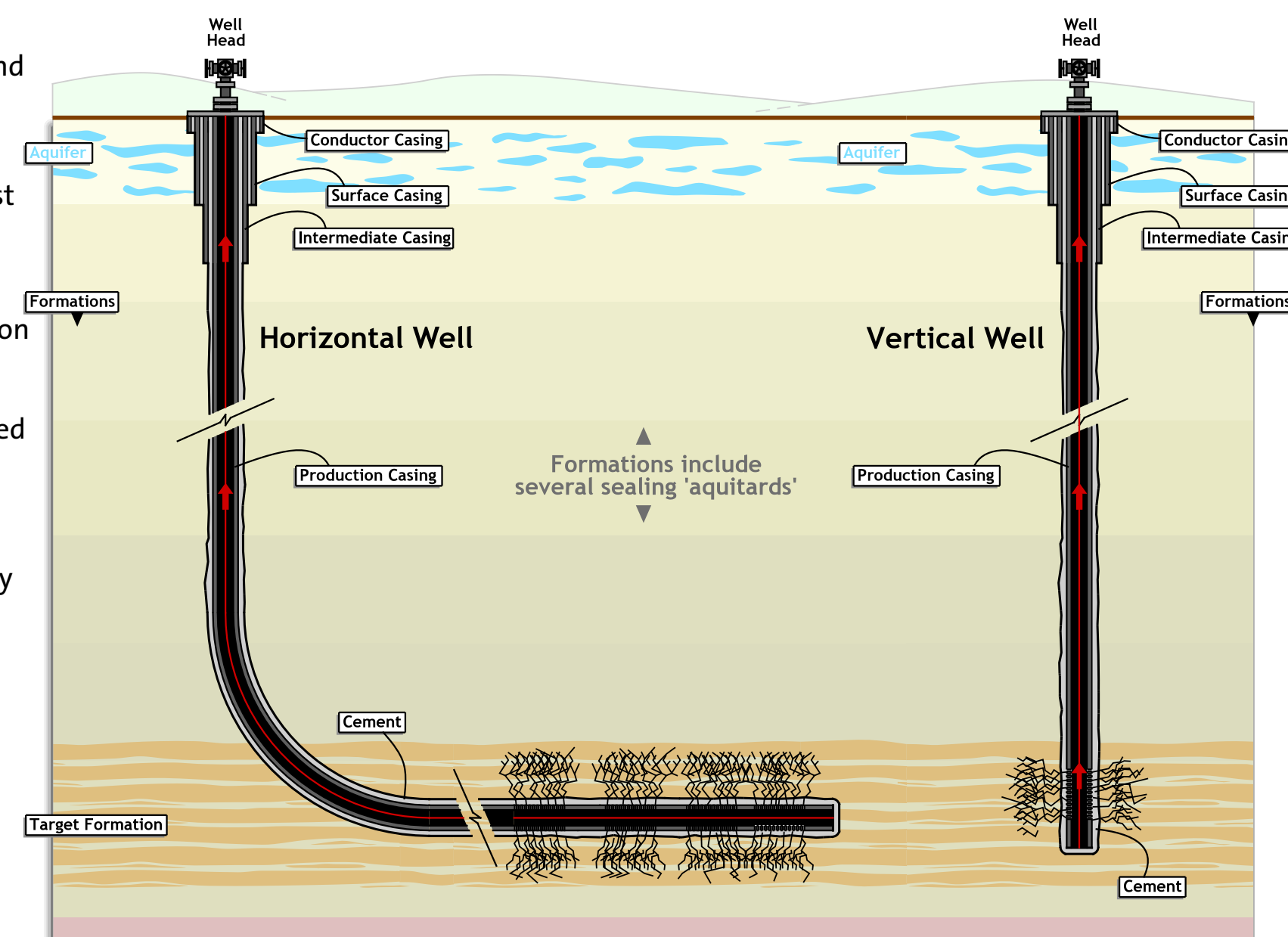
Steps in Horizontal Drilling:

- 1 Negotiate and agree access, obtain approval and bring in drilling rig and equipment
- 2 Drill vertical section of well using conventional methods
- 3 Drill kick-off (curved) section, with the use of a downhole motor mounted directly above the bit, in order to make the turn from vertical to horizontal. Downhole instruments called MWD (measuring while drilling) packages transmit sensor readings upward, allowing operators at the surface to build the angle
- 4 Drill horizontal wellbore, still using MWD to hold the angle and direction
- 5 Case off the well with steel casing and cement to allow for completion and fracture stimulation, preparing the well for production



