



PEL122 & PEL123 Fracture Stimulation Activities

Environmental Impact Report

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Summary

This Environmental Impact Report (EIR) addresses the application of fracture stimulation to the exploration and appraisal of shale oil and gas in the Permian and Pre-Permian sedimentary formations in the Arckaringa Basin. Fracture stimulation is the injection of fluid, largely water, into a petroleum well, to create small cracks or fractures in the formations near the well and allow oil and gas to flow to the well more easily. Fracture stimulation of conventional oil and gas reservoirs has been successfully undertaken in several hundred wells in the Cooper Basin since 1968, to improve the commerciality of low permeability zones. More recently, a number of operators have successfully completed fracture stimulations in shales within the Cooper and Beetaloo Basins including Origin Energy, Santos and Beach Energy.

SAPEX is committed to maintaining effective communication and good relations with all stakeholders. SAPEX has been undertaking a program of consultation with directly affected parties and other stakeholders. Issues raised to date have been integrated into this report where relevant.

The Great Artesian Basin (GAB) is the dominant hydrogeological feature in the region. Major aquifers over the project area include the Cadna-Owie Formation and the Algebuckina Sandstone as described in (CSIRO 2012). In the southern portion of PEL122 & PEL123, the Algebuckina Sandstone pinches out with only the Cadna-Owie Formation remaining. Here the GAB sub-crops at surface notable by the surface topography changing from stony plains to sand dune country. Existing drill hole data indicates the GAB formation can be weathered in part/full with common clayey bands formed causing isolated aquifer lenses. In these areas, the target formations are expected to be shallowest at approximately 700m with at least 500m of interburden between the target and the base of the GAB. Further north in PEL122, the Stuart Range Formation dips into the Boorthanna Trough and is interpreted to be up to 1200m deep. Here interburden between the Stuart Range Formation and the base of the GAB is better developed with expected thickness of 750 – 1,000m. The Boorthanna Formation is stratigraphically below the Stuart Range Formation and therefore deeper than the depths mentioned above.

Aspects of the environment addressed in this document that are potentially (or commonly perceived to be) impacted by fracture stimulation activities include:

- Aquifers; where the potential hazards are mainly related to injection of fracture stimulation fluids.
- Springs and potential impacts to groundwater dependent ecosystems which are listed threatened communities in the EPBC Act
- Soil, shallow groundwater, surface water, fauna and flora, where the potential hazards are mainly related to storage and handling of fuel, chemicals and flowback fluids.
- Other issues such as public safety and risk, cultural heritage, noise and air emissions, radioactivity and seismicity, where the potential hazards are related to a more general range of site activities.

The assessment of potential impacts to deeper aquifers and surface springs indicates that:

- Leakage to aquifers due to loss of well integrity is not likely to occur and the risk is managed by well design and construction, pressure testing and cement bond logging, monitoring of injection pressures, safety trip out systems on pumping units, and installation of a tubing string after stimulation.
- Fracture propagation into overlying Great Artesian Basin (GAB) aquifers and potential contamination of these aquifers is not likely to occur due to stress barriers and the significant physical separation between the targets and the GAB aquifers and the natural stress barriers.
- Leakage to GAB aquifers through geologic media and impact to surface springs is not likely to occur, as the Permian and Pre-Permian target intervals are separated from the GAB by a thick sequence of low permeability Mt Toondina siltstone.

With respect to impacts to soil, shallow groundwater and surface water, the assessment indicates that:

- Spills or leaks of fuels and stimulation additives are mitigated by storing and handling of materials with appropriate secondary containment and immediate clean up and remediation of any spills.
- Pond design, construction, location and operational controls mitigate risks to the integrity of the pond liner and wall that may result in spills or leaks of pre-stimulation water or flow-back fluids that are contained within the ponds. Spill response procedures result in immediate assessment, fencing, clean up and remediation measures in the event of a leak or spill.

The body of this EIR reviews the potential of the activities to impact on public safety, cultural heritage, stock, native fauna and flora or result in significant noise and air emissions, radioactivity and seismic events. Each of these has been assessed to be a low risk.

SAPEX is confident that with the implementation of the management measures outlined in the EIR, the proposed activities do not present a significant level of environmental risk.

1 Introduction

SAPEX Limited (SAPEX) [a company that forms part of the Tri-Star Petroleum Group] holds a number of Petroleum Exploration Licences (PELs) in the Arckaringa Basin in northern South Australia. SAPEX plans to undertake fracture stimulation activities within PEL122 and PEL123 to assist in the recovery of potential hydrocarbons within low permeability plays. This Environmental Impact Report (EIR) has been prepared as a requirement of the *Petroleum and Geothermal Energy Act 2000* to provide information on the proposed activities, the potential environmental impacts and their management. This EIR only covers PEL122 and PEL123 within the south eastern portion of the basin with the Arabana Native Title determination forming the boundary within PEL122.

SAPEX intends to evaluate the size and commerciality of the oil and gas resources within target shale formations including the Stuart Range and Boorthanna Formations. These exploration targets fall within the category of ‘unconventional’ hydrocarbons as they have lower permeability than conventional oil and gas reservoirs. Within PEL123, the target zone in the Stuart Range Formation is located at depths of approximately 650m increasing to 1,200m in PEL122. Shale targets in the Boorthanna Formation are expected to range between 1,000 – 1,800m within both licences.

In order to maximise recovery of oil and gas and potentially allow commercial production, wells drilled in shales are treated by a process known as fracture stimulation. The fracture stimulation process involves the injection of fluid, largely water, to create small cracks or fractures in the formations near the well, which allow oil and gas to flow to the well more easily.

Fracture stimulation of conventional oil and gas reservoirs has been carried out in several hundred wells in the Cooper Basin since 1968, to improve the commerciality of lower permeability zones. It is considered to be a relatively routine and low risk component of oil and gas drilling and well operations in this basin.

This Environmental Impact Report has been developed to address the fracture stimulation of shale oil and gas reservoirs in the Stuart Range and Boorthanna Formations in the Arckaringa Basin. This document focuses on the fracture stimulation process carried out after the well has been drilled. It does not re-visit other aspects of drilling and well operations (such as preparation of the well lease and access, drilling, casing and cementing of the well, camps, well operation and monitoring, initial production testing, well abandonment and well lease restoration) which are covered by the Environmental Impact Report and the Statement of Environmental Objectives for Drilling in the Arckaringa Basin.

1.1 Location

The Arckaringa Basin is located 800 km north-west of Adelaide in South Australia and covers an area of approximately 80,000km² (see **Figure 1**). SAPEX currently holds PELs 117, 118, 119, 121, 122, 123, 124, PELa604 and PELa635 which cover approximately 57,500km² of this region. A limited amount of petroleum exploration was carried out in the basin between the 1960s and the 1980s, including aeromagnetic and gravity surveys, several seismic surveys, stratigraphic drilling (12 drill holes) and four exploration wells. More recently, Linc Energy completed a number of wells targeting both conventional and unconventional target within PEL121 and PEL122. No commercial discoveries of oil or gas have been made.

The Arckaringa Basin contains early Permian–age sediments that are analogous to the Cooper Basin oil and gas productive areas, but are at shallower depths. The main formations are the Mt Toondina (source, seal), the Stuart Range (source and seal) and Boorthanna (source, reservoir and seal). The Permian sediments are underlain unconformably by thick pre-Permian (Adelaidean to Cambrian) sequence. The Stuart Range and the Boorthanna Formations are SAPEX’s proposed targets for oil and gas exploration using modern seismic techniques (as described in a separate EIR for Geophysical Operations), modern geological interpretation techniques and drilling (as described in a separated EIR for Exploration Drilling Activities) and fracture stimulation techniques (as described in this EIR).

This EIR will only apply to PEL122 and PEL123 within the south eastern portion of the basin with the Arabana Native Title determination forming the boundary within PEL122 as shown in **Figure 1**. A 5km trigger zone (shown in **Figure 2**) has been identified around surface springs. Additional consultation with both State and Federal Government Agencies (and potential impacts to MNES under EPBC) is required during the stage 3 approval process prior to any stimulation activities being approved within these trigger zones. Sapex notes the trigger zones only apply to fracture stimulation activities under this EIR and SEO and not exploration drilling activities (see Arckaringa Basin Exploration Drilling Activities 2013 EIR & SEO).

1.2 Project Proponent

SAPEX Pty Ltd (SAPEX) was formed in 2000 as a private company and was listed on the Australian Stock Exchange in 2007. SAPEX was acquired wholly by Linc Energy Ltd (Linc) in 2008. Linc Energy undertook extensive exploration within the basin between 2009 and 2015 including regional seismic and drilling. In 2016, Linc was liquidated and subsequently SAPEX was acquired wholly by Tri-Star Petroleum.

Founded in Texas, USA, in 1979 to explore and develop its Permian Basin oil reserves, Tri-Star began its Australian exploration in 1988. After 20 years of exploration and development in Queensland, Tri-Star's Australian tenures form the bulk of its reserves.

In Australia, Tri-Star operates both coal and gas interests, and is participating as non-operator in exploration and development joint ventures with members of coal seam gas (CSG) to liquefied natural gas (LNG) projects, including Gladstone LNG (GLNG) and Australia Pacific LNG (APLNG).

The CSG tenures which Tri-Star discovered and developed at Durham Ranch, Spring Gully and Fairview CSG fields are not only the best in Australia, but some of the best in the world. Well productivity, production life, and proximity to major infrastructure and ports, compare favourably with other CSG fields in Australia and elsewhere. Tri-Star has an enviable track record of environmental stewardship, operating for twenty-eight years with zero Environmental Infringement Notices.

Tri-Star maintains a large portfolio of both coal and petroleum tenure within South Australia covering the Arckaringa, Pedirka and Simpson Basins. Tri-Star also operates in the Northern Territory and Queensland.

The group's US operations continue to focus on production of West Texas Intermediate crude oil at wells in Texas's Kent, Martin and Glasscock counties.

1.3 About this Document

This document has been prepared to fulfil the requirements of an Environmental Impact Report (EIR) for fracture stimulation activities. It has been prepared in accordance with current legislative requirements, in particular Section 97 of the *South Australian Petroleum and Geothermal Energy Act 2000* and Regulation 10 of the *Petroleum and Geothermal Energy Regulations 2013*. This document relates to fracture stimulation activities to be carried out in SAPEX's Petroleum Exploration Licences 122 and 123 in the South Australian Arckaringa Basin. (see **Figure 1**). This document is based on the *740-Arckaringa Basin Drilling Environmental Impact Report-Rev3_ (SAPEX, 2013)*.

The regulator, Department for Energy and Mines (DEM), is to undertake an Environmental Significance Assessment of this document to classify the activities which are the subject of this EIR as 'low', 'medium' or 'high' impact. Following this classification, a Statement of Environmental Objectives (SEO) will be developed reflecting the activities and impacts detailed in this document or other assessments that may be required depending on the classification. The SEO will outline the environmental objectives that must be achieved and the criteria on which achievement of the objectives is to be assessed.

This document relates to fracture stimulation activities using high volumes of water in oil and gas targets in the Arckaringa Basin, South Australia. Within PEL123, the target zone in the Stuart Range Formation is located at depths of approximately 700m increasing to 1,200m in PEL122. Shale targets in the Boorthanna Formation are expected to range between 1,000 – 1,800m within both licences.

As indicated in Summary, this document focuses on the fracture stimulation process carried out after the well has been drilled. Other aspects of drilling and well operations such as preparation of the well lease and access, drilling, casing and cementing of the well, camps, well operation and monitoring, initial production testing, well abandonment and well lease restoration are covered by the Arckaringa Basin Exploration Drilling Activities Environmental Impact Report (SAPEX 2007 and 2013), and the Arckaringa Basin Exploration Drilling Activities Statement of Environmental Objectives (SAPEX 2007 and 2013) and are not re-visited in this document.

Existing EIR's are also in place for other Arckaringa Basin operations that are not covered in this document, including the Geophysical Activities Environmental Impact Report (SAPEX 2007 and 2013).

This document (and the resultant SEO) covers a relatively broad geographical area, rather than relating to a specific site or sites. This approach has been applied in many other EIRs and SEOs that have been developed under the *Petroleum and Geothermal Energy Act 2000* for the Arckaringa Basin and other regions of the State. Additional site-specific and technical detail for operations at individual well sites must

be provided under the activity notification / approval requirements of the Act, including a demonstration that the activities are covered by (and are compliant with) an applicable SEO.

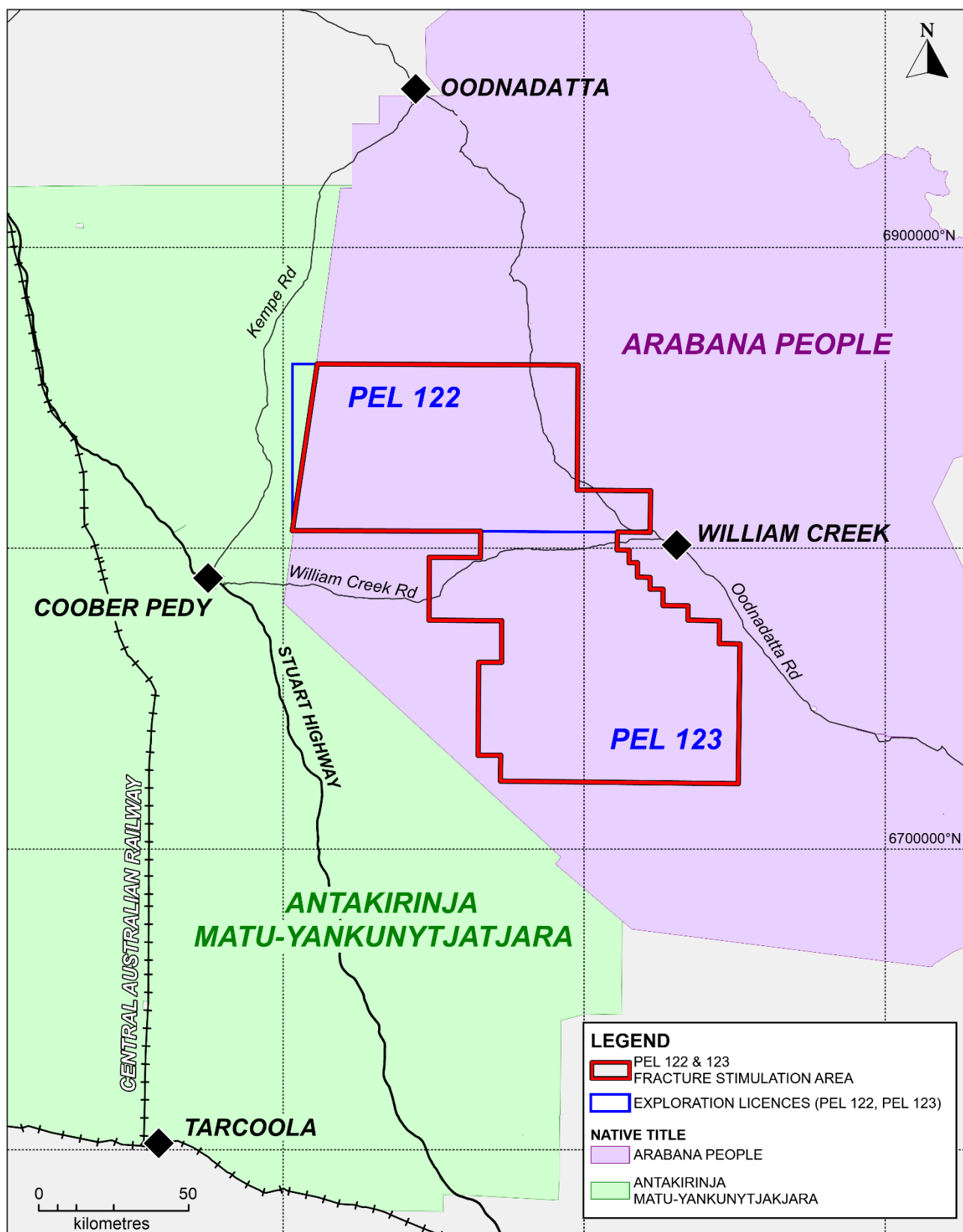
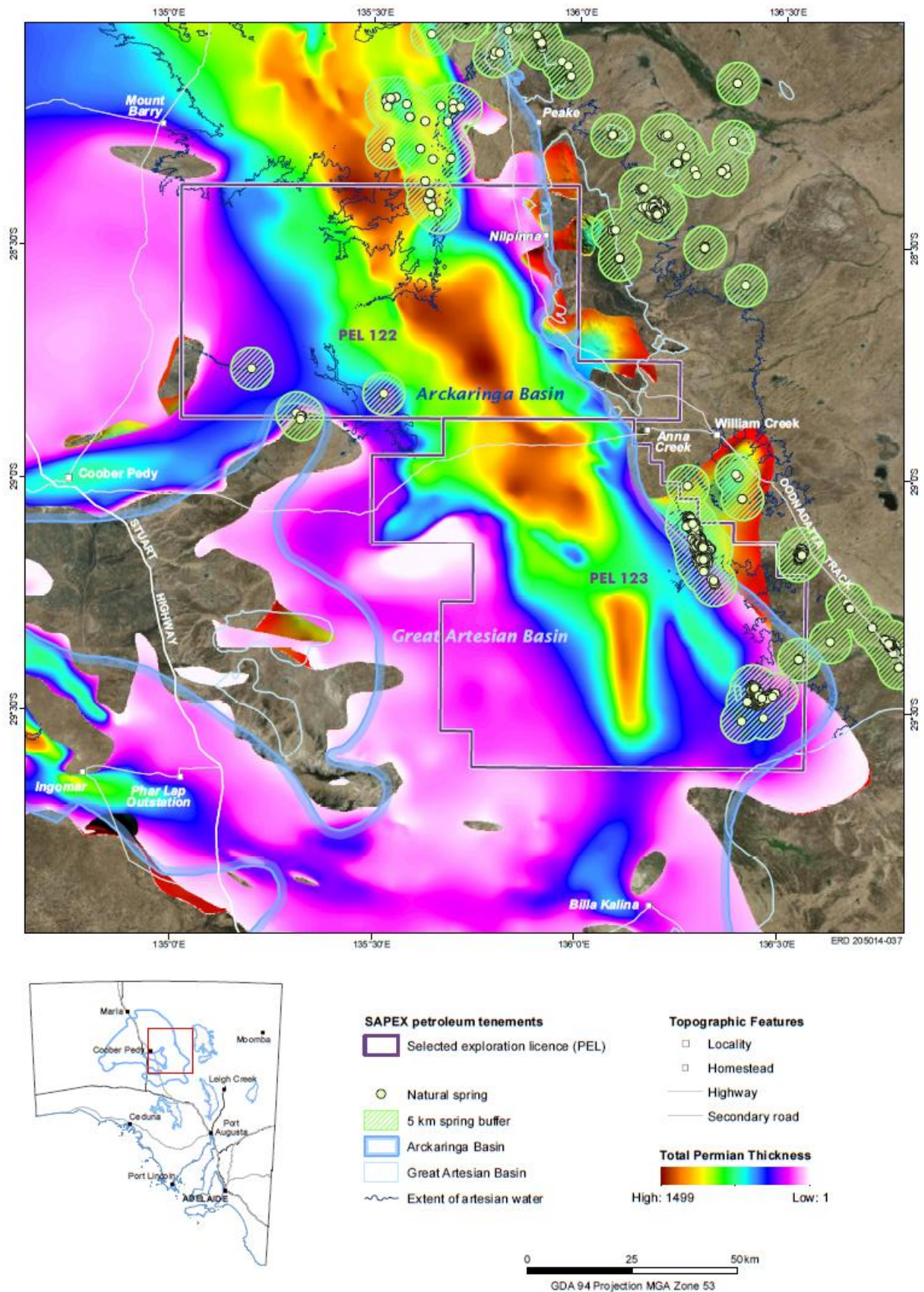


Figure 1: PEL 122 and 123 Location Map



Government of South Australia
Department for Energy and Mining

PETROLEUM EXPLORATION LICENCES 122 & 123 over ARCKARINGA-BOORTHANNA TROUGH

Figure 2: Boorthanna Trough with 5km spring trigger zone. (note the figure does not represent the latest published basin extent).

2 Legislative Framework

This section briefly describes the legislative framework that currently applies to petroleum licensing in South Australia.

2.1 Petroleum and Geothermal Energy Act and Regulations

The legislation governing onshore petroleum exploration and production in South Australia is the *Petroleum and Geothermal Energy Act 2000* and *Petroleum and Geothermal Energy Regulations 2013*.

Key objectives of the legislation are:

- to protect the natural, cultural, heritage and social aspects of the environment from risks associated with activities governed by the Act.
- to provide for constructive consultation with stakeholders, including effective reporting of industry performance to other stakeholders.
- to provide security of title for petroleum, geothermal energy, and other resources governed by the Act and pipeline licences.

The Act and Regulations are objective-based rather than prescriptive (McDonough 1999). An objective-based regulatory approach principally seeks to ensure that industry effectively manages its activities by complying with performance standards that are cooperatively developed by the licensee, the regulatory authority and the community. This contrasts with prescriptive regulation where detailed management strategies for particular risks are stipulated in legislation.

Regulated resources, as defined in Part 1 of the Act, are:

- a naturally occurring underground accumulation of a regulated substance
- a source of geothermal energy, or
- a natural reservoir.

A reference in the Act to petroleum or another regulated substance extends to a mixture of substances of which petroleum or the other relevant substance is a constituent part.

Regulated substances as defined in Part 1 of the Act are:

- petroleum
- hydrogen sulphide
- nitrogen
- helium
- carbon dioxide, and
- any substance declared by regulation to be a substance to which the Act applies.

Regulated activities, as defined in section 10 of the Act, are:

- exploration for petroleum or another regulated resource
- operations to establish the nature and extent of a discovery of petroleum or another regulated resource, and to establish the commercial feasibility of production and the appropriate production techniques
- production of petroleum or another regulated substance
- utilisation of a natural reservoir to store petroleum or another regulated substance
- production of geothermal energy
- construction of a transmission pipeline for carrying petroleum or another regulated substance
- operation of a transmission pipeline for carrying petroleum or another regulated substance.

2.2 Statement of Environmental Objectives

As a requirement of section 12 of the Act, a regulated activity can only be conducted if an approved SEO has been developed. The SEO outlines the environmental objectives that the regulated activity is required to achieve and the criteria upon which the objectives are to be assessed. The SEO is developed on the basis of information provided in an EIR. The EIR is provided by the licensee and contains an assessment of the potential impacts of an activity on the environment.

As detailed earlier, subsequent to classification by the regulator of the activities covered by this EIR, a corresponding SEO for fracture stimulation activities in the Arckaringa Basin will be developed for consultation and approval.

2.3 Environmental Impact Report

In accordance with Section 97 of the *Petroleum and Geothermal Energy Act 2000*, an Environmental Impact Report (EIR) must:

- take into account cultural, amenity and other values of Aboriginal and other Australians insofar as those values are relevant to the assessment
- take into account risks to the health and safety of the public inherent in the regulated activities
- contain sufficient information to make possible an informed assessment of the likely impact of the activities on the environment.

As per Regulation 10 of the *Petroleum and Geothermal Energy Regulations 2013*, the EIR must include:

- a description of the regulated activities to be carried out under the licence (including their location)
- a description of the specific features of the environment that can reasonably be expected to be affected by the activities, with particular reference to the physical and biological aspects of the environment and existing land uses
- an assessment of the cultural values of Aboriginal and other Australians which could reasonably be foreseen to be affected by the activities in the area of the licence, and the public health and safety risks inherent in those activities (insofar as these matters are relevant in the particular circumstances)
- if required by the minister - a prudential assessment of the security of natural gas supply
- a description of the reasonably foreseeable events associated with the activity that could pose a threat to the relevant environment, including information on:
 - events during the construction stage (if any), the operational stage and the abandonment stage
 - events due to atypical circumstances (including human error, equipment failure or emissions, or discharges above normal operating levels)
 - information on the estimated frequency of these events
 - an explanation of the basis on which these events and frequencies have been predicted
- an assessment of the potential consequences of these events on the environment, including:
 - information on:
 - the extent to which these consequences can be managed or addressed
 - the action proposed to be taken to manage or address these consequences
 - the anticipated duration of these consequences
 - the size and scope of these consequences and
 - the cumulative effects (if any) of these consequences when considered in conjunction with the consequences of other events that may occur on the relevant land (insofar as this is reasonably practicable); and
 - an explanation of the basis on which these consequences have been predicted
- a list of all owners of the relevant land
- information on any consultation that has occurred with the owner of the relevant land, any Aboriginal groups or representatives, any agency or instrumentality of the Crown, or any other interested person or parties, including specific details about relevant issues that have been raised and any response to those issues, but not including confidential information.

2.4 EIR / SEO Assessment and Approval

Once the EIR is submitted to the Department for Energy and Mining (DEM), an assessment is made by DEM to determine whether the activities are to be classified as 'low', 'medium' or 'high' impact. This in turn determines the level of consultation DEM will be required to undertake prior to final approval of the SEO.

- *Low impact* activities do not require public consultation and are subjected to a process of internal government consultation on the EIR and SEO prior to approval.
- *Medium impact* activities require a public consultation process for the EIR and proposed SEO, with comment sought for a period of at least 30 business days.
- *High impact* activities are required to undergo an environmental impact assessment under the provisions of the *Development Act 1993*.

The level of impact of a particular activity is assessed on the basis of the predictability and manageability of the impacts on the environment. Where the environmental impacts are predictable and readily managed, the impact of the activity is considered low. Where the environmental impacts are less predictable and are difficult to manage, the impact of the activity is potentially high.

Once the approval process is complete, all documentation, including this EIR and its associated SEO, must be entered on an environmental register. This public Environmental Register is accessible to the community from the DEM website.

2.5 Approval to Carry Out a Regulated Activity

Prior to commencing a regulated activity (e.g. exploration drilling), Section 74(3) of the Petroleum and Geothermal Energy Act requires that:

- the Minister's prior written approval is required for activities requiring high level official surveillance; and
- notice of activities requiring low level official surveillance is to be given as required in the conditions or by regulation.

New operators (such as SAPEX) are classified as requiring high level supervision for fracture stimulation activities. In order to obtain written approval for fracture stimulation activities, an application and activity notification (in accordance with Regulation 20) must be submitted to the Minister at least 35 days prior to the commencement of activities.

The activity notification must provide specific technical and environmental information on the proposed activity and include an assessment to demonstrate that it is covered by an existing SEO.

Consequently, the activity notification process provides an additional opportunity for DEM to ensure that the proposed activities and their impacts can be effectively managed and are consistent with the approvals obtained in the EIR and SEO approval process. This is particularly relevant for activities that are conducted under a generic SEO, as it provides site-specific detail that is not usually contained in the generic documents.

The site-specific detail provided would include an assessment of the environment of the proposed location, investigation of specific issues (such as the likelihood of occurrence of threatened species or locations of mound springs or areas of sensitive landscape) and proposed measures to minimise impacts to key issues (e.g. low impact techniques for sensitive areas, sensitive locations to avoid).

2.6 Other Legislation

A variety of legislation applies to petroleum exploration activities. Legislation that is particularly relevant to petroleum exploration is listed below (note that this is not a comprehensive list of all applicable legislation).

Commonwealth

Defence Regulation 2016

Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)

Native Title Act 1993

Aboriginal and Torres Strait Islander Heritage Protection Act 1984

South Australia*Aboriginal Heritage Act 1988**Crown Land Management Act 2009**Environment Protection Act 1993**Heritage Places Act 1993**National Parks & Wildlife Act 1972**Native Title (South Australia) Act 1994**Native Vegetation Act 1991**Natural Resources Management Act 2004**Petroleum and Geothermal Energy Act 2000 [Regulations 2013]**Public and Environmental Health Act 1987 [(Waste Control) Regulations 2010]**South Australian Public Health (Wastewater) Regulations 2013**Work Health and Safety Act 2012 [Regulations 2012]*Commonwealth Environment Protection and Biodiversity Conservation Act

Approval under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) would be required for activities that impact matters of national environmental significance (e.g. listed threatened species or communities, Ramsar wetlands, World Heritage properties, National Heritage places).

In regard to petroleum activities in the Arkaringa Basin, issues that potentially require approval under the EPBC Act are relatively limited and can generally be avoided by site selection and implementation of field procedures (e.g. avoiding impacts to surface drainage and significant wetland areas or flagging and avoiding significant sites). Based on current knowledge, SAPEX believes that a requirement for approval under the Act is not likely to be triggered.

If fracturing activities are proposed with the 5km trigger zone shown in Figure 2, additional consultation with both State and Federal Government Agencies (and potential impacts to MNES under EPBC) is required during the stage 3 approval process prior to any stimulation activities being approved within these trigger zones.

Native Vegetation Act

It is noted that exploration activities that are approved under the Petroleum Act and Geothermal Energy Act 2000 are exempt from requiring approval under the Native Vegetation Act 1991 for clearance of native vegetation, provided that the activities are in accordance with accepted industry environmental management practices for facilitating the regrowth of native vegetation and there is no practicable alternative involving the clearance of less vegetation or of vegetation that is either less significant or more degraded (see Native Vegetation Regulations 2017).

Environment Protection Act

The Environment Protection Act imposes a general duty of care not to undertake an activity that pollutes, or might pollute the environment unless all reasonable and practicable measures have been taken to prevent or minimise any resulting environmental harm. Environmental authorisations are required to undertake activities prescribed under the Act. The Environment Protection Act does not apply to petroleum exploration activity undertaken under the Petroleum and Geothermal Energy Act or to wastes produced in the course of an activity (not being a prescribed activity of environmental significance) authorised by a lease or licence under the Petroleum and Geothermal Energy Act when produced and disposed of to land and contained within the area of the lease or licence.

Natural Resources Management Act

Drilling of new water sourcing bores requires a permit under this Act. Extraction of groundwater within the Far North Prescribed Wells Area generally requires a licence / allocation under this Act, however there is an authorisation in place to take groundwater for drilling, construction and testing of hydrocarbon wells. This Act and the SA Arid Lands Regional Natural Resources Management Plan (SAAL NRM Board 2017) also set out a number of water affecting activities that must not be undertaken without a permit. These are usually avoidable by careful planning and siting of infrastructure to maintain water flows.

National Parks and Wildlife Act

This Act provides for the establishment and management of reserves and the conservation of wildlife in a

natural environment. Tallaringa Conservation Park, and the Breakaways Conservation Park are established under this Act, which provides the Department of Environment, Water and Natural Resources rights as landowner and direct involvement in the approval of Petroleum and Geothermal Energy Act licences and Statements of Environmental Objectives that cover the Conservation Parks (which must be approved by the Minister for Sustainability, Environment and Conservation).

3 Background to Hydrocarbon Exploration

The following section provides a background to both conventional and unconventional oil and gas applications. This information is provided to assist in the understanding of Fracture Stimulation in the following sections.

3.1 Overview

3.1.1 Conventional hydrocarbon generation and accumulation

Sedimentary rocks, such as those prevalent in the Arckaringa Basin, are formed when sand grains and clay particles are deposited, accumulate and become buried over many millions of years. When quartz sand grains compact and cement together to form rocks, these are known as sandstones. When fine grained quartz and clay particles compact these become siltstones, shales and mudstones. When the sediments are deposited, the small pore spaces between the grains in these rocks are water filled as the sediment is carried by a river to a lake or to the sea. This pore space potentially becomes a storage place for oil and gas, collectively known as hydrocarbons, if gas and oil can eventually find its way into the rock.

The source of the hydrocarbon that migrates into the pores is organic matter that is buried with sediments. Rocks which have organic matter that generates, or has generated hydrocarbons are known as source rocks.

The simplest source rock model to understand is the conversion of a peat swamp into coal. As the organic matter becomes buried deeper, the pressure and heat in the sediment increases and the material transforms into coal. During this process, hydrocarbons are generated which escape from the structure of the coal and migrate into layers of sediment that have been deposited above the coal.

Another common source rock is shale. Shale is a fine-grained sedimentary rock made up predominantly of quartz and clay particles together with organic matter. While coal has very high organic content, typically more than 85%, shale has lower organic content typically less than 10%.

As oil is lighter than water, and gas lighter still, it migrates through the pore spaces of the overlying layers of rock. The ease with which it moves depends on the permeability of the rocks. Permeability is a measure of the ability of a rock to conduct fluid and is related to how connected the pore spaces are in the rock. The gas released from a source rock will migrate through permeable rocks upwards until it reaches a barrier. The barrier is usually caused by a layer of rock that has very little to no permeability, such as shale, and is commonly referred to as a seal or cap. The hydrocarbon will continue to migrate upward along the barrier until it either reaches a place where it will pool, or it will escape to the surface at a natural seep.

Hydrocarbons accumulate in structures or traps which have been created by folding of the rocks due to tectonic movements. Other common traps are related to the presence of faults caused by tectonic movement, or the absence of permeable rock due to the geological setting in which the permeable sandstone has accumulated. These pools of gas and oil (shown in red and green in **Figure 3**), where the hydrocarbon is contained within permeable sandstones and trapped by a sealing layer and a structure, are conventional oil and gas targets.

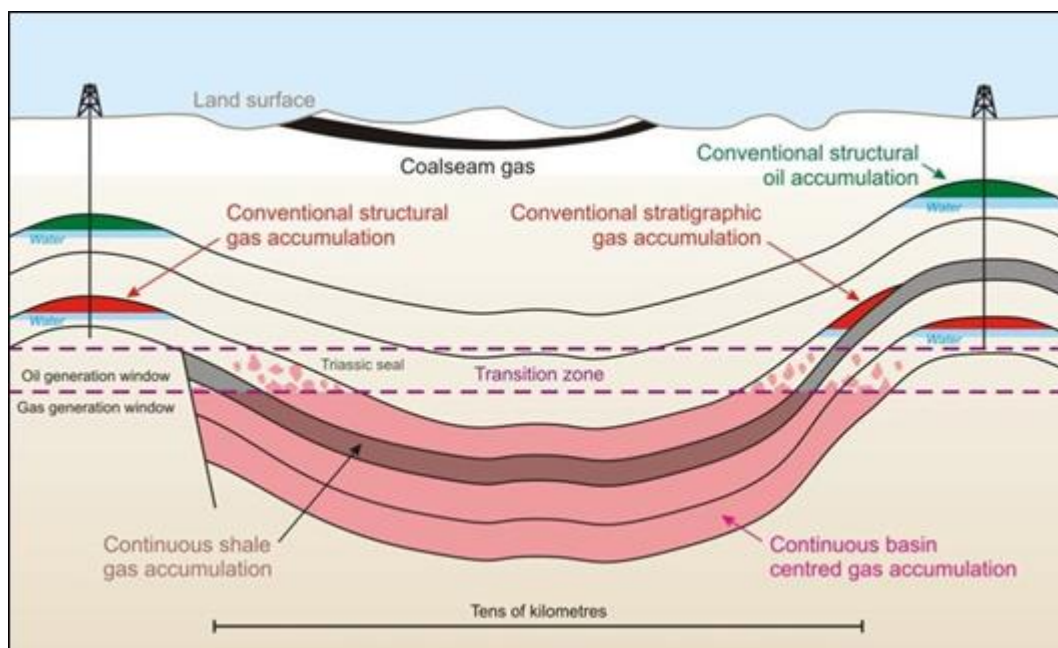


Figure 3: Illustration of the differences between conventional hydrocarbon traps in anticlines and a basin-centred gas play (modified from Schenk and Pollastro 2002)

3.1.2 Unconventional Hydrocarbon Generation and Accumulation

Shale oil, shale gas, tight gas and basin-centred gas are generally termed as unconventional hydrocarbons however the term 'unconventional' does not refer to either the oil or gas itself or the methods used to extract it. There is no difference between oil and gas produced from conventional reservoirs and that produced from basin-centred gas or shale oil/gas. The oil and gas are still sourced from organic matter and is natural oil/gas that can be processed and distributed. The method of extraction has been used throughout the world for decades, including in the Officer and Cooper Basins.

The difference between conventional and unconventional hydrocarbons refers to where the hydrocarbons is found and produced from underground. Exploration focuses on shale and tight oil and gas systems where hydrocarbons have been generated but have not been able to migrate, rather than on underground structures such as anticlines and highly permeable sandstones.

Shale oil refers to the petroleum that remains in source rocks and has not undergone migration – a kind of fracture–pore oil deposit whose source rock and reservoir are the same. These oil deposits are usually found in black mudstones and shales rich with organic matter and mature for oil generation.

Due to very low permeability of the source rock, or surrounding strata adjacent to the source, the hydrocarbons become regionally trapped by an inability to migrate further. As the hydrocarbons are not pooled in discrete traps, these accumulations are also known as continuous plays. The shales and tight gas intervals tend to extend over vast distances - several thousands of square kilometres.

The drilling of horizontal wells with multi-stage stimulation are required to understand the deliverability potential of these intervals and determine the steps to converting the resources into reserves. Without stimulation these zones will not produce and an assessment of their potential cannot be made.

4 Existing Environment

4.1 Climate

The climate in the Arckaringa Basin region is classified as arid and has a typical desert climate of hot to extremely hot, dry summers and mild, dry winters, with low and erratic rainfall. Average annual rainfall at Coober Pedy, in the centre of the region, is 158mm. Median annual rainfall, which is a more appropriate measure where rainfall is erratic, is 144mm. Rainfall can occur at any time of year, but rainfall events often occur in summer, when moist tropical air from the north-west monsoon penetrates the region. Record daily falls of between 100 and 200mm have been recorded across the region (Marla-Oodnadatta SCB 2002). A summary of climate records for Coober Pedy (Station #016007) is provided in **Table 1** (Bureau of Meteorology 2017).

The prevailing winds in the summer are from the south or south-east and the winter winds are more variable and come from either the north or the south to south-west quadrants (Bureau of Meteorology 2017).

Climate can be an important consideration when scheduling drilling activities, particularly the likelihood of heavy or prolonged rainfall. However, due to the unpredictable and erratic rainfall (which may or may not occur any time of the year) and the predominantly dry conditions experienced in the region, seasonal rainfall is not a significant factor in scheduling drilling in this region.

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Mean Daily Max (°C)	36.4	35.7	32.8	27.6	22.3	18.8	18.7	20.7	24.5	28.9	32.1	34.6	27.8
Mean Daily Min (°C)	20.7	20.8	18.2	14.0	10.1	7.2	6.3	7.4	10.1	13.6	16.6	19.1	13.7
Mean Rainfall (mm)	16.0	22.5	14.1	8.0	14.3	13.9	7.5	9.0	9.0	14.4	11.7	17.2	158.0
Median Rainfall (mm)	4.1	9.0	2.6	2.3	5.2	5.4	3.2	3.4	2.8	6.3	5.8	10.9	144.0

Table 1: Temperature and Rainfall Records for Coober Pedy

4.2 Biophysical Environment

The area of PEL122 and PEL123 intersects two bio-geographical regions¹ (or bioregions) as defined by the Interim Biogeographic Regionalisation for Australia (IBRA): the Stony Plains and the Simpson Strzelecki Dunefields bioregions. The following sections of this EIR describe the environments within PEL122 and PEL123 in each of these bioregions. The location of the bioregions is shown in Figure 4.

Each bioregion is divided into subregions under the IBRA classification and can be further divided into land systems, which are regional scale ecosystems with a recurring pattern of geology, topography, soils and vegetation (Marla-Oodnadatta SCB 2002, DEH 2009). A number of identified land systems have been mapped across the Arckaringa Basin region as part of broader land system mapping, which is used in natural resources management and soil conservation planning in pastoral areas of South Australia. The land systems occurring in PEL122 and PEL123 and their soil and vegetation characteristics are summarised in Appendix 1.

To assist in the discussion of potential impacts and environmental management measures in subsequent sections of this EIR, the major landforms encountered within these bioregions and land systems are also identified and discussed in the following sections.

¹ Biogeographic regions (bioregions) are broad landscape units based on major geomorphic features and are defined by the Interim Biogeographic Regionalisation for Australia (IBRA) Version 7.0. They are continental scale ecosystems, ranging in size from one to 20 million hectares and may include more than 30 landforms and 50 vegetation associations (DEH 2009).

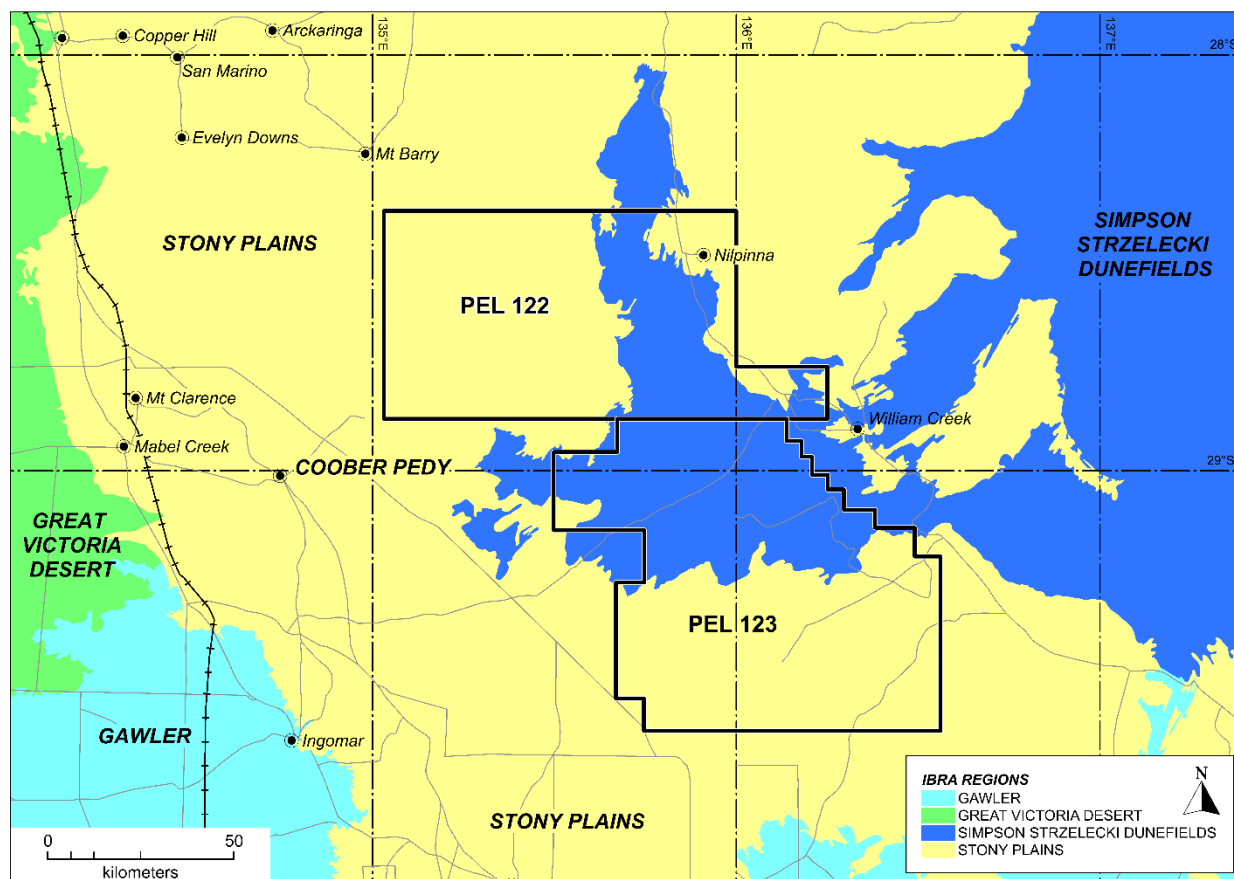


Figure 4: Bioregions of PEL122 and PEL123 and surrounding area

4.2.1 Stony Plains

The entire Stony Plains bioregion covers an area of 129,240 km² and represents 24.8% of the South Australian Arid Lands and 13.2% of the state (DEH 2009). It stretches in an arc from the Northern Territory through to south of Lake Eyre and east to the edges of the Strzelecki Desert and Flinders Ranges.