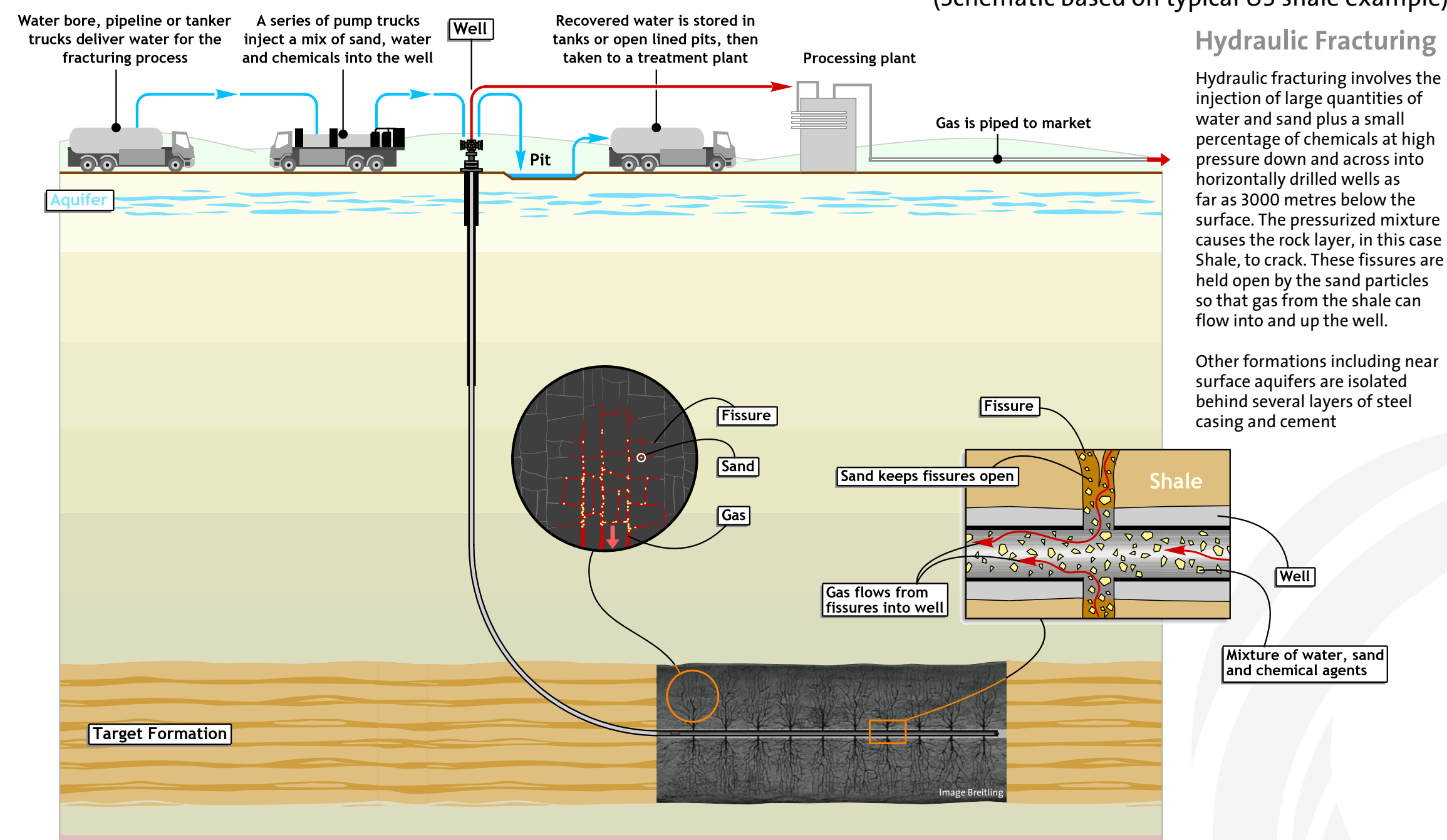
## VERTICAL WELLS vs LONG REACH HORIZONTAL WELLS

- Origin will drill both vertical and horizontal wells during the Exploration Phase/s
- Vertical wells allow a more cost effective assessment of the potential for gas and liquids in the target zones and provide some information on production capability
- Horizontal wells will be required to assess the potential for economic gas and liquid recovery rates
- Horizontal wells are most likely to be required for field development



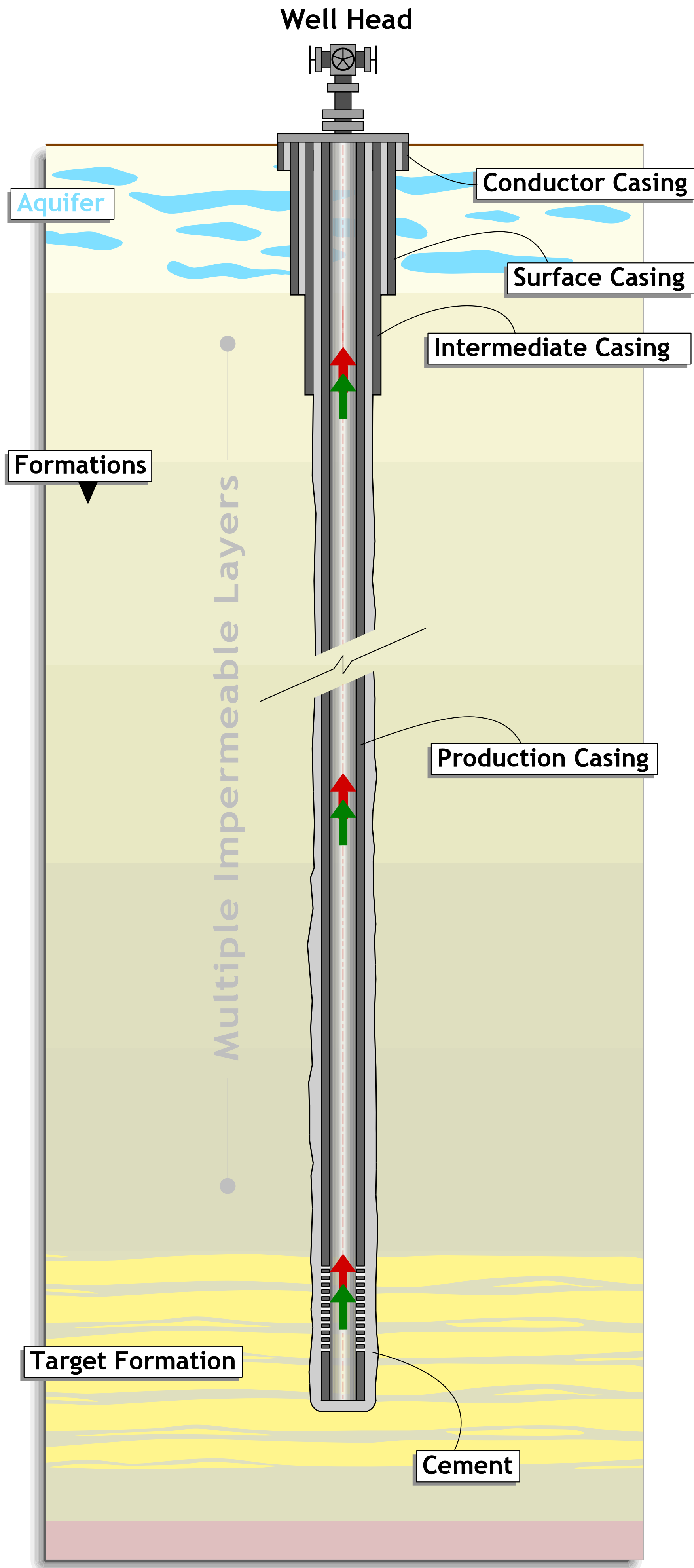
## HYDRAULIC FRACTURE STIMULATION

(Schematic based on typical US shale example)



# WELLBORE CONSTRUCTION

## Protection of aquifers



A typical wellbore consists of three main components to be installed: casing, wellhead and cement

The casing strings and cement hold the hole open and protect the surrounding formations from cross flow between permeable formations

Casing is designed to ensure that it is strong enough to withstand the worst case loads that it could be subjected to