The Stony Plains bioregion occurs predominantly in the west of PEL122 and the south of PEL123 and constitutes approximately 60% of the area of the PELs.

The land systems present in the Stony Plains bioregion covered by PEL122 and PEL123 include Baltana, Breakaway, Christie, Coongra, Moon Plain, Margaret and Oodnadatta. A full description of each of these land systems is provided in Appendix 1.

Geology, Soils & Landform

The Stony Plains bioregion can be generally described as a series of arid stony silcrete tablelands and gibber and gypsum plains with duplex soils and calcareous earths. The dominant undulating gibber and gypsum plains are dotted with occasional lakes, claypans, low hills and ephemeral watercourses and floodplains which typically drain into Lake Eyre (Miles *et al.* 2015).

The north-west of the region is interspersed by dissected silcrete-capped tablelands and mesas with extensive gibber covered footslopes on deeply weathered shales (Neagle 2003). These tablelands and mesas include the 'Breakaways' landform which occurs in the south-west corner of PEL123.

Some watercourses form major drainage systems featuring deep channels and occasional permanent waterholes (Neagle 2003). Wetlands occur throughout this bioregion with the Great Artesian Basin (GAB) springs being the most significant wetland feature.

PEL122 and PEL123 are a representative subset of the Stony Plains bioregion. They contain a variety of plains and tablelands interspersed with dunefields, hills and plateaus. Seven major landforms occur within the PEL122 and PEL123 (adapted from the landform groupings in DEH (2009)):

- Stony plains and tablelands
- Moon plains
- Breakaways and stony hills
- Dunefields and sand plains
- Drainage lines and flood plains
- Great Artesian Basin springs
- Salt lakes.

These are discussed further below and photographic examples are provided in **Plate 1** to **Plate 6**.

Stony Plains and Tablelands

This landform is typified by gently sloping plains with a cover of small to large gibber stones. Gilgai are typically present, which are stone-free, often circular depressions with clay soils that receive much of the runoff from the adjacent gibber. Gibber stones are typically derived from silcrete, but in the Coongra land system the stone cover is comprised of sandstone and shale.

The surface stones generally form a stable pavement that protects the underlying soil from erosion. Grading or removal of the stone cover can result in significant erosion (Marree SCB 2004, Santos 2006).

Stony plains occur in the Oodnadatta, Baltana, and Coongra and Margaret land systems.

Moon Plains

Plains with clay soils but without significant stone cover occur in the Moon Plain land system. The Moon Plain (located north-east of Coober Pedy) is an undulating plain with soft grey gypseous cracking clay soils and limited drainage.

Breakaways and Stony Hills

This landform includes dissected tablelands and other residual habitats forming mesas or tabletops with a capping of silcrete overlaying various shales. It is typified by the steep escarpments and mesas of the Breakaway land system, but also includes the stony hills found in a number of land systems and the more

rugged ranges such as those found in the Margaret land system.

Breakaways and stony hills occur in the Breakaway, Coongra, and Margaret land systems, with limited occurrences in other land systems including Oodnadatta, Christie and Baltana.

Dunefields and Sand Plains

Dunefields and sand plains occur in limited areas in the Stony Plains bioregion, where they overly the gibber surface or surround rocky outcrops or hills. Dune soils are typically deep red sands, while soils of plains and interdune swales range from sandy clays to calcareous and siliceous sands.

Within the Stony Plains bioregion in PEL122 and 123 there are very limited areas of dunes and sandplains, as the dunefields fall almost exclusively within the Simpson – Strzelecki Dunefields bioregion.

Drainage Lines and Flood Plains

This land form is typified by ephemeral watercourses, generally draining towards Lake Eyre. In places, these form major drainage systems featuring broad flood plains. Large, braided creeks occur throughout the region (e.g. Margaret Creek in the south of PEL123, and Neales and Arckaringa creeks north of PEL122).

Drainage lines occur in most land systems; even the less well-drained land systems (such as Moon Plain) tend to be traversed by major drainage lines.

Great Artesian Basin Springs

These high conservation value wetlands are found on the margins of the Great Artesian Basin (GAB). They can take a wide variety of geological forms from large carbonate mounds to sandy seeps (DEH 2009). Typical spring structure includes a vent where it emerges from the ground, a tail which flows from the vent and terminates in the wetland around the base of the spring (if the flow is great enough) and saline spring margins surrounding the spring. GAB springs are discussed further in Section 4.3.1.

Within the Stony Plains bioregion, GAB Springs in PEL122 and PEL123 occur in the Oodnadatta and Moon Plain land systems.

Salt lakes

Salt lakes and salt pans are formed when excess evaporation in interior basins leads to the concentration of soluble salts as a surface crust. Within the Stony Plains bioregion in PEL122 and 123, salt lakes occur in the Moon Plain land system. The largest Salt Lake in the area is Lake Cadibarrawirracanna (on the boundary of PEL122 and 123). Most other salt lakes in the PELs are relatively small.



Plate 1: Stony Plains

(Source: Linc Energy)



Plate 2: Moon Plains

(Source: Linc Energy)



Plate 3: Breakaways and Stony Hills

(Source: JBS&G)



Plate 4: Dunefields and Sand Plains

(Source: Linc Energy)



Plate 5: Drainage Lines and Flood Plains

(Source: Linc Energy)



Plate 6: Great Artesian Basin Springs

(Source: Linc Energy: Strangways Spring located outside of the licence area 5.5km east of PEL123. Spring complex is approximately 65km away from target areas)

Flora

The following information has been adapted from Brandle (1998) and Neagle (2003).

The stony desert tablelands and gibber plains feature low open shrublands variously dominated by Saltbush (*Atriplex* spp.), Bluebush (*Maireana* spp.) or Samphire (*Tecticornia medullosa*), short-lived Bindyi (*Sclerolaena* spp.), Thyme Sea-heath (*Frankenia serpyllifolia*) or Bonefruit (*Osteocarpum* spp.) Low Open Shrublands, and Barley Mitchell-grass (*Astrebula pectinata*) or Love-grass (*Eragrostis* spp.) Open Tussock Grasslands.

These plant associations are also present in the breakaways and rocky hills though often with the addition of medium shrubs, such as Wattle (*Acacia* spp.), Emubush (*Eremophila* spp.) and occasionally Silver Needlewood (*Hakea leucoptera* ssp. *leucoptera*). Also present is Mulga (*Acacia aneura* var. *aneura*) Low Woodland, as well as Beaked Red Mallee (*Eucalyptus socialis*).

Drainage channels in the upper catchments tend to have a denser version of the vegetation of the surrounding hills and breakaways with low woodlands of Wattle including Gidgee (*Acacia cambagei*), Coolibah (*Eucalyptus coolabah*) and possibly Northern River Red Gum (*E. camaldulensis* var. *obtusa*).

Floodplains and swamps are a mix of low open shrublands variously dominated by Old-man Saltbush (*Atriplex nummularia* var. *nummularia*), Lignum (*Duma florulenta*), Cottonbush (*Maireana aphylla*) or Samphires, as well as Cane-grass (*Eragrostis australasica*) Tussock Grasslands in swamps, and Mitchell-grass, Love-grass or Bindyi Open Tussock Grasslands. Salt pans are usually bare and salt crusted but often have a halo of Cane-grass Tussock Grassland or Grey Samphire (*Tecticornia halocnemoides*), Slender Samphire (*Tecticornia tenuis*) Low Open Shrubland.

Where dunefields and sand plains overlay gibber surfaces several other plant associations are prominent. Sandhill Cane-grass (*Zygochloa paradoxa*) Open Hummock Grassland dominates deep sands, especially on dunes, but Umbrella Bush (*Acacia ligulata*) Tall Shrublands and Mulga Tall Shrublands are also common. Sand plains support Nitre-bush (*Nitraria billardierei*) Low Open Shrublands or Sturt's Pigface (*Gunnopsis quadrifida*), Bladder Saltbush (*Atriplex vesicaria*) Low Open Shrublands. Small areas of calcareous loams and clays in the western Lake Eyre Basin support Low Bluebush (*Maireana astrotricha*), Bladder Saltbush, Twinleaf (*Zygophyllum* spp.) and/or Balcarra Spear-grass (*Austrostipa nitida*) Low Open Shrublands.

The Moon Plain has very little plant cover in most years, with only a few perennial species present. Mitchell grasses (*Astrebula* spp.) and Neverfail (*Eragrostis setifolia*) are two of the few perennial grasses found on the Plain, together with Annual Saltbush (*Atriplex muelleri*) and Pop Saltbush (*Atriplex spongiosa/holocarpa*), Mulka Grass (*Eragrostis dielsii* var. *dielsii*), Poverty-bushes (*Sclerolaena* spp.) and Buckbush (*Salsola australis*). Several species of Samphire (*Tecticornia* spp.) are common in the drainage lines, along with Prickly Wattle (*Acacia victoriae* ssp. *victoriae*) Old-man Saltbush (*Atriplex nummularia* ssp. *nummularia*), Lignum (*Duma florulenta*), Swamp Canegrass (*Eragrostis australasica*) and a few stunted Coolibahs (*Eucalyptus coolabah*) (Marla - Oodnadatta SCB 2002).

The Stony Plains bioregion supports a number of endemic plant species, including Barkers Mulla (*Ptilotus barkeri*), Johnston's Slipper Plant (*Embadium johnstonii*), Gypsum Groundsel (*Senecio gypsicola*) and Haegi's Stemodia (*Stemodia haegii*) and provides a habitat for a number of nationally threatened species including Dwarf Desert Spike-rush (*Eleocharis papillosa*) and Sea-heath (*Frankenia plicata*). Many of these species have been recorded, or may occur, in the vicinity of PEL122 and 123 (see Appendix 2).

Seven declared plant species (declared weeds) have been recorded on DEW databases as occurring within 20 km of PEL122 and 123: African Boxthorn (*Lycium ferocissimum*), Caltrop (*Tribulus terrestris*), Buffel Grass (*Cenchrus ciliaris*, and *C. pennisetiformis*), Athel Pine (*Tamarix aphylla*), Giant Reed (*Arundo donax*) and Three-corner Jack (*Emex australis*).

Significant Fauna

One threatened ecological community listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* is present in the region – “The community of native species dependent on natural discharge of groundwater from the Great Artesian Basin”. These communities are associated with the GAB spring wetlands that occur in the region along the margins of the GAB.

The diversity of habitats within the Stony Plains bioregion has led to the occurrence of a wide variety and

number of species in the region. The bioregion supports a number of endemic reptile species including over 140 bird species, over 30 mammal species and more than 100 species of reptile including the Gibber Dragon (*Ctenophorus gibba*), Ochre Dragon (*C. tjantjalka*), Bronzeback Legless Lizard (*Ophidiocephalus taeniatus*) and Woomera Slider (*Lerista elongata*) (Brandle 1998, DEH 2009).

The bioregion also supports a number of nationally threatened species and provides primary habitat for the Thick-billed Grasswren (*Amytornis modestus*), Plains Mouse (*Pseudomys australis*) and the Bronzeback Legless Lizard (Neagle 2003). Rare or threatened flora and fauna species that have been recorded within 20 km of PEL122 and 123 are listed in Appendix 2.

4.2.2 Simpson - Strzelecki Dunefields

The Simpson - Strzelecki Dunefields bioregion covers an area of 277,876 km² and extends across South Australia and the Northern Territory with some overlap into Queensland and New South Wales. PEL122 and PEL123 lie to the west of the bulk of this bioregion and intersect an outlying tongue that constitutes its western-most extent. Approximately 40% of the area of PEL122 and PEL123 occurs within this bioregion.

The portion of the Simpson - Strzelecki Dunefields bioregion covered by PEL122 and PEL123 is comprised of the Wattiwarriganna land system. A full description of this land system is provided in Appendix 1.

Geology, Soils & Landform

The Simpson-Strzelecki Dunefields are characterised by the vast aeolian sand dune systems of the Simpson and Strzelecki Deserts. They contain arid dunefields and sandplains with sparse shrubland and spinifex hummock grassland, and cane grass on deep sands along dune crests. In places they are interrupted by large clay pans that grade into a large playa complex of salt lakes and gypsum dunes. The main lakes in this system are located outside the Arckaringa Basin to the east and include Lake Eyre and a chain of interconnected lakes in the south-east.

Throughout the bioregion, the dune systems are generally orientated on a north-north-west to south-south-east longitudinal plane. The orientation varies across PEL122 and PEL123 and the longitudinal orientation of dunes is predominantly east-north-east – west-south-west in the southern part of the bioregion and north-north-east – south-south-west in the northern part.

The bioregion also includes the lower reaches of two of Australia's major inland river systems, Warburton and Cooper Creeks and three wetlands of national significance, Lake Eyre, Inland Salt Lakes and the Strzelecki Creek (Neagle 2003). All of these features are located in the eastern portion of the bioregion, outside the area covered by the Arckaringa Basin and PELs 122 and 123.

The Wattiwarriganna land system (which is the only Simpson-Strzelecki Dunefields land system in PEL122 and PEL123) is comprised of an extensive dune field of long parallel dunes and broad inter-dunal corridors which include sandy flats and clay pans. Numerous large watercourses dissect the land system and there are several mound springs present. Soils in the region range from deep red sandy soils on the dunes to sandy-clay soils in the swales (Marla - Oodnadatta SCB 2002).

The main types of landforms encountered in the bioregion include:

- Dunefields and sand plains
- Salt lakes
- GAB springs.

These landforms are consistent with the descriptions provided in Section 4.2.1.

Flora

Vegetation of the dunes is dominated by a hummock grassland of Sandhill Canegrass (*Zygochloa paradoxa*) or a tall shrubland of Horse Mulga (*Acacia ramulosa*). Umbrella Bush (*A. ligulata*) occurs in isolated stands and Narrow-leaved Hophbush (*Dodonaea viscosa* ssp. *angustissima*) is also moderately common. Few understorey species grow under or near these two shrubs. Silver Needlebush (*Hakea leucoptera* ssp. *leucoptera*) also occurs as scattered plants and mulga occurs on some dune footslopes. The understorey includes Tall Kerosene Grass (*Aristida holathera*), Buckbush (*Salsola australis*) and Cattle Bush (*Trichodesma zeylanicum*) (Marla - Oodnadatta SCB 2002).

Interdune corridors include both sandy flats and claypans. Sandy flats support low shrublands of Sturt's pigface (*Gunnopsis quadrifida*), Cottonbush (*Maireana aphylla*), Low Bluebush (*Maireana astrotricha*),

Bladder Saltbush (*Atriplex vesicaria*), Emubushes (*Eremophila* sp.), Sennas (*Senna* sp.) and Neverfail (*Eragrostis setifolia*), with Mulga grass (*Aristida contorta*) dominant in the understorey. Some claypans support Swamp Canegrass (*Eragrostis australasica*), Old Man Saltbush (*Atriplex nummularia* ssp. *nummularia*), Cottonbush, Neverfail and Lignum (*Duma florulenta*). Blue rod (*Stemodia florulenta*) is common at claypan margins (Marla - Oodnadatta SCB 2002).

Larger watercourses are usually lined with Coolibah (*Eucalyptus coolabah*), with Sandhill Wattle, Old Man Saltbush, Cottonbush, Sennas, Samphire (*Tecticornia* sp.), Neverfail, Cupgrasses (*Eriochloa* sp.), Silky Browntop (*Eulalia aurea*) and Swamp Canegrass all present in the understorey (Marla - Oodnadatta SCB 2002).

GAB springs support their characteristic vegetation including Common Reed (*Phragmites australis*), Bore-drain Sedge (*Cyperus laevigatus*), Cutting Grass (*Ghania trifida*), Bare Twig Rush (*Baumea juncea*), Sea Rush (*Juncus kraussii*) and Salt Couch (*Sporobolus virginicus*) (Marla-Oodnadatta SCB 2002).

As noted in Section 4.2.1 there are seven declared weed species recorded within 20 km of PEL 122 and 123.

Significant Fauna

One threatened ecological community listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* is present in the region – “The community of native species dependent on natural discharge of groundwater from the Great Artesian Basin”. These communities are associated with the GAB spring wetlands that occur in the region along the margins of the GAB.

A number of nationally threatened fauna species have been recorded in the extensive dunefields of this bioregion. Nationally threatened species recorded within 20 km of PEL122 and 123 include the Crest-tailed Mulgara (*Dasyurus cristicaudata*), as well as the Plains Mouse (*Pseudomys australis*) and Thick-billed Grasswren (eastern) (*Amytornis modestus*) which are both more typically associated with habitats found in the Stony Plains bioregion.

Rare or threatened flora and fauna species that have been recorded within 20 km of PEL122 and PEL123 are listed in Appendix 2.

4.3 Surface Water Resources

Surface water features in the region include rivers, creeks, associated flood plains, salt lakes, internally draining dunefield clay pans and Great Artesian Basin (GAB) springs. The majority of the major rivers are north of PEL122 & PEL123 and drain into Lake Eyre, while rivers and creeks in the southern portion terminate in salt lakes or clay pans. These features collectively form part of the Lake Eyre Basin.

Surface water in the region is generally ephemeral and is only present following localised rainfall. Permanent surface water can be found at points where artesian water flows to the surface, such as pastoral bores or the GAB springs.

4.3.1 GAB Springs

PEL122 & PEL123 overlies the western edge of the Great Artesian Basin (GAB) and is within the South Australian groundwater provinces of the Eromanga Basin. Artesian conditions occur on the northern border of PEL122 and on the eastern boundary of PEL123. The GAB aquifer outcrops at the surface to the west of Coober Pedy and deepens in a north-easterly direction to around 250m at Lake Eyre (Marla - Oodnadatta SCB 2002). Vertical leakage from the GAB occurs via a series of springs (known as GAB springs or mound springs) which appear around the southern and south-western margins of the basin (Armstrong 1990).

GAB springs have been described as “oasis in the desert” and are foci for plant, animal and human life. They have very high biological and cultural significance (Boyd 1990). They support unique flora and fauna, some of which is endemic to the springs and is considered threatened on a national level. As indicated in Section 4.2.1, the ecological community associated with GAB springs is protected under the *Environment Protection and Biodiversity Conservation Act 1999*. Many of the springs are significant Aboriginal places with abundant archaeological material (Boyd 1990).

GAB spring structure is highly variable, but typically includes a vent where it emerges from the ground, a tail which flows from the vent and terminates in the wetland around the base of the spring (if the flow is great enough) and saline spring margins surrounding the spring (DEH 2009). Mounds can develop at the spring vent by the deposition of carbonate or trapping of windblown material by spring vegetation (Marree SCB 2004).

There are a number of GAB springs present in the eastern portion of PEL 123, many of which have been identified as features of high biological and cultural significance. Their location are shown in **Figure 5**, the approximate location of PEL122 and PEL123 is shown with a blue polygon. Major springs include:

- Spring complex around Francis Swamp located 40km east of the target area (within PEL123)
- Strangways Springs located 65km east of the target area (Outside PEL)
- Wabma Kabardu Mound Springs Complex located 80km south east of target area (Outside PEL)

Recent work by DEWNR 2015/03 have identified potential for some springs to be sourced from deeper aquifers beneath the GAB including the Boorthanna Formation and pre-Permian basement. Evidence comes from the southern region of the Arckaringa Basin where uplift has caused erosion of the Mount Toondina and Stuart Range Formation (aquifers) leaving the GAB in direct contact with the formations mentioned above.

DEWNR 2016/02 completed a detailed study of GAB Springs within the northern parts of the Arckaringa Basin to inform the Bioregional Assessment Programme in the Lake Eyre Basin. The aim of the project was to improve data knowledge through field investigations to inform future decision making and management for the South Australian portion of the Lake Eyre Basin and areas overlying the Arckaringa and Pedirka Coal Basins. The report concludes springs on the western margin of the Great Artesian Basin are currently impacted by low flows, high grazing pressure and high nutrient loads.