Cement is pumped down the casing string and back up the outside of the casing

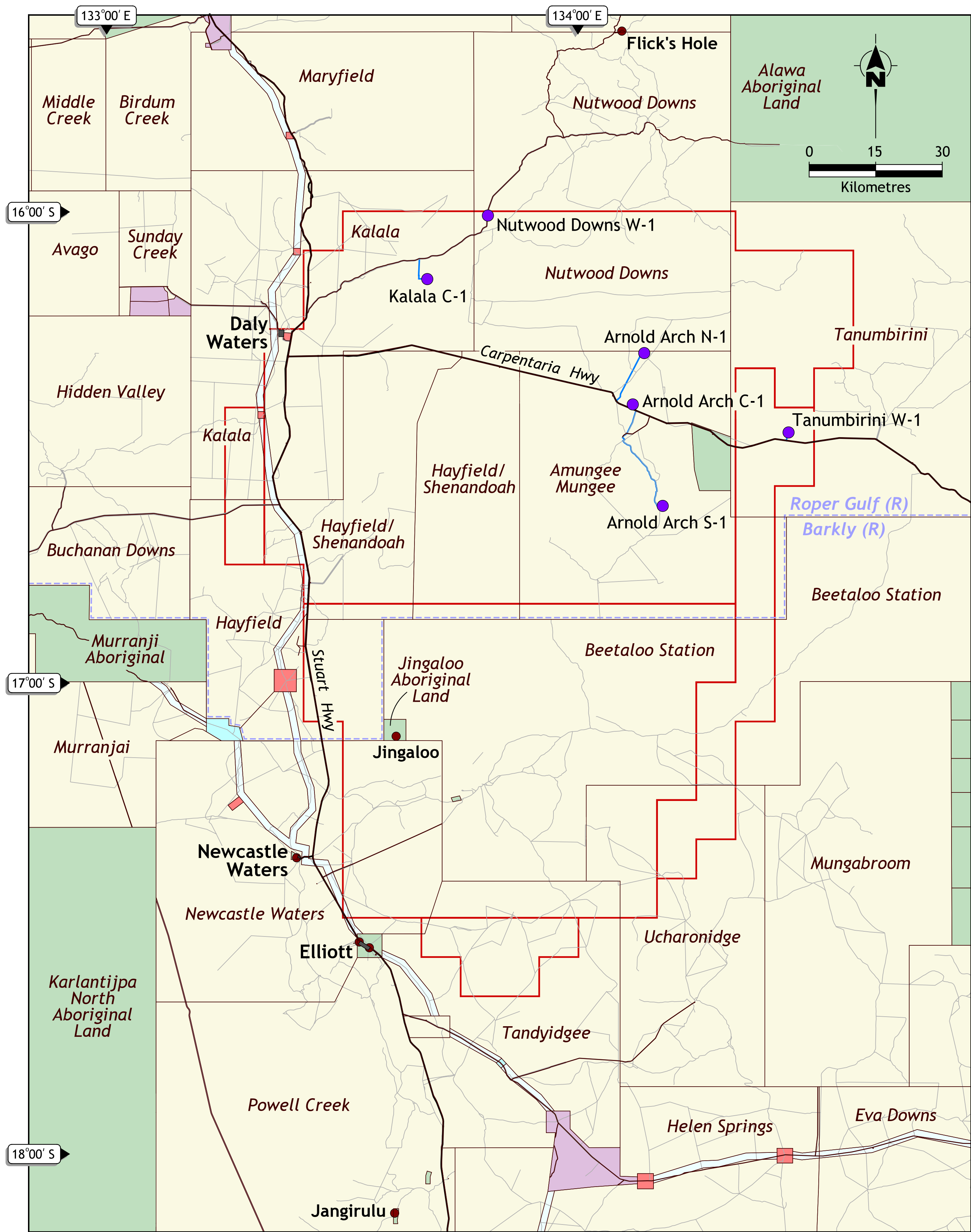
Well appropriately decommissioned at end of useful life

Elimination of risk of aquifer contamination also achieved by:

- Regulatory controls and oversight
- Execution of best practices by reputable and proven operators
- Casing and cementing design performance standards
- Cement bond logs
- Pressure tests



# 2016 WORK PROGRAM



## Legend

- |                  |                      |                   |                               |
|------------------|----------------------|-------------------|-------------------------------|
| Beetaloo permits | Pastoral Lease       | Government        | Potential well location       |
| Sealed road      | Freehold             | Vacant Crown Land | Proposed access route         |
| Unsealed road    | Crown Lease          | Reserve           | Local Government Areas (2014) |
| Unsealed track   | Aboriginal community | Town              |                               |





# BEETALOO BASIN SOCIAL & COMMERCIAL IMPACT

Origin works closely with its contractors in utilising local service providers where possible. The main focus in selection of services is capabilities and cost in order to effectively deliver the required needs of an exploration drilling project.

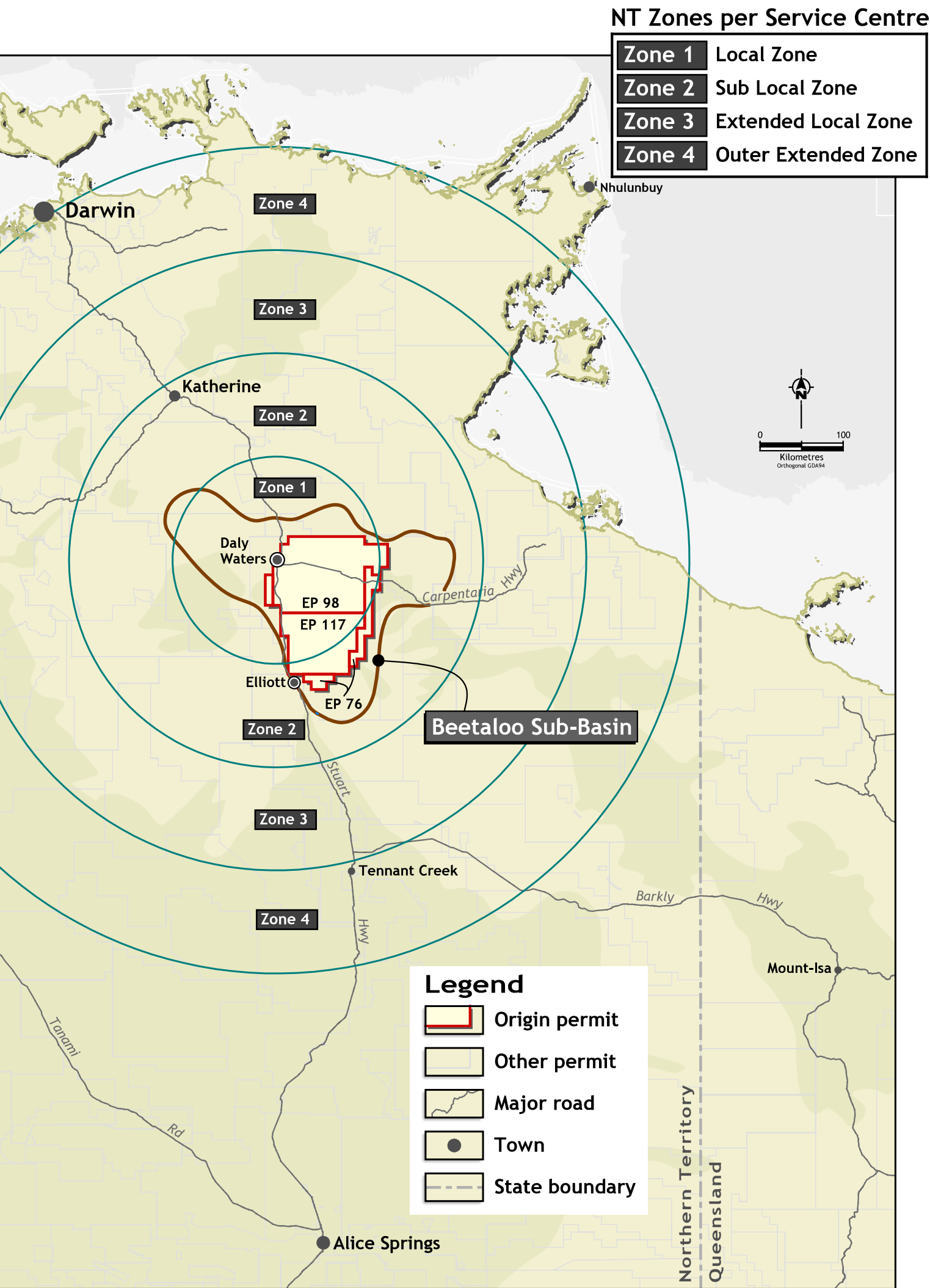
There are two streams of work packages that make up the program and these are broken into:

## CIVIL CONSTRUCTION

- Roads, drilling pads, camp pads, water storage and bores

## DRILLING & STIMULATION

- Deep well drilling and casing, fracking spreads



## REGIONAL BUY PROGRAM

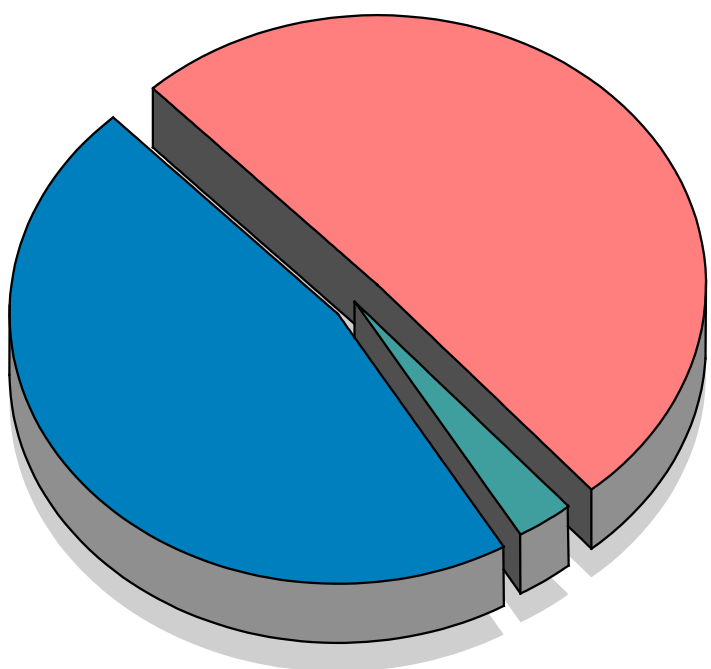


Origin's Regional Buy program has focused on sourcing from local service providers and centres.

Given the isolation of the project, this mainly consists of Daly Waters region, Elliot, Tennant Creek, Katherine and Darwin.

Our civil program achieved 20% of total budget going into the local economy.