Sapex acknowledges the significance of the GAB springs and have identified a 5km trigger zone as shown in **Figure 2**. Additional consultation with both State and Federal Government Agencies (potential impacts to MNES under EPBC) is required during the stage 3 approval process prior to any stimulation activities being approved within these trigger zones.

4.3.2 Lake Eyre Basin

DEWNR (2015/43) describes the Lake Eyre Basin (LEB) is an internally-draining basin that takes up almost one sixth of Australia's land mass in the arid and semi-arid interior (**Figure 6**). It is unique in being one of the only unregulated dryland river systems in the world and having the most variable flows in the world. The first assessment of the health of LEB rivers found them to be in near-natural condition. The LEB

contains wetlands of national and international importance for supporting Australia's waterbird populations and nationally threatened and endemic species are found in the SA LEB. The ecology is driven by the flow regime and cycles from 'boom' periods following large floods through to 'bust' periods with little to no flow.

The Basin gradient is very flat (less than 1% slope), except at the outer margins where it is fringed by low ranges (mostly around 300 to 400 m above sea level). Kati Thanda-Lake Eyre (North and South) is the terminus for most catchments in the Basin, however, under current climatic conditions, thirty-two percent of the Basin area does not contribute run-off to Kati Thanda-Lake Eyre. Much of the Basin experiences long periods of little to no flow, punctuated by small to medium floods and the occasional large flood where entire floodplains of catchments are inundated.

PEL122 and PEL123 are in the South-Western corner of the basin with PEL123 being 55km west of Lake Eyre South. Their location is shown in **Figure 6**.

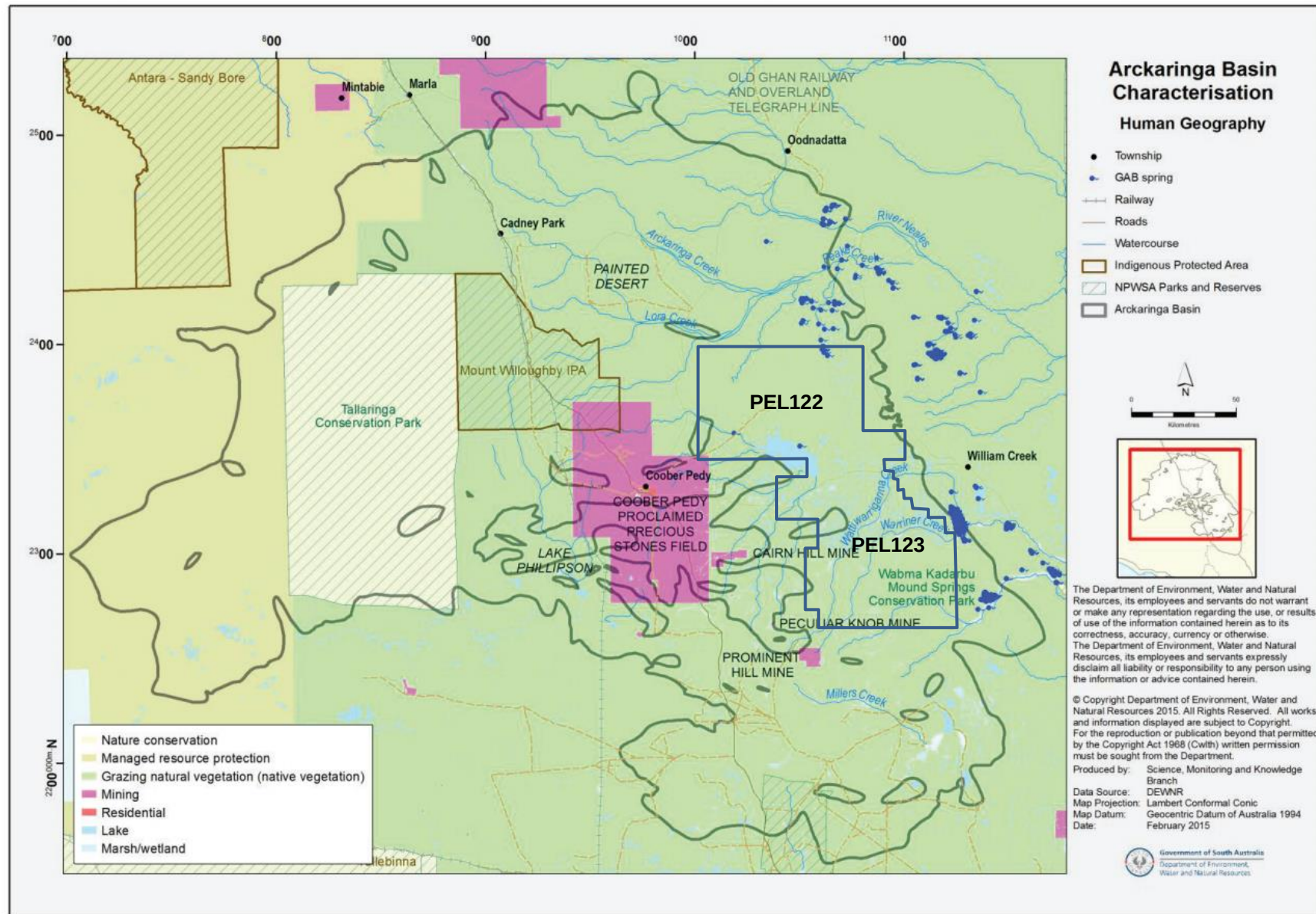


Figure 5 Arckaringa Basin Spring Location (DEWNR 2015/03)

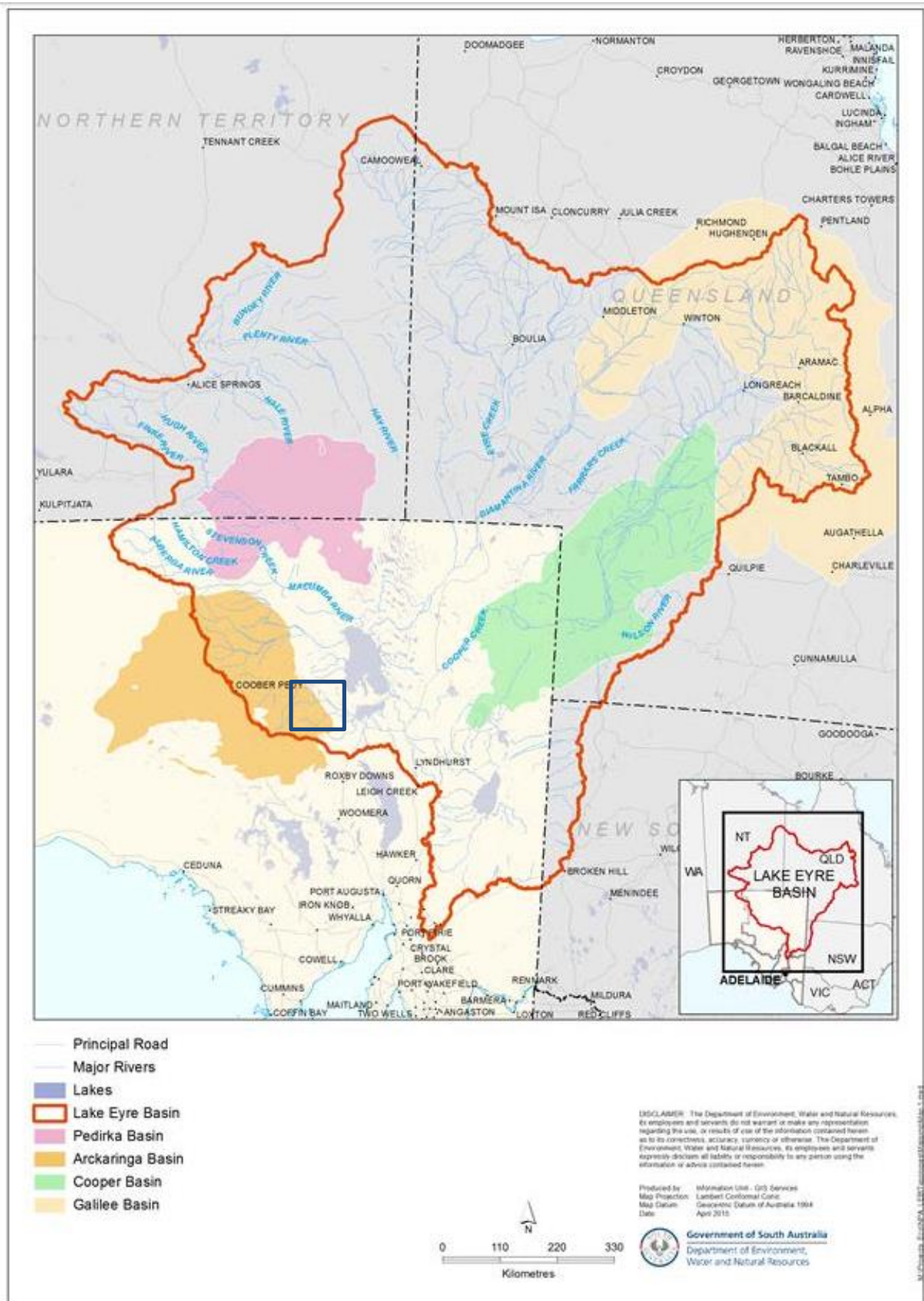


Figure 6 Lake Eyre Basin, showing the major waterbodies and location of Permian Basins (DEWNR 2015/43).

4.4 Arckaringa Basin Geology

4.4.1 Structural Setting

The Arckaringa Basin is an intra-cratonic basin, which contains sediments of mainly early Permian age. The main regional tectonic features are shown in **Figure 7**. These are the age equivalent of oil and gas productive Permian intervals in the Cooper Basin. The Arckaringa Basin covers an area of about 80,000 square kilometres in the northern South Australia.



Figure 7: Regional Structural Setting (note the basin extent has been updated since this map was published).

It is composed of a central platform area of gently undulating shallow crystalline basement surrounded by peripheral depressions. The basin was formed by faulting of the marginal depressions, oriented in a northwest to southeast direction, such as the Boorthanna and Phillipson Troughs. These troughs contain in excess of 2,000m of Permian sediments (See **Figure 2**, the green to red contour identifies a thick Permian sequence known as the Boorthanna Trough, this the target area for ongoing exploration). The Permian sediments are underlain unconformably by thick pre-Permian (Adelaidean to Cambrian) sequence. Mesozoic Eromanga sediments (Middle Jurassic to Early Cretaceous) are spread as a thin veneer (up to 300m) over most of the Arckaringa region, thickening to the north and north-east. It is generally less than 10m of Tertiary cover over the basin area (Drexel and Preiss 1995).

The Arckaringa Basin is bounded by the Early Proterozoic Gawler Craton in the south, late Proterozoic to early Palaeozoic eastern Officer Basin in the west and to the east it is fault bounded against the Peak and Denison Inliers. These ranges comprise the Precambrian crystalline rocks, overlain by folded and metamorphosed sediments of the Adelaide Geosyncline and are intruded by Early Palaeozoic granites. The north and north-eastern margin are not readily defined due to lack of outcrop and subsurface data (Hibburt 1984).

4.4.2 Stratigraphy

Composite generalised stratigraphy of the Arckaringa Basin is presented in **Figure 8**. The location of the petroleum exploration wells referenced throughout this section is provided in **Figure 10**.

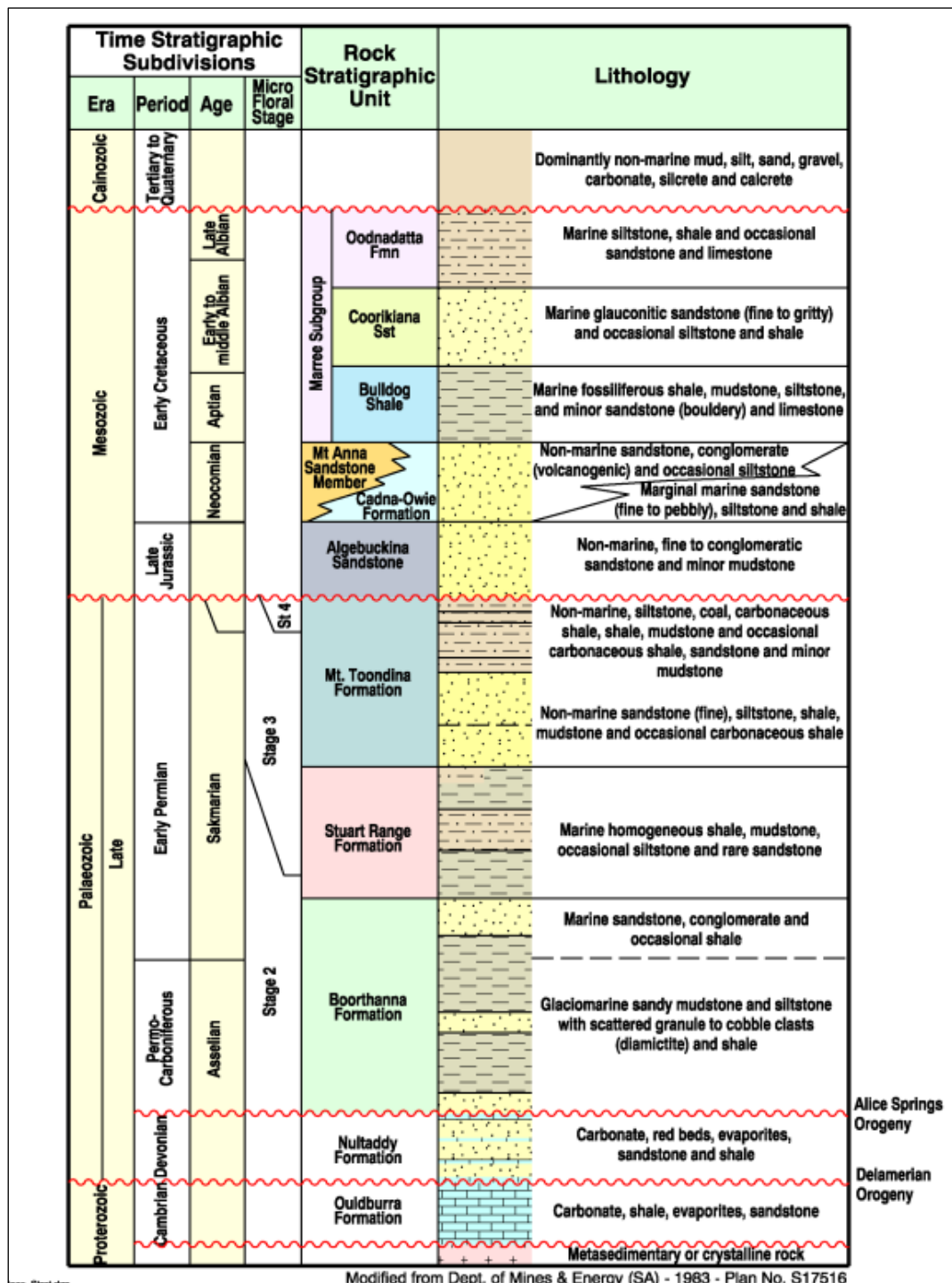


Figure 8: General Stratigraphic Column of the Arckaringa Basin

Mesozoic Sediments (Eromanga Basin)

The early Permian sediments are overlain by an abbreviated Eromanga Basin succession which consists of Algebuckina Sandstone, Cadna-owie Formation and Bulldog Shale. The Jurassic Algebuckina Sandstone is sand-dominated deposited in the braided fluvial system with typical lithology of white kaolinitic quartz sandstone and conglomerate composed of well-rounded quartz pebbles. The early Cretaceous Cadna-Owie Formation has been deposited in the marginally marine to non-marine environment.

Its lithology is typically fine to medium grained brownish sandstone, silty and micaceous and it may also contain quartz pebbles. The Bulldog Shale is a shelf mud deposited from suspension in an epicontinental sea and it consists of dark grey, bioturbated and fossiliferous shaly mudstone. The Bulldog Shale could provide a top seal for the Cadna-owie Formation and Algebuckina Sandstone. The total Eromanga Basin sequence, in the Arckaringa Basin, is up to 300m thick. Following this phase of rapid deposition, erosion

and deep weathering occurred during the Late Cretaceous to Paleocene (Alexander and Hibburt 1996).

The Algebuckina Sandstone and Cadna-Owie Formation collectively form the Great Artesian Basin within the Arckaringa area. This is discussed in more detail in Section 4.5

Permian Sediments (Arckaringa Basin)

The Arckaringa Basin sediments have been deposited during late Carboniferous to early Permian. Three major sedimentary units (Boorthanna, Stuart Range and Mount Toondina formations) have been defined from the seismic, drilling and mapping in the area (**Figure 9**).

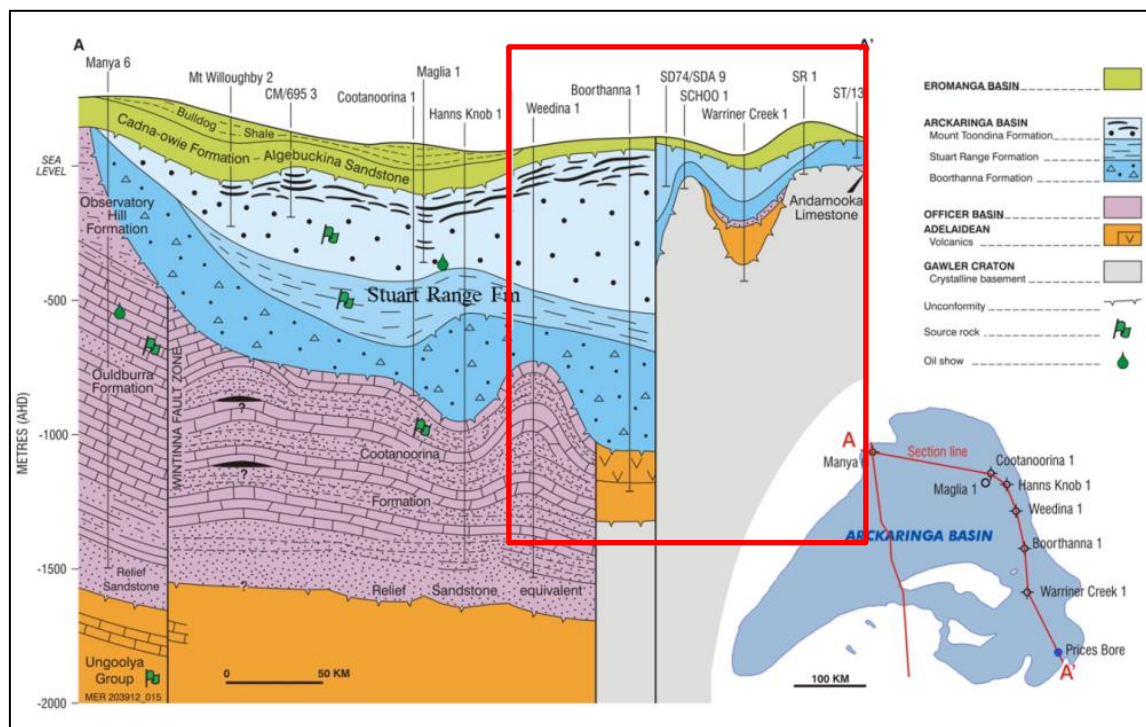


Figure 9: Schematic Cross-Section of the Arckaringa Basin (Project Area in red)

Mount Toondina Formation

The Mount Toondina Formation overlies, usually conformably but occasionally disconformably, the Stuart Range Formation. Three units have been recognised from seismic and wells. The basal unit has only been intersected in the south (Boorthanna 1 and Arkeeta 1) and it consists of anoxic marine shale with interbedded limestone indicating a restricted marine environment. The overlying middle unit comprises fluvio-deltaic sands prograding from the east with interbedded siltstones. Termination of marine deposition was brought about by crustal isostatic recovery or eustatic fall bringing about a return to freshwater conditions. The age of the Lower Mount Toondina Formation has been determined by palynology to be Kungurian 276-270 Ma (Purcell 2012).

The upper unit is deposited in a predominantly lacustrine environment with coals deposited during phases of swamp development, and sandstones representing fluvial incursions. The coals have seams, which are up to 8m thick, with cumulative thicknesses up to 30m. The Mount Toondina Formation is lithologically similar to the time equivalent Purni Formation in Pedirka Basin and the Patchawarra Formation in the Cooper Basin (Moore 1982).

Sedimentation ceased as a consequence of positive epeirogenic movements at the end of Early Permian. Apart from some erosion in the eastern side of the basin no other deposition records are preserved in the Arckaringa Basin from Late Permian and Triassic.

Stuart Range Formation

Following glaciation, marine transgressive conditions prevailed with eustatic rise in sea level and flooding of glacio-isostatically depressed lowlands resulting in deposition of the Stuart Range Formation, which usually conformably overlies the Boorthanna Formation, but it is mainly unconformable in the Boorthanna

Trough).

The Stuart Range Formation is blanket marine shale of Early Permian (Sakmarian to Artinskian) and consists of dark grey to black shales and siltstones with some minor interbedded sandstone. It is predominantly deposited in quiet, restricted marine conditions but with occasional lacustrine intervals. It provides a top seal and potential source rock that could charge sandstones within the upper part of the Boorthanna Formation.

The total thickness estimated from seismic is between 70-300m, however the thickest intersection reported is 491m in Lake Phillipson Bore 1 (Moore 1982; Hibburt 1984). Thick organic rich black shales and siltstones with excellent source rock potential have been intersected in Arck 1, Wirrangula Hill 1A and Pata 1, all located in the central Boorthanna Trough (Linc 2011) (see **Figure 10**).

Boorthanna Formation

The Boorthanna Formation comprises a basal glaciogene sequence and upper marine unit with rhythmically bedded sandstone. The earliest sedimentation commenced with a period of glaciation and is dominated by glaciogene sediments including diamctites, which were transported by glaciers and deposited in the marine environment interbedded with laminated mudstone and minor sandstones and carbonates. It is assumed the sea had access from the southwest. The faulting which was particularly active during the Early Permian ice age continued into the post glacial period and resulted in a number of turbidity currents, which provided transport of the coarse clastics forming the upper unit of the Boorthanna Formation. This sequence, which consists of medium to coarse grained sandstones, has demonstrated reservoir potential in a number of wells.

The maximum thickness intersected is 646m at Pata 1. The age of the Boorthanna Formation has been determined by palynology to be Asselian to Sakmarian (299-284 Ma), Purcell 2012).

Pre-Permian Sediments (Officer Basin)

The stratigraphy of the pre-Permian sequence is poorly known due mainly to poor stratigraphic control and only few well intersections. Precambrian crystalline basement of the Gawler Craton, together with the varying thickness of Adelaidean to Cambrian sediments underlie most of the Permian in the basin (Priddle 1983). Based on the available seismic interpretation and limited well data it appears that pre-Permian sequence is present and up to 4km thick in the eastern Officer Basin (PEL 117), Boorthanna Trough (PEL 121 and PEL 122) and south-eastern part of the basin (PEL 123). The Pre-Permian sequence is very thin or absent in the central and south-western parts of the basin. No stratigraphic date has been determined through palynological analyses. Numerous oil and gas shows have been recorded in the pre-Permian sequence in the Officer Basin to the west.

The earliest preserved sedimentation in the area probably occurred during Adelaidean to Cambrian in a fault-bounded trough. Following uplift and erosion of the Ordovician Delamerian Orogeny, sedimentation recommenced with the possible deposition of a Siluro-Devonian sequence of shaly carbonates and terrigenous sediments, mainly red beds. Deposition of these rocks ceased with the onset of the Carboniferous Alice Springs Orogeny (PIRSA 2011).

The lithologies intersected to date comprise mainly carbonates (dolomites) interbedded with anhydrite, dolomitic shales and minor sandstone indicating a predominantly quiet-water restricted marine environment including evaporitic tidal flats and sabkhas (Cootanoorina 1 and 2, William Creek 1 and Weedina 1) or red beds with a dolomite matrix and minor anhydrite (Eba 1), together with interbedded siltstones affected by multiple diagenesis (Hanns Knob 1 and Haystack 1). The effect of diagenesis found in these sediments appears to be spatially irregular. The basal part of the pre-Permian sequence in the Boorthanna Trough consists of metamorphics intersected in Birribiana 1, Weedina 1 and Boorthanna 1 (Linc 2011).

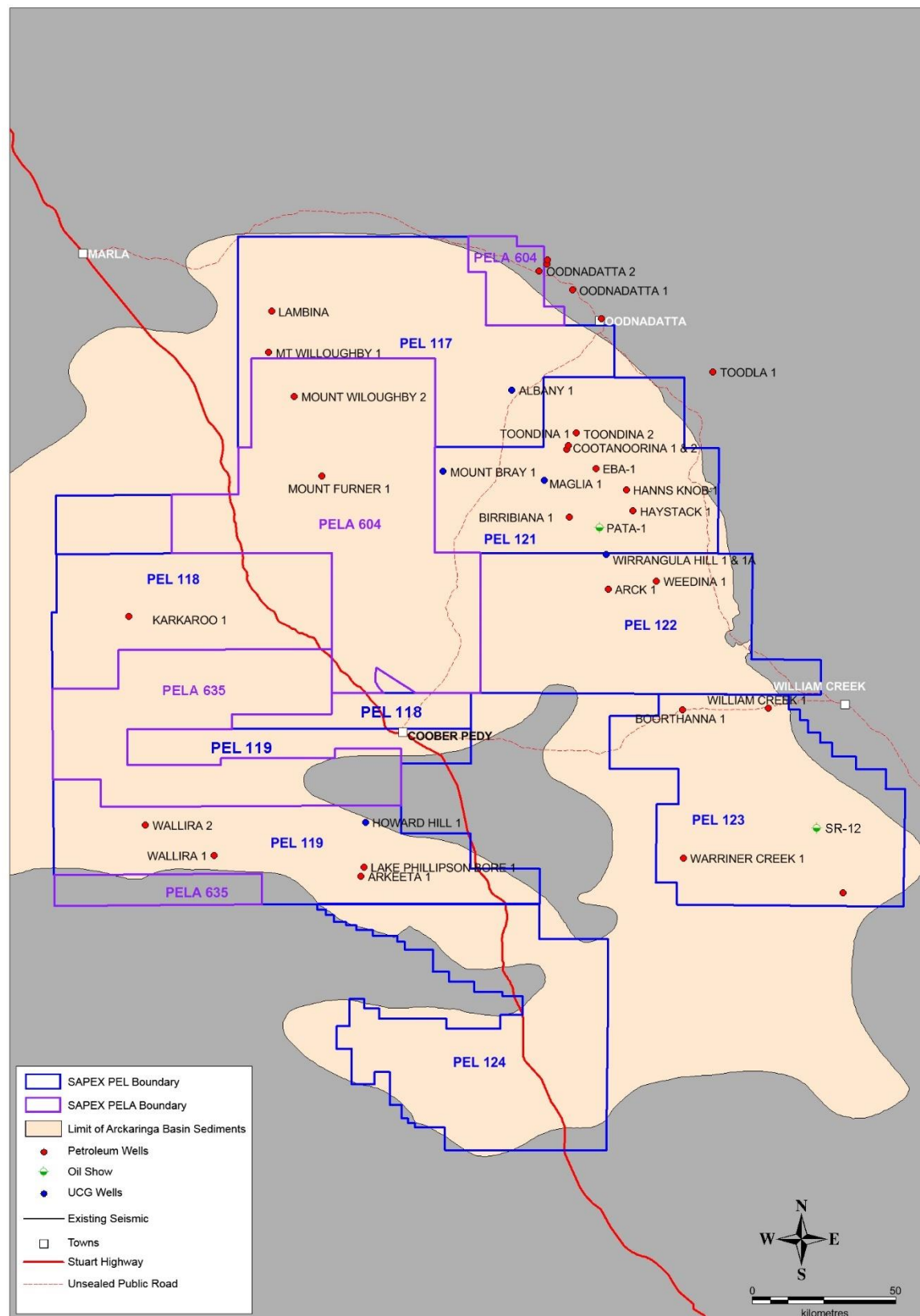


Figure 10: Location of historical petroleum exploration wells (note the basin extent has been updated since this map was published).

4.4.3 Unconventional Oil and Gas Potential

Background

Black shales with high organic content were recognized within the Stuart Range Formation in the Arckaringa Basin during early exploration work from the 1980s. The potential commercial value of this formation has recently been recognized as the petroleum industry begins to focus globally on unconventional hydrocarbon resources.

Linc Energy drilled two core holes in the Boorthanna Trough portion of the Arckaringa Basin during 2011 (Arck 1 and Wirrangula Hill 1A) and 1 well in 2014 (Pata 1). Samples collected from these core holes have been thoroughly evaluated using modern analytical methods designed to identify hydrocarbon encapsulated in the shale and establish the first real attempts to quantify the parameters which are critical for commercial production. In addition to the new core samples, Linc and Tri-Star obtained and re-tested samples where available from all drill holes which penetrated the Stuart Range Formation within the Arckaringa Basin. This new analytical work indicates that the Stuart Range Formation contains excellent source rock with encouraging characteristics for development as an unconventional shale oil resource.

In 2011 and 2012 Linc Energy has conducted comprehensive geochemical analyses on the core and cuttings samples from Pata 1, Arck 1, Wirrangula Hill 1A, Warriner Creek 1, SR 3, SR 12, Karkaro 1, CR/82 AWH 2, CR/82 AWH 3 and DH1. The results indicate very good to excellent source rock potential for the Stuart Range Formation in the Boorthanna Trough (PEL122) and in the southeast area within PEL 123 where higher than expected maturity of 0.59% to 0.72% Ro at relatively shallow depths is perhaps an indicator that the area has been subjected to higher heat flow or was more deeply buried before local uplift and erosion. Total Organic Carbon (TOC) results from the wells indicate the Stuart Range Formation is an organic rich shale with excellent potential for liquids generation.

Prospective Shale Oil and Gas Targets

The primary shale target in the Arckaringa Basin is the organic rich black shales of the Stuart Range Formation. The additional targets are interbedded shales of underlying Boorthanna Formation which are expected to be mature for oil generation over large areas of the Arckaringa Basin. There is very limited information about the source rock properties of pre-Permian sediments (Officer Basin), but numerous oil shows and source-oil correlations indicate that this section is likely to be within the oil window, except in deep troughs where overmature, gas-prone conditions are indicated. Good quality source rocks are also intersected in the basal unit of the Lower Mount Toondina Formation, which overlies the Stuart Range Formation, however this formation is unlikely to be thermally mature for significant hydrocarbon generation and expulsion.

All available information relating to the Stuart Range Formation, Boorthanna Formation and pre-Permian sediments has been analyzed and compiled into a computerized data set capable of generating basic interpretive maps. The data utilized includes core, cuttings and logs from drillhole intersections and correlations to the regional seismic lines. Independent consultants have worked with all available seismic lines including re-processed lines of 1980s vintage to pick formation tops across the entire basin.

Additional data from future drilling and seismic surveys will contribute greatly to our understanding of the Stuart Range Formation and the other targets. Although the existing data is limited, the overall shape and geometry of the Stuart Range and other formations is apparent and likely to be fairly accurate on a basin-wide scale.

Based on very limited data from the source rock and thermal maturity analyses, the Boorthanna Formation is expected to be mature for oil generation in the Boorthanna Trough (PEL122) and over large areas of the PEL 123 in the south-eastern part of the Arckaringa Basin. One core sample from the upper Boorthanna Formation in Pata 1 yielded good shale oil potential with generative capacity of 60.04mg HC/g of rock.

A regionally thick correlatable basal siltstone/shale glacial unit in the Boorthanna Formation has been identified in Hanns Knob 1, Birribiana 1, and Boorthanna 1 wells in the central Boorthanna Trough (**Figure 11**). All these wells were drilled on the structural highs, so it is expected that this unit will be thicker and more organically richer where deposited in the deep troughs with restricted and quiet marine depositional environment.

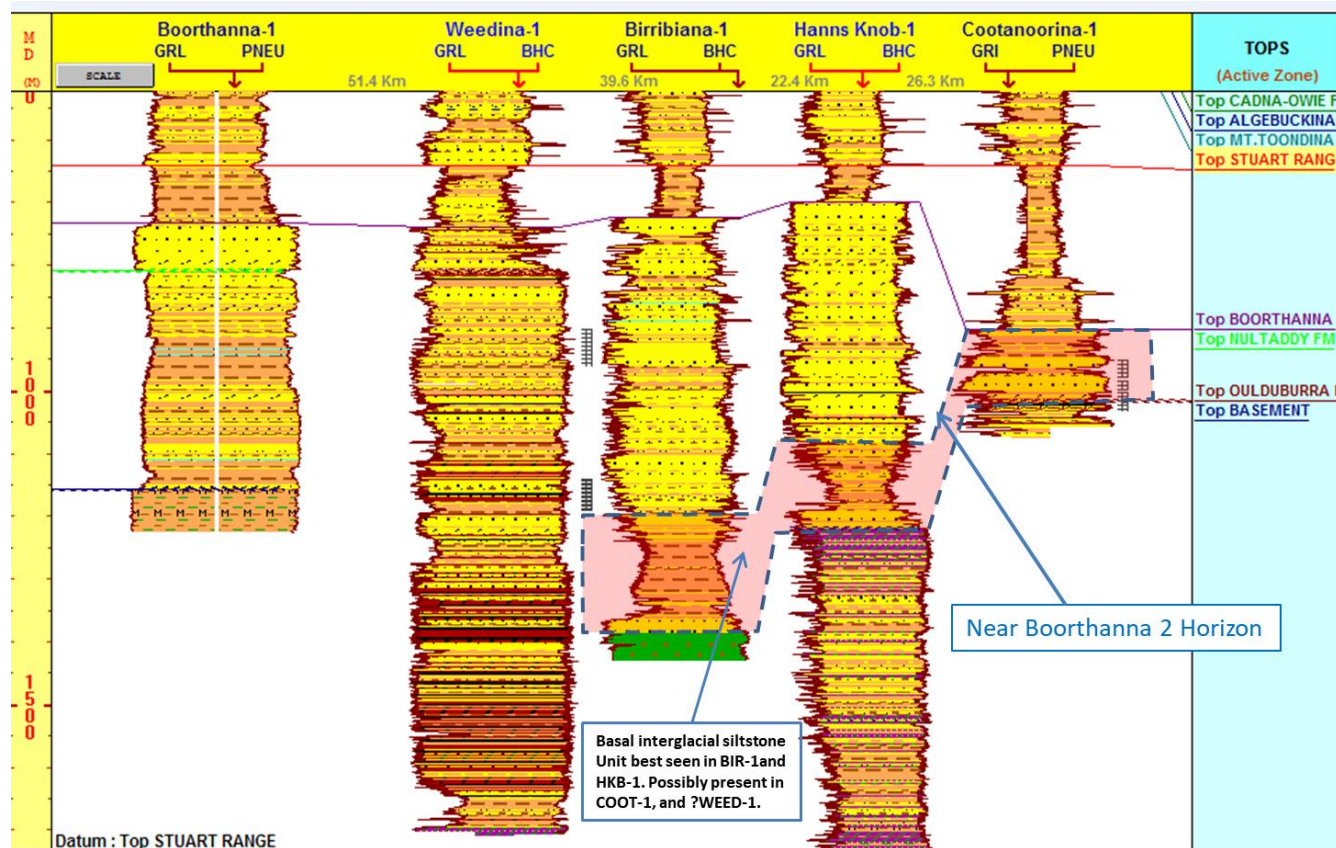


Figure 11: Stratigraphic well correlation in the Boorthanna Trough

Stress Regimes and Fracture Orientation

The stress orientations and magnitudes within the target rocks are important as they influence the orientation and growth of induced fractures during fracture stimulation. Stress studies using borehole data (caliper and image logs) indicated the average maximum horizontal stress (SHmax) orientation for the Arckaringa Basin was approximately east-west which is consistent with the maximum stress orientation interpreted in wells drilled in the Boorthanna Trough (Pata 1 & Eba 1).

In general, fractures will propagate in the maximum horizontal stress direction and the fracture will open in the minimum stress direction. Geomechanical studies of existing exploration wells in the Arckaringa Basin indicates the upper Permian strata within the Mount Toondina Formation is in a reverse faulting stress regime at shallow depth changing to a strike-slip stress regime at greater depths (in the lower Mount Toondina Formation at approx. 300m). Therefore, fractures are likely to be of vertical orientation and propagate in the maximum stress direction which is expected to be horizontal.

Stress Contrasts and Fracture Containment

The geomechanical studies discussed above have indicated that there is a significant variation in elastic properties and stress magnitudes between lithologies in the Boorthanna Trough which will impact on the height growth of induced fractures during fracture stimulation. These variations will act as stress barriers between the target zone and the overlying aquifers.

The calculated minimum horizontal stress magnitude (shown as a green line in **Figure 12**), has a similar magnitude to the calculated vertical stress (shown as a sloping black line in **Figure 12**). Where the minimum stress is less than the vertical stress, induced fractures are likely to be vertical. Where the minimum horizontal stress exceeds the vertical stress, induced fractures are expected to be horizontal.

Significant changes in stress regime can result in the containment of fracture growth. As seen in the example in **Figure 12**, the minimum horizontal stress exceeds the vertical stress within the Upper Mount Toondina Formation indicating fracture growth will change from vertical to horizontal at this point. In the unlikely event fracture growth penetrates all the way through the upper Stuart Range and the lower

Mount Toondina Formation (which is not likely as it is over 500m) containment will occur at these boundaries.

As a result, it's unlikely that induced fractures would propagate beyond the lower Mount Toondina Formation. In addition, the relatively impermeable nature of the Stuart Range Formation and the lower Mount Toondina Formation provide an excellent geological barrier (minimum 500m of rock), between the target formations and the Jurassic aquifers of the Great Artesian Basin.

It should be noted the well in **Figure 12**, Hahn's Knob 1 was drilled on a structural high and therefore formation tops are shallower than the expected target depths for an unconventional well. During exploration, more detailed assessments will be made to determine localised stress regimes within the target areas, this is discussed further in Section 6.

This stress information available indicates both the Arckaringa & Eromanga basins are in similar stress regimes as the Cooper Basin.

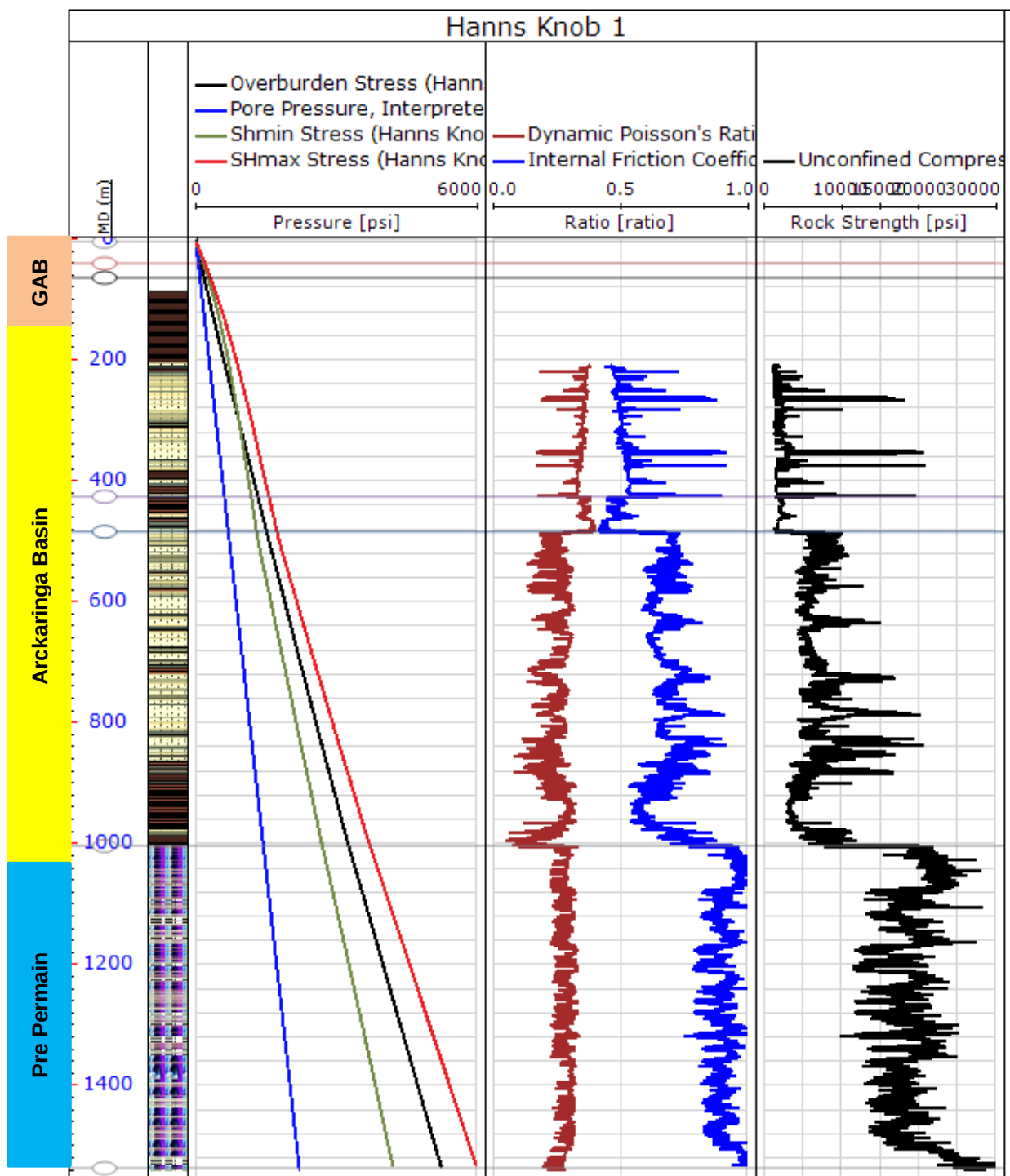


Figure 12: Calculated vertical and horizontal stresses (Source Baker Hughes)

4.5 Hydrogeology

A general summary of the Arckaringa Basin hydrogeology is provided by Coffey 2007, from which the following information has been taken.

The Arckaringa Basin lies under the south - western edge of the Great Artesian Basin (GAB) and appears hydrogeologically partially separated from the central aquifer at basin scale by the Peak & Denison Inlier, an area of outcropping basement rocks.