● Darwin ● Katherine ● Local



Beetaloo Project Site

## DCGI TRAINING PACKAGE Well Site Induction Process



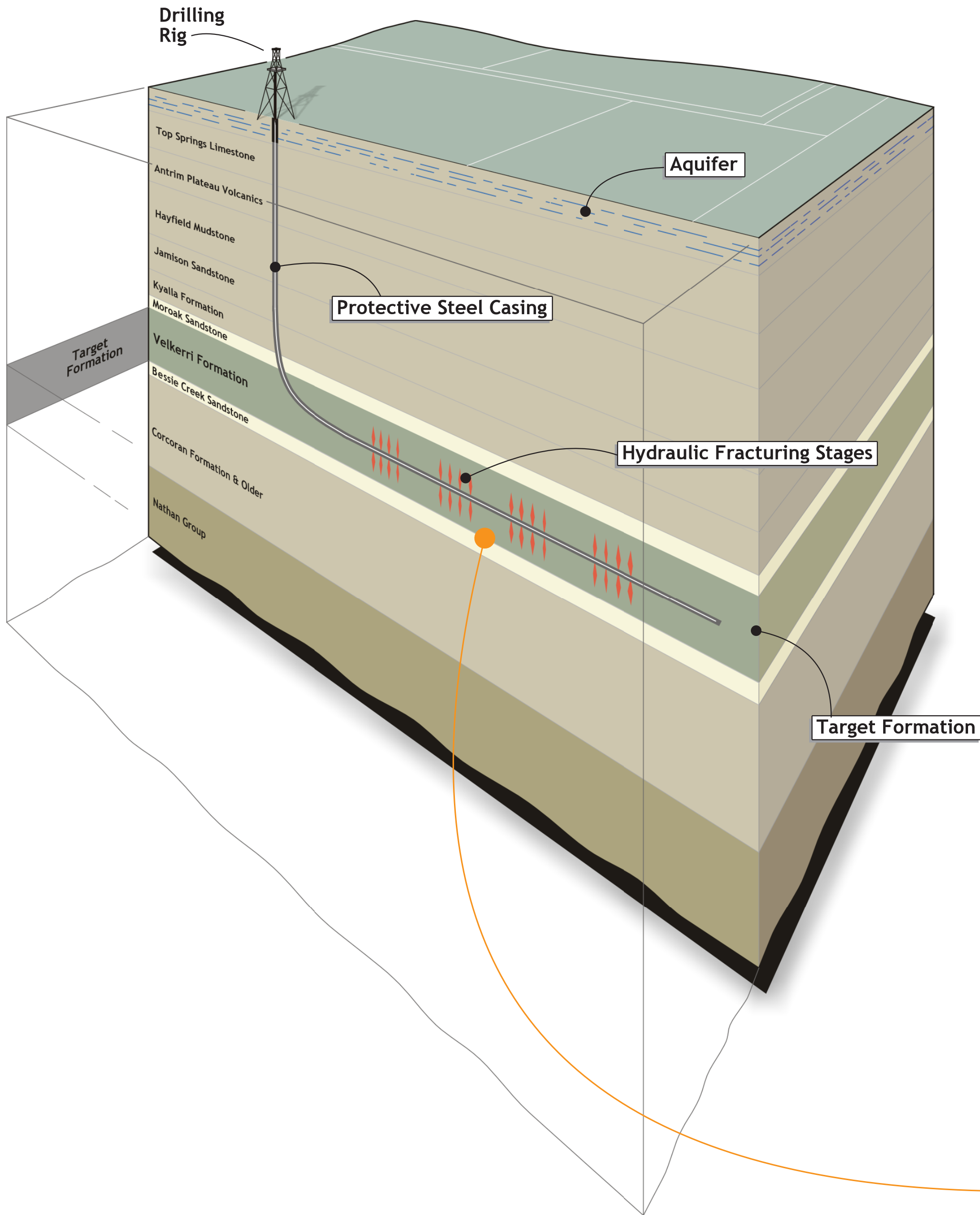
In order to ensure the safety of all personnel, Origin hosted an induction training day in Katherine & Darwin in April 2016.

DCGI Training allows personnel to enter an Origin work site and in fact any other Petroleum work site that recognises this industry wide training accreditation. This is an initiative that will increase the capabilities of local workers and businesses towards future opportunities.



# HYDRAULIC FRACTURING

## Potential for groundwater connectivity from the reservoir zone



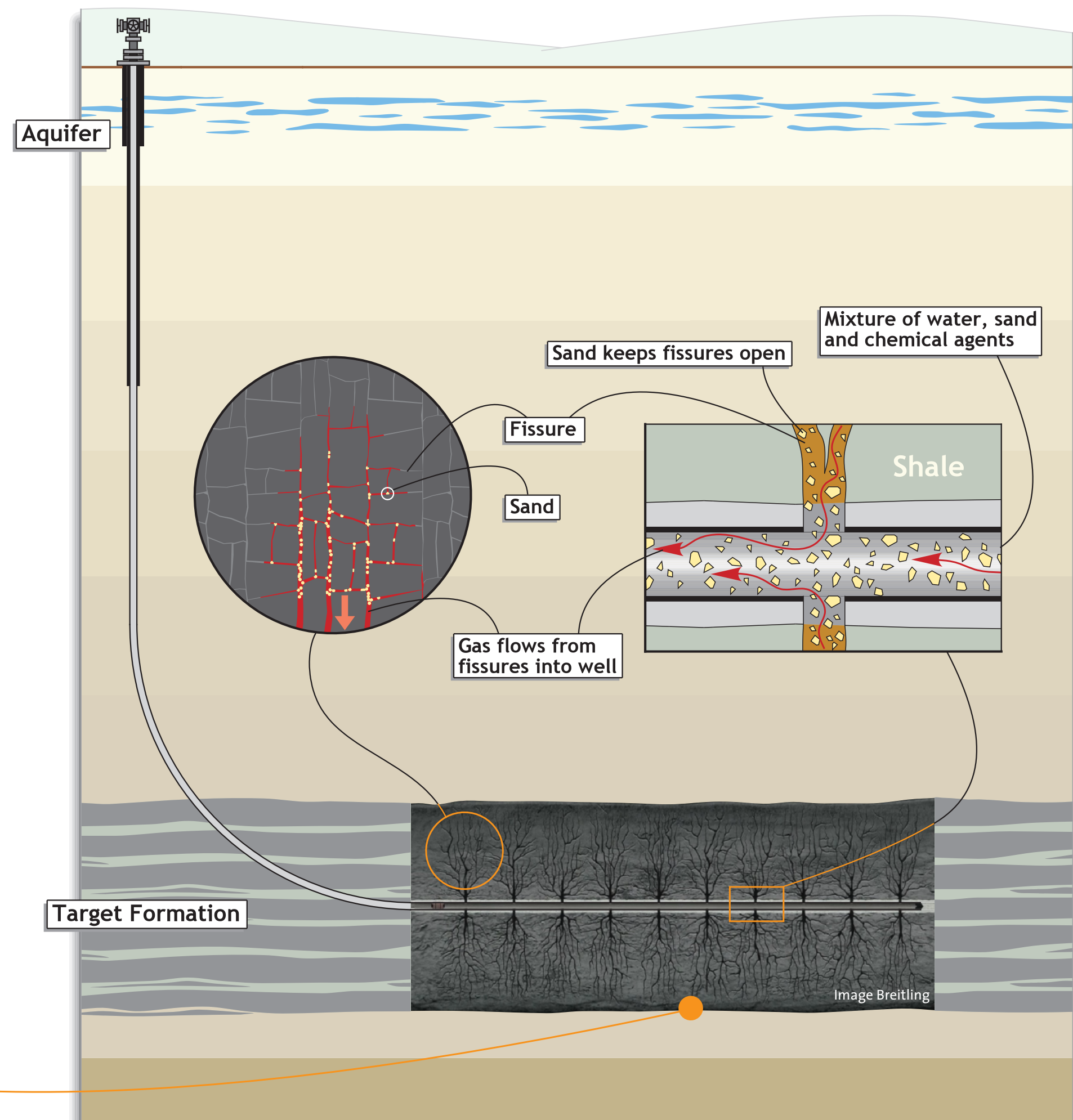
- Induced fractures do not create communication pathways between reservoir and aquifer levels, because:
  - Physical distance between Velkerri formation and Tindall aquifer
  - Aquitard properties of the intervening geological layers
  - Volume of water and sand is insufficient to create the energy/pressure require to create pathways
- Potential for existing conduits (for example, natural vertical fractures or old abandoned wellbores) providing a pathway for injected fluid to reach a fresh water zone