Similarly, to other parts of the GAB, the Mesozoic Sandstones (Cretaceous Cadna-Owie Formation & Jurassic Algebuckina Sandstone) are the most important water yielding rocks. These formations appear to be hydrogeologically interconnected at a regional scale and would act as a single aquifer system.

The Algebuckina Sandstone forms the main aquifer and has been extensively developed for pastoral usage. It thickens from the sub-crop, in a north easterly direction across the GAB. This confined aquifer is known to be artesian in parts of the Arckaringa Basin in areas where the potentiometric surface lies above ground level, individual wells in the artesian zone may produce in excess of 4.3 ML/day.

In some areas the overlying Cretaceous Cadna-Owie Formation is of sufficient thickness and areal extent to be hydrogeologically significant. Since no continuous aquifer is known in the lower part of the Cretaceous it is likely that sandy horizons in this formation are isolated lenses.

The Cretaceous Bulldog Shale forms a confining layer over the Mesozoic Sandstones. Permian-age rocks extensively underlie the Sandstones of the GAB including the Mount Toondina, The Stuart Range and Boorthanna Formations. These rocks are relatively impermeable and usually form the hydrogeological base of the basin.

The major groundwater intake areas are the elevated eastern margin of New South Wales and Queensland. The general groundwater flow direction appears to be to the south-west towards South Australia. The flow pattern has not been accurately defined and the general direction of flow is probably valid on a regional scale but may vary in local detail. Within the Arckaringa Basin there are minor subsidiary intake areas along the western rim of the margin and along the eastern range where the Algebuckina Sandstone crops out along the Peake – Denison Inlier. It is probable that there is direct rainfall recharge to the Mesozoic aquifers in their outcrop areas along the flanks of the Peak - Denison Ranges.

Groundwater discharge, in the artesian areas, occurs in the form of natural upward movement into overlying sediments, springs, free-flowing artesian bores and, where the potentiometric surface lies below ground level, pumped sub-artesian bores.

Groundwater hydrochemistry is described in DEWNR (2015/03) where an investigation was completed using bores on the flanks of the Arckaringa Basin and in the South towards the Billa Kalina Sub Basin (see **Figure 13**). DEWNR (2015/03) noted similarities in major ion chemistry of groundwater from different aquifers as shown in **Figure 13**. Although trends in major ion hydrochemistry are evident, the high degree of overlap between groundwater sample-groupings based on aquifer provenance indicates that such trends may be more closely related to spatial distribution rather than hydro-stratigraphy.

DEWNR (2015/03) concludes that most samples are primarily dominated by Na⁺-Cl⁻ chemistry, although a clear evolutionary trend that displays a change in anionic composition from proportionally high concentrations of HCO₃⁻ to proportionally low concentration can be observed in some GAB aquifer and spring samples (**Figure 13**). These same samples also contain a proportional Na⁺ + K⁺ concentration of <10%.

Table 3 provides a summary of the regional hydrogeology.

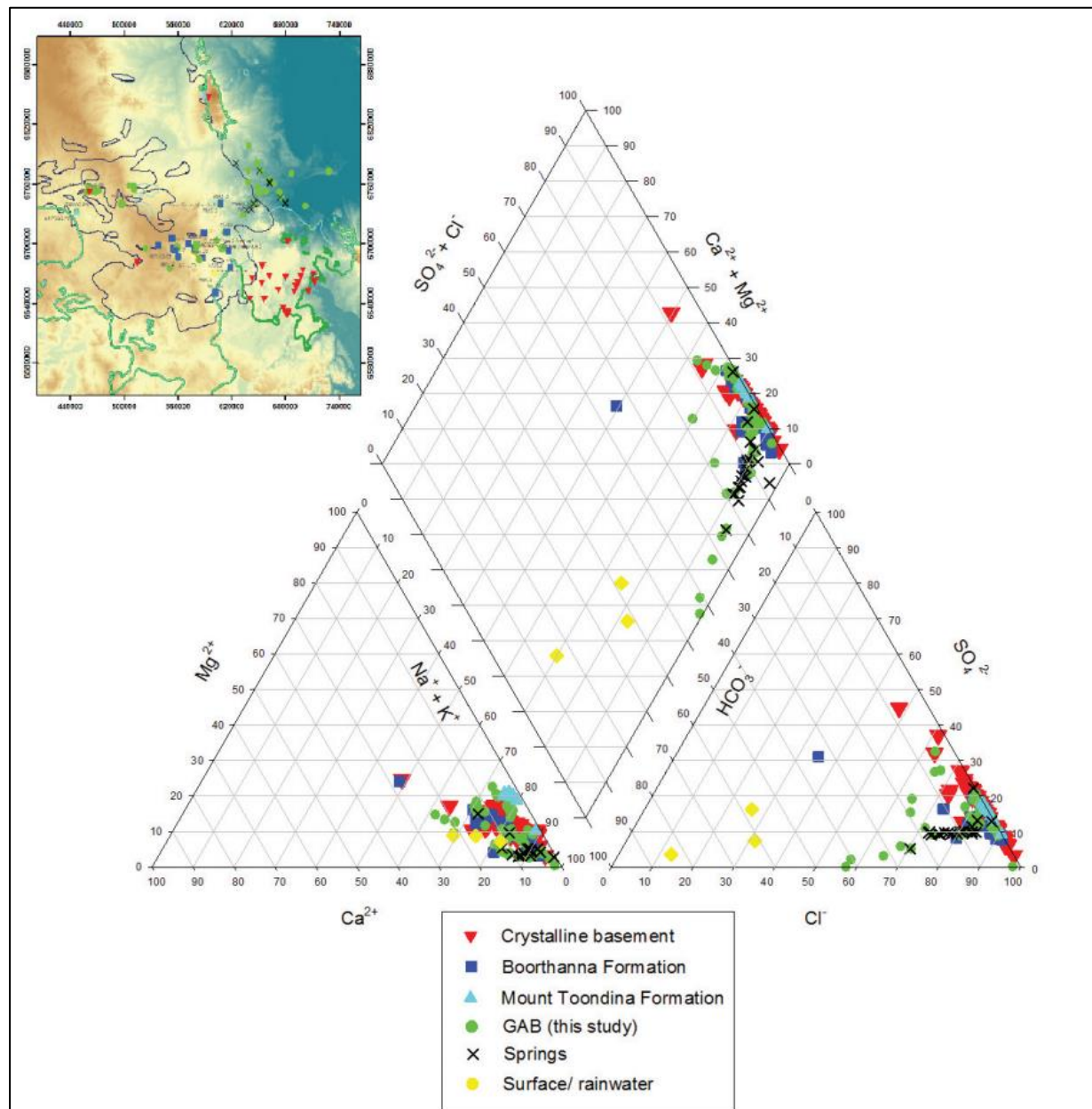


Figure 13 Piper plot displaying major ion data coloured according to aquifer provenance. Inset shows distribution of sample sites

Mesozoic Aquifers (Great Artesian Basin)

Coffey (2007) provides a review of the hydrogeology within the Mesozoic Eromanga Basin overlying the Arkaringa Basin. A cross section is provided in Figure 16 for reference, note the area highlighted by the red square approximates the target area for this EIR. The report identifies one regional aquifer system over multiple formations including the Cadna-Owie Formation and the Algebuckina Sandstone:

- The Cadna-Owie Formation and the Algebuckina Formation combine to form the Great Artesian Basin. This Cadna-Owie Formation is described as a uniform fine – medium sandstone with some silt, rare gravel and occasional thin lenses of siltstone/claystone. The upper section can contain hard sandstone bands with siliceous and/or sideritic cement.
- The Algebuckina Sandstone consists of a uniform, fine – medium – coarse poorly consolidated sandstone. Carbonaceous lenses on bedding plans are common and occasional lenses of silty sandstone hard bands. Poorly lithified coarse sandstone and pebbles are common throughout, particularly in the lower Algebuckina Sandstone at the Permian unconformity.
- Existing data indicates water quality (based on Coffey 2007) within the GAB formations is fresh to brackish (600 – 4,000 mg/l TDS) with salinity increasing to the South West. The dominant anion is chloride with variable sulphate and bicarbonate. Because grain size increases and percentage fines decrease with depth, the permeability may be expected to also increase with depth.
- During 2013 – 2014, Linc Energy completed a baseline groundwater monitoring program on existing bores and mound springs focussing on the eastern Boorthanna Trough (Figure 14 – most developed in GAB sediments). The monitoring was completed over 3 separate timeframes (September 2013, June 2014 & December 2-14) with results published in Linc Energy (2016). Inline with conclusions above, the cation and anion concentrations indicate the water is saline, this is further supported by the total dissolved solids ranging from 2,110 mg/l – 10,900mg/l with the average being 4,160mg/l. Overall, salinity tends to increase from PEL122 to PEL123 as shown in Figure 15.

Other analysis data available includes metals, phenolic compounds, total petroleum hydrocarbons (TPH), PAH, BTEXN and Surfactants, these are published in Linc Energy (2016).

The southern portion of PEL122 & PEL123, the Algebuckina Sandstone pinches out with only the Cadna-Owie Formation remaining. Here the GAB outcrops at surface notable by the surface topography changing from stony plains to sand dune country. Existing drill hole data indicates the GAB formation can be weathered in part/full with common clayey bands formed causing isolated aquifer lenses. Water is generally sub artesian and saline (up to 12,000mg/L TDS). Water quality improves towards Lake Eyre on the eastern side of the mound spring network along with artesian pressure.

The early Cretaceous Bulldog Shale forms the confining aquitard to the GAB aquifers. Minor, sporadic, laterally discontinuous perched aquifers are known to exist at shallow depths within or at the base of the weathered zone (8 – 15m) however this isn't common. Water quality is saline with a measured salinity of approximately 25,600 mg/l TDS.

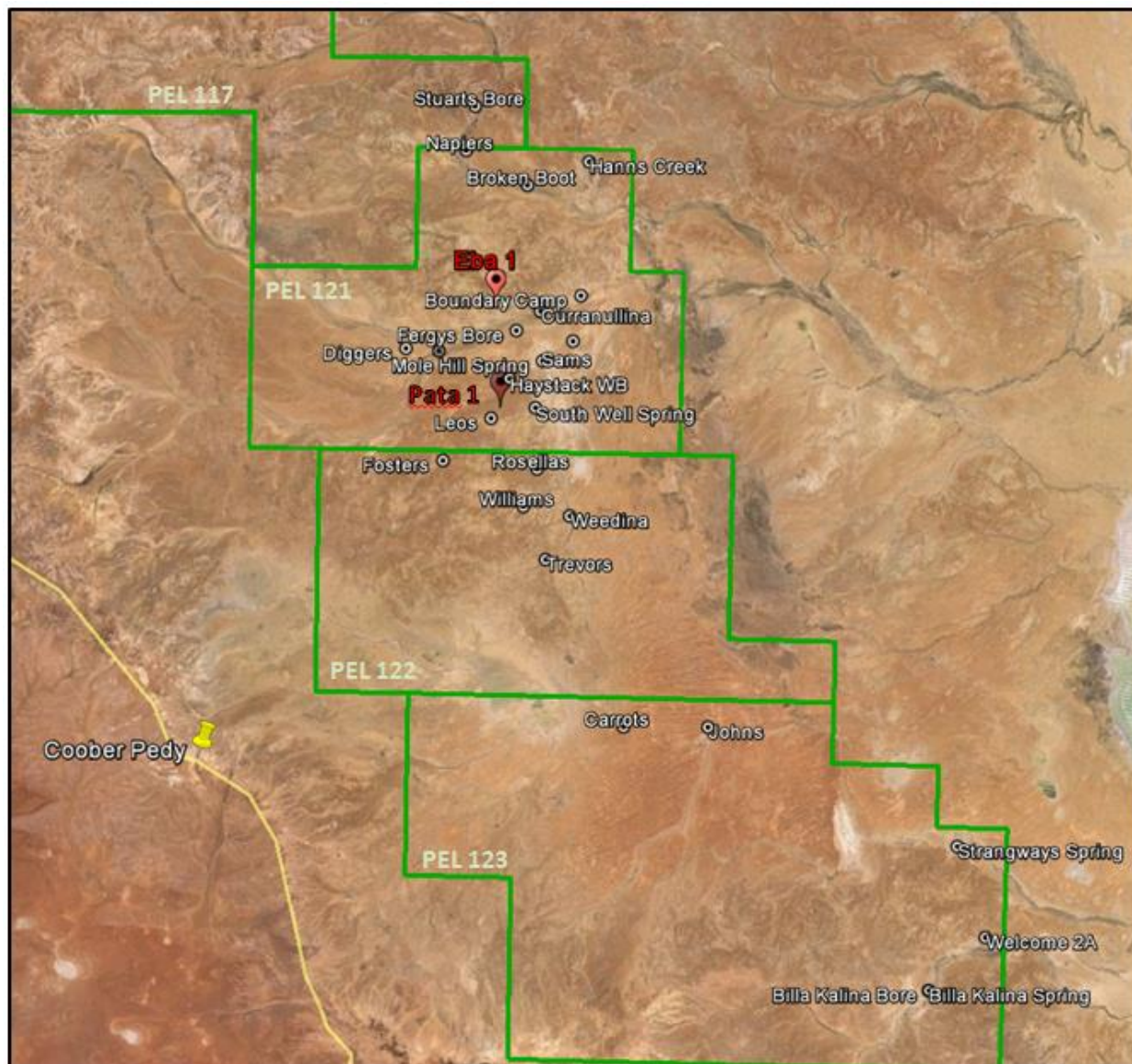


Figure 14: Map of groundwater bore and spring sampling locations

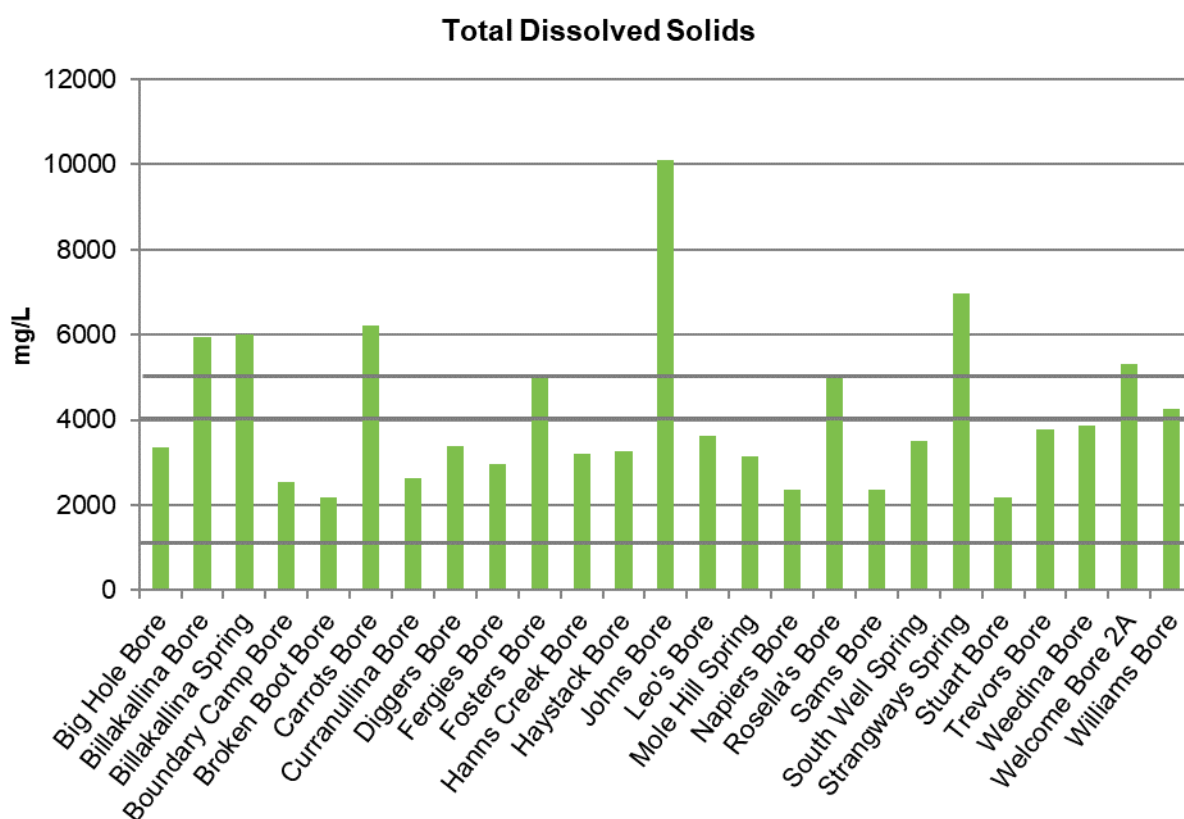


Figure 15: Average TDS Values in the Eromanga Basin Monitoring Bores and Springs (Source Linc 2016)

Permian Aquifers

DEWNR (2013) provides the most recent review of the Hydrogeology within the Permian Arckaringa Formation sediments. A cross section is provided in Figure 16 for reference, note the area highlighted by the red square approximates the target area for this EIR. DEWNR (2013) identifies two regional aquifers systems:

- The Mount Toondina Formation which is described as comprising an upper section consisting of grey carbonaceous shales, coals and interbedded grey sandstones, siltstones and sandy shales. The sandstones and coals in the upper section are described as aquifers that are potentially interconnected with the overlying GAB although this is contrary to the conclusion in Coffey (2007). The lower section of the Mount Toondina Formation is described as less carbonaceous and slightly sandier forming a potential aquitard. This formation provides geological separation between the target Stuart Range Formation and the GAB aquifer and provides the necessary isolation for the proposed fracture stimulation activities.

Existing data indicates water quality within the Mount Toondina Formation is saline to ultra-saline (73,198 – 155,065 mg/l TDS), extremely hard (13,862 – 24,125 mg/L CaCO₃) and slightly acidic (pH 6.5 – 7.0). Hydraulic connectivity ranges from 0.9 – 9x10⁻³ m/d in coal seams and 9 x 10⁻⁴ – 9 x 10⁻⁵ in stoney interbeds. Permeability ranges from 1.48 x 10⁻¹² – 4.5 x 10⁻³ cm². Porosity ranges from 4 – 36.6%.

- The Boorthanna Formation is described as two units. The upper unit consists of interbedded marine clastics, with grain size ranging from silt to boulders, while the lower unit is comprised of glaciogene sandy to bouldary claystone diamictite and shale intercalations. The lower unit is restricted to deeper parts of the basin including the southern Boorthanna Trough. The sandstone and conglomerate layers are potential aquifers and have been targeted in earlier exploration as reservoirs. The shales, siltstone and diamictite layers are potential aquitards.

Most information concerning the hydrogeological characteristics of the Boorthanna Formation is sourced from the south eastern Arckaringa Basin in the Billa Kalina sub-basin. This area is approximately 10km south of PEL123 (**Figure 17**) and is a water source for major mining complex's including Prominent Hill, Cairn Hill and Peculiar Knob. Here, the Boorthanna Formation is described as being heterogenous at a local scale with multiple isolated sandstone aquifers capable

of supplying brackish to moderately saline water (7,000 – 50,000 mg/L TDS). This heterogeneity is reflected in stated lateral hydraulic conductivity figures in the Boorthanna Formation which vary from 0.02 – 5 m/d. It is thought the relatively isolated semi-discontinuous aquifers are related to sporadic turbidity flows within an otherwise quiescent glacio-marine environment and that further discontinuity may arise from syn and post depositional faults.

Permeability ranges from 2.96×10^{-9} – 1.97×10^{-9} cm² and porosity ranges from 3.6 – 25%.

The Stuart Range Formation, which is the primary target for fracture stimulation, is stratigraphically located between the Mount Toondina and the Boorthanna Formation. No aquifers of any significance are known to occur within the Stuart Range Formation. Hydraulic conductivity of core samples indicates a hydraulic conductivity of 1×10^{-4} m/d.

Arckaringa Basin Aquifer Connectivity

The Department for Environment and Water (DEW) completed a number of projects between 2013 and 2015 consisting of reports, maps and models on the hydrogeology of the Arckaringa Basin. These were completed to support bioregional assessments completed by the Australia Government in order to better understand the potential impacts of coal seam gas and large coal mining development on water resources and water dependant assets. Project information produced by DEWNR includes:

- Arckaringa Basin and Pedirka Basin Groundwater Assessment Report (DEWNR 2013)
- A Hydrogeological Characterisation of the Arckaringa Basin (DEWNR 2015/03)
- Arckaringa Basin Aquifer Connectivity (DEWNR 2015/14)

While the proposed fracture stimulation activities are not related and should not impact the coal resources within the Arckaringa Basin, many conclusions relating to the hydrogeological structure, aquifer connectivity and groundwater chemistry are still relevant and discussed further below.

DEWNR (2015/03) concluded the complexity of the Arckaringa Basin geology stems from fluvio-glacial activity during the Permo-Carboniferous time rather than faulting. This architectural complexity may have resulted in sub-basinal hydrogeological systems that are isolated from regional systems evident by differing hydrochemical evolution and radiocarbon distributions of groundwater. Aquifer communication is generally controlled by thickness of Permian sediments and lithology at the Great Artesian Basin unconformity.

From a regional perspective, connectivity is most important where the GAB aquifer is in contact with sandier units of the Mount Toondina Formation. In such areas, similarities in hydrogeological properties between differing basinal strata will be conducive to inter basinal groundwater flow. This connectivity can be amplified by the presence of paleochannels within the unconformity between the Eromanga Basin and the Arckaringa Basin increasing the potential for both cross-formational flow and recharge to Permian aquifers. This connectivity will generally affect coarser sands and coals of the Upper Mount Toondina Formation where porosity and permeability is highest. As discussed in section 4.5, within the deeper areas of the basin such as the Boorthanna Trough, fine siltstones and shales are present within the middle to lower Mount Toondina Formation and would act as an aquitard.

For deeper aquifers such as those within the Boorthanna Formation, the removal of younger sedimentary horizons on the basin margins (in particular the Stuart Range Formation) by erosion prior to the deposition of the GAB or younger sedimentary units, provides potential for interconnectivity between the Boorthanna Formation and overlying aquifer units. This is largely evident in the south-eastern margins of the basin in the Billa Kalina sub basin where the Mt Toondina and Stuart Range Formation are absent (DEWNR 2015/03).

In areas where the Stuart Range Formation is thicker and better developed such as in the deeper sections of the Boorthanna Trough, it acts as a regional aquitard isolating the Boorthanna Formation from overlying aquifers. DEWNR (2015/14) tested this by drilling a continuous core hole in the south of the basin through the GAB sediments and into the Arckaringa Basin to provide an assessment of vertical flow via hydraulic, hydrogeological and hydrochemical analysis. At the location, all formations were relatively thin (compared to deeper areas of the Boorthanna trough) with the Bulldog Shale being 18m thick, the GAB aquifer being 29m thick and the Stuart Range Formation being 57.5m thick. The Mount Toondina Formation was absent. The investigation concluded there is a low degree of connectivity between the Arckaringa Basin and overlying GAB aquifer. It was determined that flow (flux) through the Stuart Range Formation aquitard is small, in the order of millimetres per 1000 years. Where the Stuart Range Formation is thicker, and the lower Mount Toondina Formation aquitard present, flux is expected to be significantly lower.

The CSIRO (2012) regional hydrogeological assessments concluded the Cretaceous and Jurassic sequence overlying the Arckaringa Basin forms an independent yet hydrogeologically partially interconnected sub basin of the Great Artesian Basin referred to as the ‘*Western Eromanga Region*’. This region refers to the area of Eromanga Basin west of the Birdsville Track Ridge.

4.6 Groundwater Use

Under the Environmental Protection (Water Quality) Policy 2015, the Environmental values of different reservoir units within PEL122 and PEL123 are described in **Table 2**.

Aquifer	Aquatic Ecosystems	Recreation and Aesthetics	Drinking Water for human consumption	Primary Industries – irrigation and general water use	Primary Industries – Livestock drinking water	Primary Industries – aquaculture and human consumption of aquatic foods
GAB	N/A	N/A		X	X	X – N/A
Boorthanna	N/A	N/A			X	X – N/A

Table 2: Environmental Values of Different Hydrogeological Units in accordance with the Environmental Protection (Water Quality) Policy 2015.

Existing groundwater use within PEL122 and PEL123 is for pastoral activities with most bores developed within the Great Artesian Basin sediments. While water quality in parts of the GAB appears suitable for irrigation, weather conditions are too hot for cropping as discussed in Section 4. Water extraction within PEL123 is limited due to the upwarp of cretaceous sediments. As discussed in Section 4.5, the GAB formation sediments are heavily weathered in the area leading to the development of isolated aquifer lenses containing salty water. This is evident by the lack of developed water bores west of the spring complex, generally most bores registered on the map shown in **Figure 17** were abandoned after drilling.

Further north in PEL122, a water bore network has been developed within the artesian GAB to support cattle grazing activities, Station boundaries are shown in **Figure 17**.

West of PEL122, a number of production bores have been developed in the GAB to supply water to the township of Coober Pedy. These bores are located approximately 13km west of the PEL122 boundary and are outside of the Boorthanna Trough target zone. Bore locations are shown in **Figure 17**.

To the south and west of PEL123, both production and monitoring bores have been developed to support major mining operations at Prominent Hill, Cairn Hill and Peculiar Knob. These bores extract water from the Great Artesian Basin (Cairn Hill) and the Boorthanna Formation (Prominent Hill and Peculiar Knob) within the Billa Kallina Sub Basin – see **Figure 17**. (DEWNR 2013). A number of monitoring bores drilled by Prominent Hill are located within PEL123.

DEW maintain a state monitoring bore network for the Far North PWA, further information can be found on the DEW Groundwater Data Website².

It is noted **Figure 17** includes both water bore and spring locations.

² <https://www.waterconnect.sa.gov.au/Systems/GD/Pages/Default.aspx>

Formation	Use	Extent	Salinity	Pressure System	Permeability
Eromanga Basin					
Bulldog Shale	Aquitard	Basin wide	25,600 ppm	Main confining bed to GAB. Minor sporadic, laterally discontinuous perched aquifers occur at shallow depths	1.78 x 10 ⁻⁸ – 4.3 x 10 ⁻⁸ cm ²
Cadna-Owie Formation	Aquifer	Basin wide	600 – 12,000 ppm	Main GAB Aquifer – Generally sub artesian to artesian. Lower unit may contain isolated sandy lenses. Formation subcrops in the south of the basin evident by presence of sand dunes at surface	Average artesian flow 0.5 – 1 ML/day but can be as high as 13ML/day in the borefields near Lake Eyre South
Algebuckina Sandstone	Aquifer	Basin wide		Main GAB Aquifer – Generally sub artesian to artesian – formation pinches out towards the south of the Arckaringa basin	
Arckaringa Basin					
Upper Mount Toondina Formation	Aquifer	Basin wide with higher connectivity within coals	73,198 – 155,065ppm	Potential connectivity with overly GAB aquifer, particularly in the north of the basin where coals sub-crop into base of Algebuckina Sandstone	1.48 x 10 ⁻¹² – 4.5 x 10 ⁻³ cm ²
Lower Mount Toondina Formation	aquitard	Basin wide	Unknown	Variable – may be the same or greater or less the GAB	
Stuart Range Formation	Aquitard	Basin wide	Unknown	Variable - Potential for over pressured zones in deeper section of the Boorthanna Trough. Confining bed to Boorthanna Formation	Very low - Tight
Boorthanna Formation	Potential aquifers and aquitards	Isolated semi discontinuous aquifers	7,000 – 50,000ppm	Variable – aquifers occur in isolated semi discontinues pods. Potential connectivity with GAB on basin edges where formations are in direct contact	2.96 x 10 ⁻⁹ – 1.97 x 10 ⁻⁸ cm ²
Pre Permian	Potential aquifers and aquitards	Basin Wide	Unknown	Potential for over pressured zones in centre of Boorthanna Trough. may be the same or greater or less the GAB	Highly variable, may include natural fractures

Table 3: Summary of regional hydrogeology

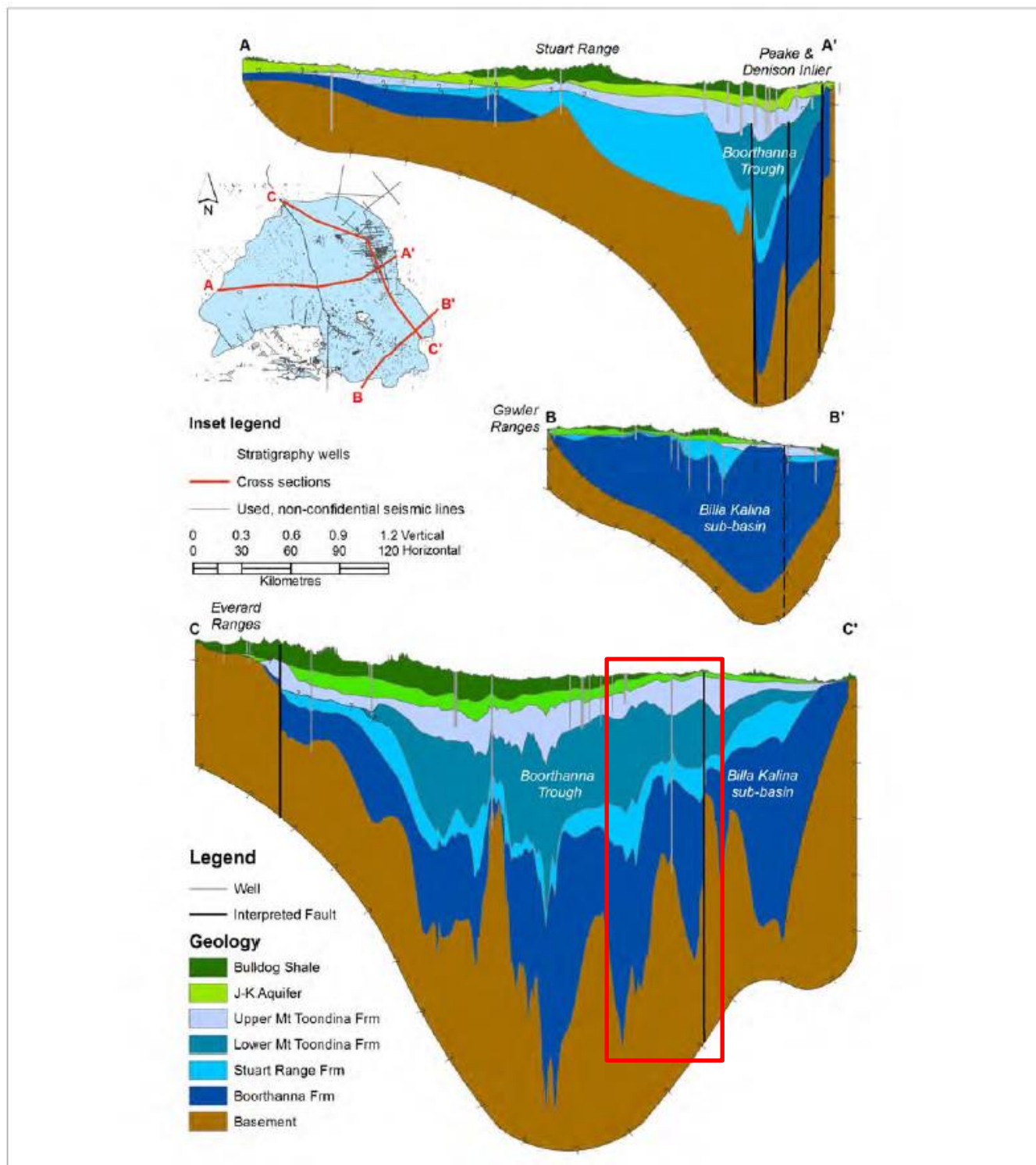


Figure 16: Interpreted cross-sections based on surfaces from seismic and well data. Source (DEWNR 2013)

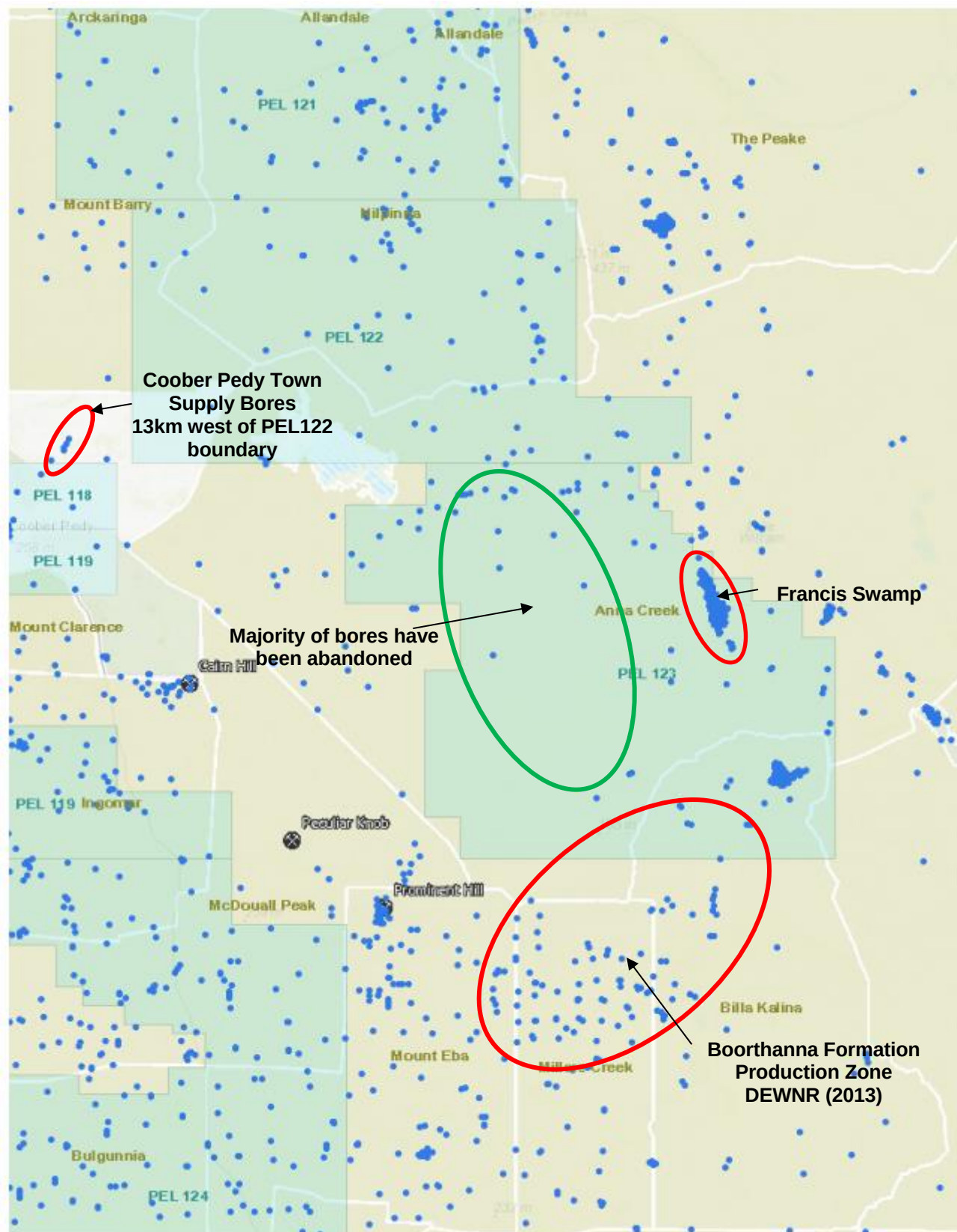


Figure 17: Major Mining Operations and Pastoral Licences with Water Wells Drilled and springs in the Region (SARIG 2017)

4.7 Heritage

A search of matters protected under the EPBC Act and the South Australian heritage register has indicated that a number of historic State-listed heritage sites occur in the vicinity of PEL122 and PEL123. There are no sites on the National Heritage List or the Commonwealth Heritage (which are protected under the EPBC Act) in the vicinity of the PELs. A number of sites from the now obsolete Register of the National Estate exist in and around the PELs and although these sites have no statutory protection, they are included in the following discussion for completeness. A summary of the State-listed sites is provided in **Table 4**

4.7.1 Indigenous Heritage

There are numerous indigenous heritage sites located throughout the Arckaringa Basin. Many of these sites are of cultural significance and reflect Aboriginal occupation of the region.

Many of the GAB Springs in the region are an important component of Aboriginal culture. Much of the history of Aboriginal occupation of the land is also evident throughout the landscape in the form of middens, quarries, worksites, campsites and burial sites. Stone working sites and an artefact scatter have been identified in the DPTI roadside significant site database along the William Creek Road in PEL 123.

The *Aboriginal Heritage Act 1988* provides protection to Aboriginal sites, objects and remains. Work Area Clearances are carried out with the relevant Native Title group in advance of all activities to ensure that indigenous cultural heritage values and significant places are not impacted.

4.7.2 Historical Heritage

Non-indigenous heritage in the region dates back to early exploration of the region in the mid to late 1800's and the expansion of pastoralism. The GAB springs along the south-west margin of the Great Artesian Basin were influential in this expansion, particularly in providing access to permanent water. The overland telegraph line and the Marree to Alice Springs railway line also passed through region of the GAB springs. Other heritage sites in the region are associated with early mineral exploration and the discovery of opal in Coober Pedy in the Stuart Ranges in 1915.

Many of the historical heritage sites in the region are associated with the exploration and development of the region by Europeans in the past 160 years. Prominent historical heritage includes the 'Old Ghan' or Marree to Alice Springs Railway and associated settlements, settlements associated with the Overland Telegraph Line (e.g. Strangways Spring site), and settlements associated with early pastoral expansion and mining developments. Registered heritage sites within 25 km of PEL 122 and 123 are listed in **Table 4**.

Table 4: Registered heritage sites within 25 km of PEL 122 and 123 (listed on SA Heritage Register)

Name	Location
Strangways Springs Site (Former Telegraph Station)	5.5 km E of PEL 123
Edward Creek Railway Siding Complex	4.5 km N of PEL 122
William Creek Hotel	Oodnadatta Track, William Creek 10km E-SE of SE corner of PEL 122
Coward Springs Railway Site	25 km E of PEL 123

4.7.3 Natural Heritage

Sites with recognised natural heritage value in the region include a number of the GAB Spring complexes along the western edge of the Great Artesian Basin which provide important habitat for a number of indigenous plant and animal species, and other sites providing habitat for rare and threatened flora.

The now obsolete Register of the National Estate identifies several sites in the vicinity of the PELs including the Billa Kalina Spring complex in the south-east of PEL123, Moon Plains in the west of PEL122 (which supports a high diversity of rare species) and a site at Strangways Springs approximately 4 km east of PEL123 that provides habitat for the state-threatened plant *Hemichroa mesembryanthema*. The

Breakaways Conservation Park is 17 km west of PEL 122 and Wabma Kadarbu Mound Springs Conservation Park is 16 km east of PEL123.

4.8 Land Use

The current land uses in the project area include pastoralism, mining, conservation, tourism and defence. There is no agriculture within PEL122 and PEL123.

4.8.1 Pastoralism

The main land use in the Arckaringa Basin is pastoralism, with sheep and cattle grazing having been carried out over the past century. Cattle are grazed throughout the north of the region on large pastoral leases, while sheep are restricted to leases south of the Dog Fence, which crosses the PEL123 east of Coober Pedy. A limited number of properties are certified for organic production.

Pastoral leases within PEL122 & PEL123 include:

- Mount Barry
- Nilpinna
- Anna Creek (including The Peak)
- Billa Kalina
- Stuarts Creek.

4.8.2 Mining

Currently the most significant mining activities in the Arckaringa Basin are opal mining at Coober Pedy and the Prominent Hill mining operation, which is located 130 km south east of Coober Pedy. Also located 90km south east of Coober Pedy is Peculiar Knob mining operation and 55km south east of Coober Pedy is the Cairn Hill mining operation. All mines listed about are located west of PEL123 outside of the target area as shown in **Figure 18**.

Petroleum and mineral exploration also occur across the region although there aren't any major projects to date within the target area other than SAPEX's interest.

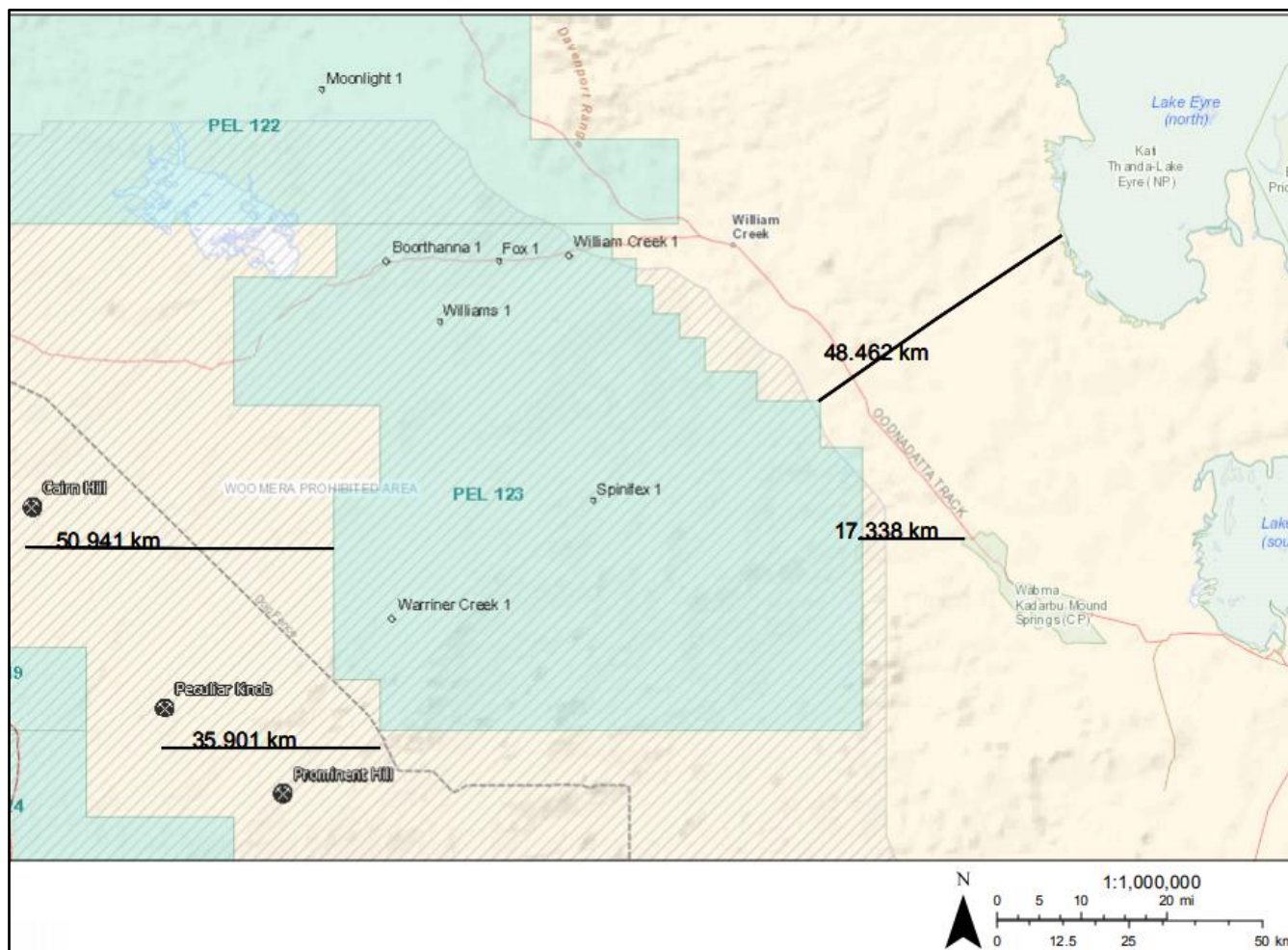


Figure 18: Operating mines within the region and vicinity to Lake Eyre and Wabma Kadarbu Mound Springs (SARIG 2018)

4.8.3 Conservation

The Arckaringa Basin has three areas formally designated for conservation:

- Breakaways Conservation Park
- Tallaringa Conservation Park
- Wabma Kadarbu Mound Springs Conservation Park.