### Unlikely because:

- Pressure required to overcome hydrostatic head and frictional losses between reservoir and fresh water
- High leak off into faults and natural fracture systems
- Extremely low density of existing wells

### Mitigation techniques:

- Mapping of large structures/faults - avoidance
- Use of microseismic to monitor completions in areas where potential conduits have been identified



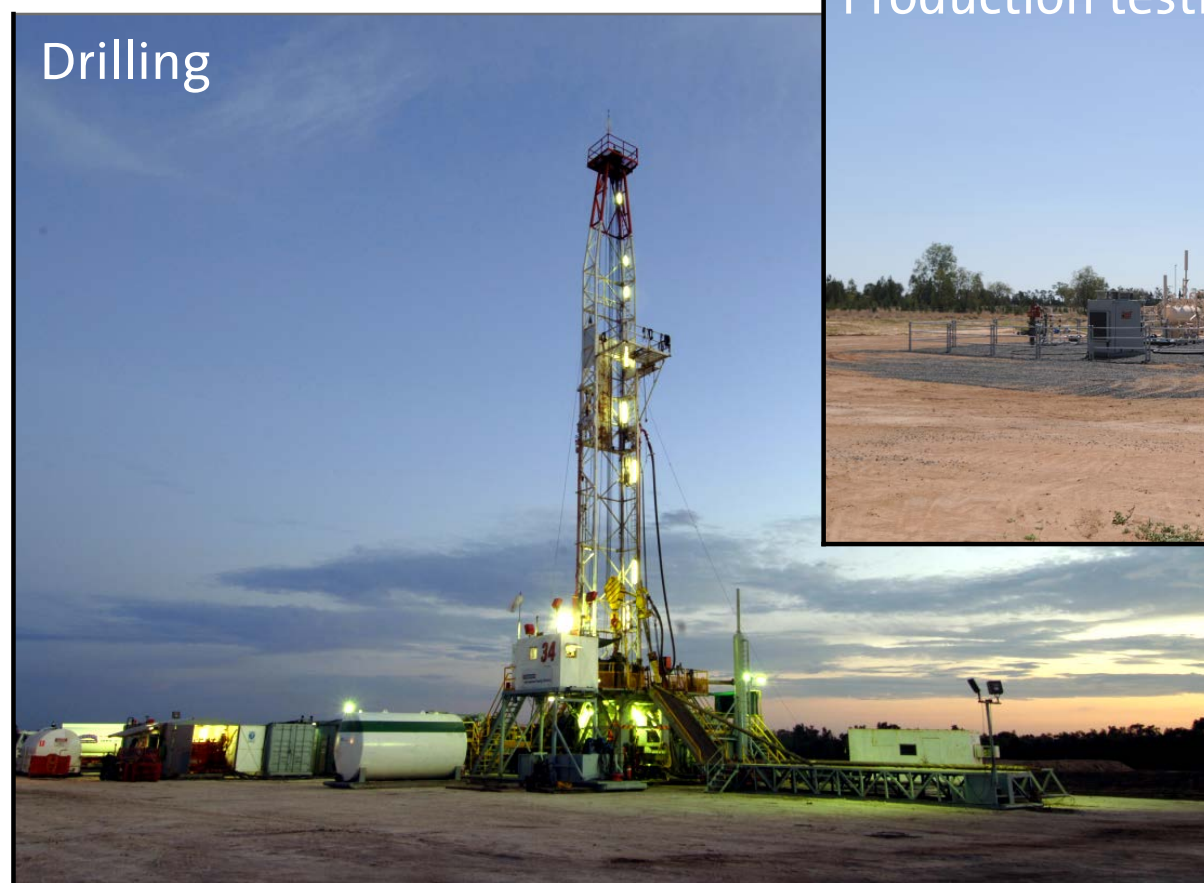




# GAS EXPLORATION AND DEVELOPMENT

## VERTICAL WELL

Various development stages of a successful vertical well:



## PIPELINES

Various stages of pipeline activity:

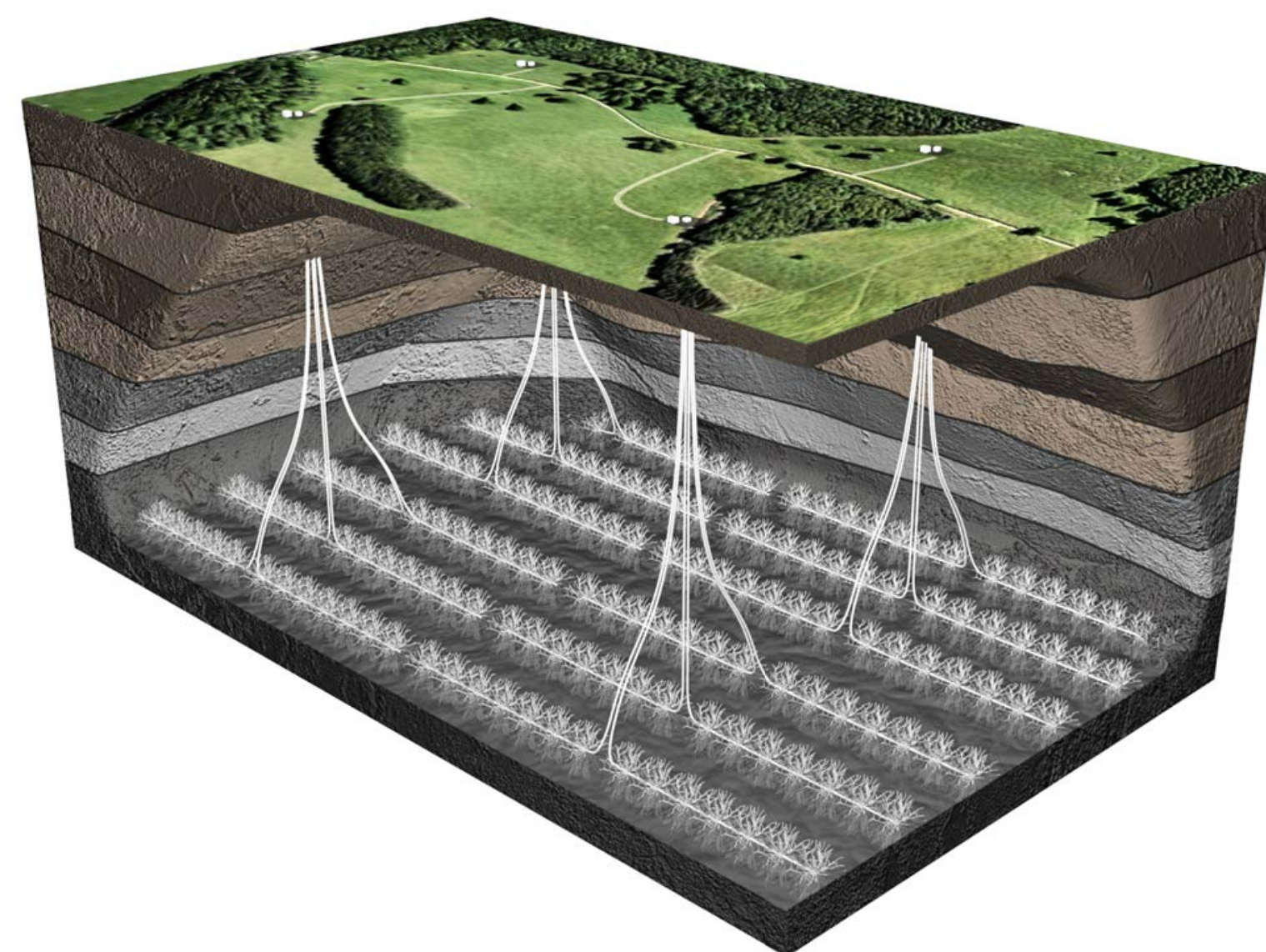


Ongoing operation(s) (post rehabilitation)



## A TYPICAL PAD DEVELOPMENT WITH LONG REACH HORIZONTAL WELLS

This example is 6 wells per pad



## PILOT TEST PAD

A typical (US) pilot test pad

This example has 8 producing wells, similar layout for a production pad

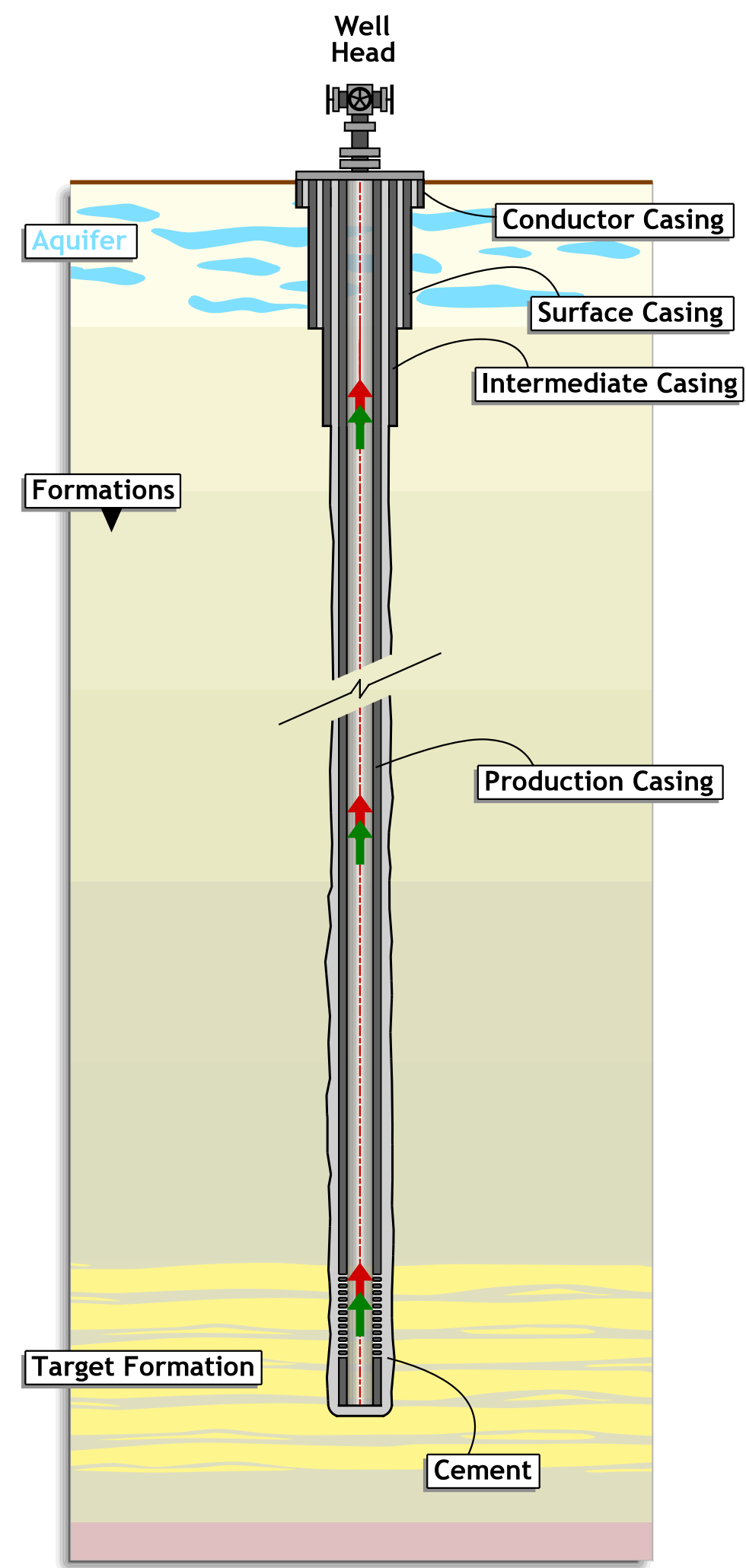






# EXPLORATION WELL DRILLING

**WELLBORE CONSTRUCTION**  
The wellbore construction ensures aquifers are protected behind multiple steel casings.



Drill Site

6-9 months prior	Field Surveys	~7 days	Undertake environmental, sacred site, cultural heritage, water baseline and civil surveys
	Civil Works	~14 days	Clear land, dig pits, build access roads, fence area, etc. Civil construction equipment.
1-2 months prior	Move In/Rig Up	~14 Days	Mobilise drilling rig (likely from interstate) and move it onto site. Set up drilling rig and associated equipment on site.
	Top Hole Sections	~10 Days	Drill top hole sections and set casing and cement. Main goals to protect surface aquifer and set the well up to achieve target depth.
	Install and Test BOP	~2 Days	Install and test blowout preventer. Critical piece of safety equipment used to hold back pressure from the well if required.
	Drill Production Hole	~30 Days	Drilling to our target depth for investigating the resource.
	Cutting Core	~5 Days	Cut cylindrical cores from the reservoir rock to bring to surface for testing.
Main Activity	Wireline Evaluation	~2 Days	Running specially designed electronic tools downhole to measure various properties of the rock that help geophysicists identify it.
	Decommission or Suspend Well	~2.5 Days	The well will be secured, either for later re-entry for testing or for decommissioning.
Immediately after drilling or several years later			

Minimal Land Disturbance

## WORK FLOW







# ABOUT ORIGIN ENERGY

Origin is the leading Australian integrated energy company. Being integrated, Origin has diverse operations spanning across the energy supply chain; from gas exploration and production to power generation and energy retailing.

## FAST FACTS

Australian company

5,000+

employees

160,000+

shareholders

Focused on major exploration areas in Australia

4.3 million

electricity, natural gas and  
LPG customer accounts  
across Australia

6,010 MW

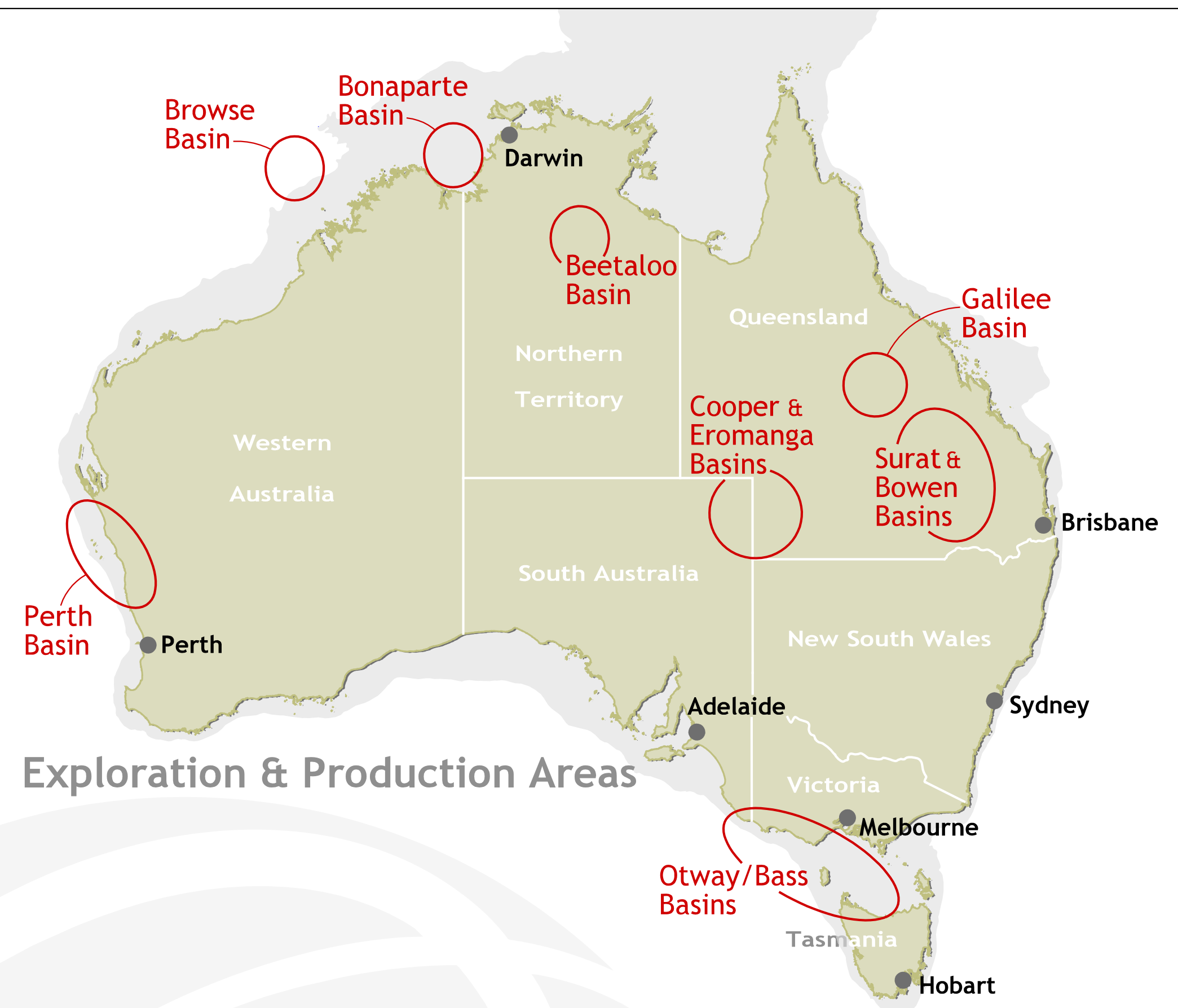
owned or contracted  
power generation  
capacity

Portfolio

of renewable energy  
opportunities in  
Australia and  
Internationally

Market leading

green energy retailer



## HOW WE OPERATE

Origin operates by honouring its principles, commitments, values and objectives related to stakeholders, communities, and sustainable practices.

We work with local communities and stakeholders to build positive and harmonious foundations for long-term relationships, ongoing access to and provision of energy sources to domestic and international markets.

Origin respects the uniqueness of each and every community in which it operates by listening to and utilising stakeholders' local knowledge to improve project decision-making and enhancing Origin's place in the community as a long-term partner.

We realise that locals know the land and region in which we operate far better than we do and we try to leverage this knowledge to provide beneficial outcomes.

VIC - Otway Gas Plant



NT - Beetaloo Project



QLD - CSG Development Well



TAS - Yolla



QLD - Surat Basin Gas Plant



QLD - Reedy Creek