All areas listed above are located outside of PEL122 & PEL123, the locations of Wabma Kadarbu Mound Springs Conservation Park and Lake Eyre are shown in **Figure 18**.

4.8.4 Tourism

Significant tourist attractions within the region include Coober Pedy and its opal mining, GAB springs and historical infrastructure associated with the Old Ghan Railway and the Overland Telegraph Line. Nature tourism, bush walking, wildlife, 4WD experiences, camping and indigenous tourism all occur throughout the region across all land tenures.

Tourism visitation in the region is largely restricted to townships, parks and the main network of sealed and unsealed roads connecting them including the Stuart Highway and the Oodnadatta Track.

William Creek is the Gateway to Lake Eyre with tourists visiting the area via access roads and joy flights. Generally, access is during the winter months, the average vehicle for major roads access is provided below (Coober Pedy Tourism and Events Committee 2015).

- Coober Pedy to William Creek Road averages 4 cars per 24-hour period (9 people)
- William Creek to Oodnadatta average 27 cars per 24-hour period (59 people)
- Total cars along the Oodnadatta Track is 167 per 24-hour period (367 people)

4.8.5 Defence

The majority of PEL123 and a portion of PEL122 lie within the Woomera Prohibited Area. There is limited Defence activity across most of this area but entry to the Prohibited Area (except on main road corridors) requires permission from the Commonwealth Department of Defence, in accordance with SAPEX's 5-year Deed of Access (Petroleum Exploration) 2013.

4.8.6 Native Title

There are two Native Title Determinations across PEL122 and PEL123:

- SCD2011/001– Antakirinja Matu-Yankunytjatjara
- SCD2012/002 – The Arabana People

All planned Fracture stimulation activities will be completed within the Arabana Native Title area. While a small portion of the Antakirinja Matu-Yankunytjatjara area falls within PEL122, this section is not included in this EIR (Refer to **Figure 1**).

Native title agreements between SAPEX and the Arabana was signed off by the Minister in October 2006. The agreement is conjunctive and cover activities from exploration through to development and production. Under the requirements of these agreements, heritage clearances for any field work will be undertaken prior to the commencement of field activities.

4.9 Socio-Economic

4.9.1 Population Centres

The major town in the region is Coober Pedy, which is located approximately 800 km north-west of Adelaide and has a population of approximately 1,801 people (ABS 2015). The south west corner of PEL122 is approximately 32km north east of Coober Pedy, PEL123 is 73km to the east (See **Figure 1**).

The only regional town near PEL122 and PEL123 is William Creek located approximately 10km west of PEL123. The population of William Creek is 6 (2001 census).

4.9.2 Infrastructure

There is extensive transport infrastructure present in the region including the Stuart Highway (part of the national highway network) and the Adelaide-Darwin Railway, both of which are primary transport routes between South Australia and the Northern Territory. There are also a number of unsealed public roads. Major roads within PEL122 and PEL123 include:

- Oodnadatta Track (Marla-Oodnadatta – unsealed)
- William Creek Road (Coober Pedy-William Creek - unsealed)
- Oodnadatta-Marree Track (unsealed).

The major roads in the region are multiple use roads. These roads carry a relatively high traffic volume that is predominantly a mix of heavy vehicles, light industrial/pastoral vehicles and tourist vehicles. Station access roads and internal tracks are generally restricted to pastoral use or occasional tourist traffic and carry a low volume of traffic.

The Dog Fence, constructed to allow sheep grazing in the southern portion of the state, crosses PEL122 and PEL123.

5 Description of Fracture Stimulation Activities

5.1 Overview

As discussed in Section 3, shale reservoirs have very low natural permeability. In order to assess the potential for production of oil and gas from these targets it is necessary to improve connection of the pore space within the rock back to the well. This is achieved by the process of fracture stimulation.

Fracture stimulation involves the injection of fluid into the target rock interval at pressures sufficient to split the rock and create high conductivity flow paths to the well, as illustrated in **Figure 19**. The injected water is slightly modified with a gelling agent to enable proppant material (sand or ceramic material similar to sand particles), to be pumped into the rock to hold the induced fractures open. Further additives are used to control corrosion, friction, remove bacteria and assist with recovering the stimulation fluids from the interval when the well is flowed back to production.

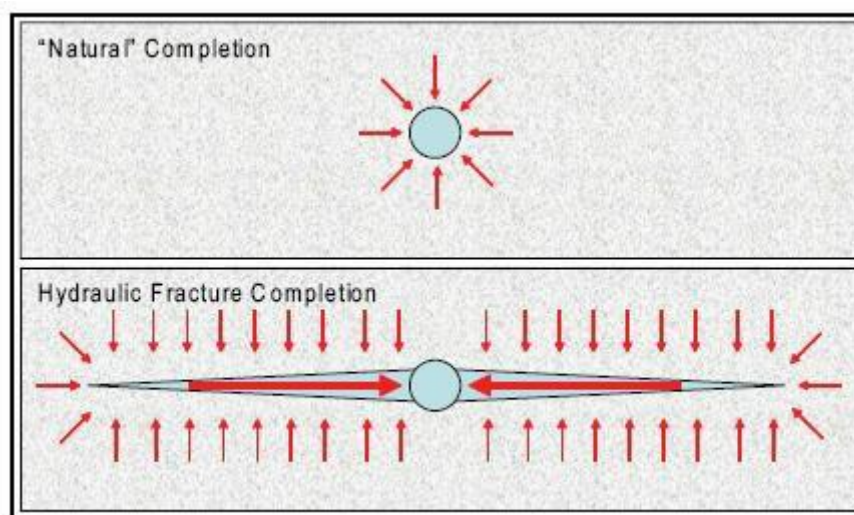


Figure 19: Illustration of flow paths in a non-fractured and a fractured well (Source: API 2009)

Fracture stimulation has been used in the Cooper Basin for over forty years in several hundred wells to improve the commerciality of lower permeability zones. This section describes the application of fracture stimulation to a shale reservoir in the Arkaringa Basin. It outlines the principles of well design and construction (which ensure that injected fluid is contained in the well and injected into the target formation) and goes on to describe the fracture stimulation process, the fluids used, monitoring of stimulation, well completions, flowback and production testing, water use and other associated issues.

5.2 Well Design and Construction

It is not the intention of this EIR to revisit well design and drilling operations as these are covered under the existing Exploration Drilling Activities EIR and SEO (SAPEX 2007 and SAPEX 2013). However, well design and construction is described here as it is important in ensuring well integrity under all the operating conditions that the well is expected to experience, and is particularly important during the fracture stimulation treatment and subsequent testing operations.

Well design ensures that the wellhead, steel casing, cement and production tubing are suitable for:

- the high temperatures
- the pressures required to initiate fracture stimulation treatments deep underground
- the stresses induced when large volumes of cool fluids are pumped, at pressure, into the well during stimulation
- the flow back of high temperature reservoir fluids
- the flow back of sour gases.

When wells are drilled, a series of metal casing strings are installed and cemented into the ground at various depths to provide mechanical stability and isolation of the wellbore from the formations and aquifers that are penetrated during drilling. The strength of the casing and the depth at which it is set is determined through understanding of the geological environment and the pressures that are anticipated in the

formations that are drilled through.

The well design process also accounts for the operational conditions that are anticipated during the life of the well including fracture stimulation and production fluids, pressures and temperatures. These final parameters impact on the production casing, the last string of casing that is installed and cemented into the well bore. This casing string's size, strength, coupling and material must satisfy the identified operational conditions and industry standard design safety factors.

An indicative well design for a vertical exploration well is shown in **Figure 20**. This schematic assumes the Bulldog Shale is present at surface leading to potential artesian intersections within the Cadna-Owie Formation and Algebuckina Sandstones. In areas within PEL123 where the GAB Formations sub-crop (evident by the surface presence of sand dunes), the intermediate casing string may not be required. In these cases, the surface casing will be set deeper into the Mount Toondina or upper Stuart Range Formation. Actual well construction will be assessed on a case by case basis and submitted to DEM during the notification period as per legislative requirements.

The layers of casing shown in the diagram are:

- The conductor pipe, which is installed at the surface and provides the initial stable structural foundation for the well.
- The surface casing string, which extends from the surface to the upper Mount Toondina Formation isolating GAB sediments
- The intermediate string, which extends from surface to the top of the Stuart Range Formation
- The production casing string, which is inside the intermediate casing and runs from the surface to the total depth of the well.

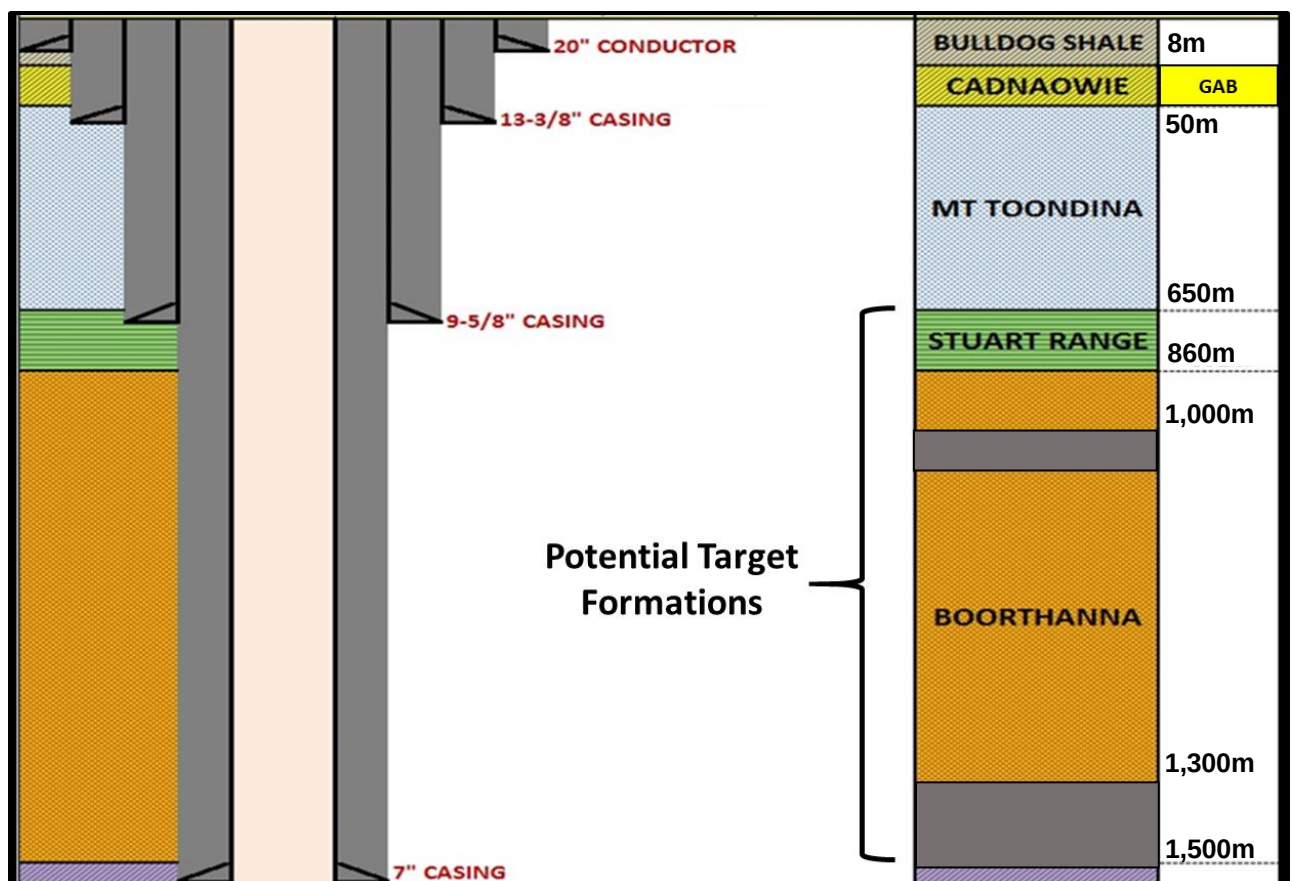


Figure 20: Indicative well design and depths – GAB formation may also include Algebuckina Sandstone (not included due to scaling issues)

SAPEX will also be drilling wells with horizontal sections within the target intervals to determine their potential for deliverability. These wells will have the same well construction as shown in **Figure 20** except that approximately 300m above the target zone the well trajectory will be steered from vertical around an approximate 300m radius bend to become horizontal in the target layer. Once in the target zone the well will be drilled a further 1000 - 3000m as shown in **Figure 21**.

As indicated, each casing string in the well is cemented into the borehole. Cement integrity is important for

isolating formations along the well bore. Cement integrity is verified by various means, including observation of the cement back to surface as per the cement design and cement bond logs of the production casing string, which use an acoustic tool to detect whether spaces are present behind the casing. Casing centralisation, cement design, volumes and pumping parameters are important in setting up a good seal between the casing and the well bore. The correct cement design and implementation prevents production fluids from migrating up the hole via the well bore - casing annulus eliminating potential cross flow into aquifers.

Wells are pressure tested prior to commencing fracture stimulation, to confirm the integrity of the casing and cement.

In order to connect the inside of the casing with the target formation, normally a technique known as perforating is used. Shaped charges, also known as guns, are lowered into the hole and detonated to create holes in the casing, cement and penetrate tens of centimetres into the rock.

With continual refinement of downhole equipment, the way that zones in the target formation are accessed is changing. Sliding sleeves and packers can be run on casing to provide an alternative to perforating. A ball is dropped from the surface into the bore hole to engage with the sleeve. When the ball lands in the sleeve, pressure is applied to slide open a door in the casing revealing ports that now allow fluid to flow into the rock. These techniques speed up the fracture stimulation process. Similar techniques with sleeves activated by coiled tubing are also being applied in the industry.

SAPEX will initially use standard perforation techniques but will, where appropriate, look to incorporate these technological advances to improve efficiency and understand the potential of the resource. In all cases the integrity of the well and isolation of aquifers will be applied in the well design process.

5.3 Fracture Stimulation

A typical fracture stimulation treatment involves pumping of several discrete stages, which can be broadly classified as:

- **Pad stages** – Small volumes of friction reduced water are injected. The initial pad volume, injected at pressure, is used to split the rock and propagate the fracture. During the early stage a small amount of hydrochloric acid may be pumped to clean up perforation holes. Additionally, small amounts of fine grained sand may be used to further abrade the perforations and improve connection with the rock. At other times during the job additional pad volumes may be used to sweep proppant into the reservoir.
- **Proppant stages** – Once the fracture has initiated proppant is introduced. In order to carry the proppant in suspension to the rock the fluid is viscosified with a gelling agent. Typically, the higher the injection rate of fluid the less gel is required to carry the proppant. Additionally, finer grained proppants require less gel to carry them. Gel breakers or surfactants are added during the stage to aid in later recovery of injected fluids from the fracture.
- **Flush/Displace** – A final volume of water to push the sand from the well bore into the rock to clean the well bore for the next stimulation job.
- **Plug/Perforate** – Once the stimulation treatment is placed, a wireline unit is rigged up to run a plug that will isolate the zone that was stimulated from the next interval to be stimulated. The wireline will also perforate the casing ready for the next stimulation treatment.

The process above outlines the activities associated with stimulating a single zone in the well. With the multiple targets identified in the Permian and Pre-Permian formations, this process is repeated several times within a single wellbore.

In a vertical well, it is anticipated that as few as one but potentially up to five zones may be fracture stimulated. In a horizontal well, with a length of 1,500m, stimulation treatments are likely to be placed every 100m requiring 15 treatments in the well.

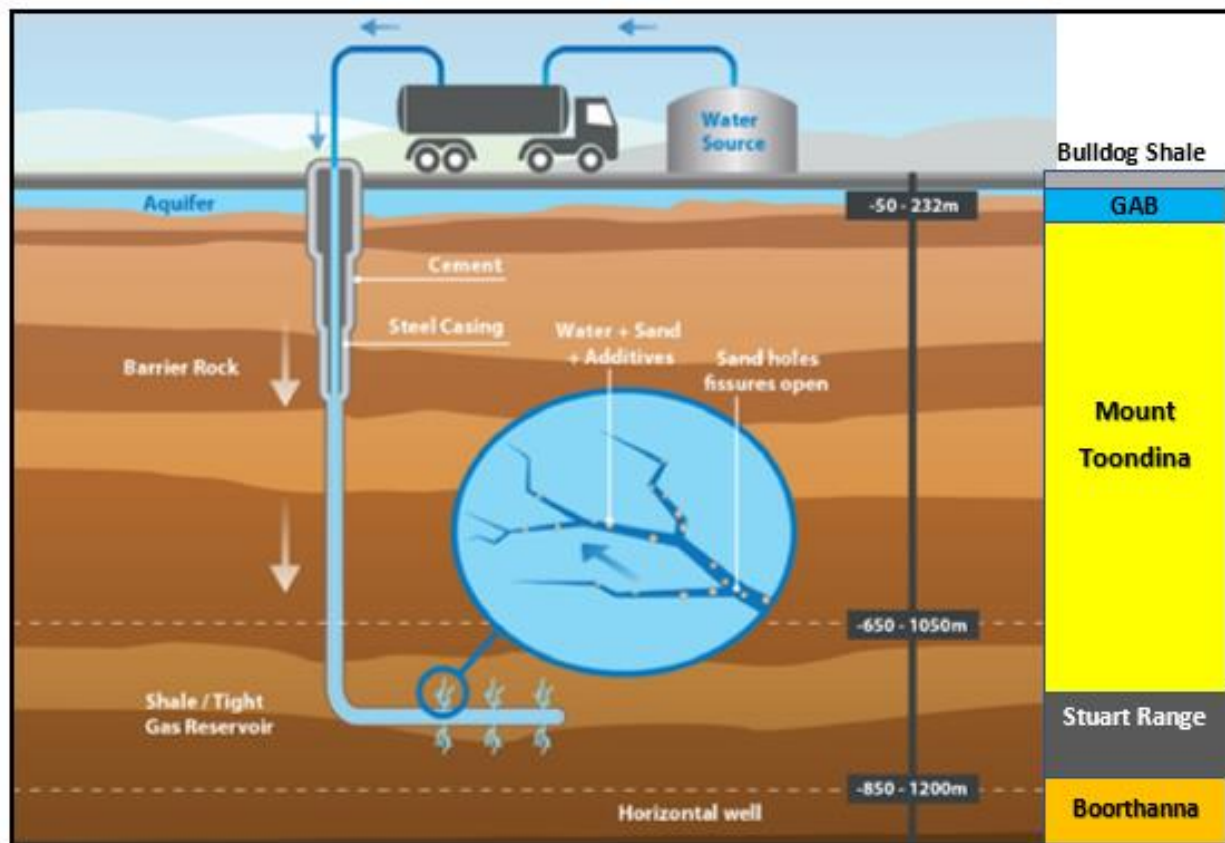


Figure 21: Example of fracturing in a horizontal well (Source: DEM)

5.3.1 Fracture Stimulation Equipment

The fracture stimulation process requires equipment for pumping, proppant loading, blending, pipework and valves, tanks, chemical additives and monitoring. The monitoring equipment is used to track the volume of fluids and the concentration of proppant being pumped, and most importantly the injection pressure. The injection pressure gives an indication of how the treatment is progressing.

As fracture stimulation involves injection of fluid and proppant, mechanical integrity of pipework is integral to safe placement of each treatment. As with the well design process, stimulation equipment is designed to meet the pressures expected during the treatment process with secondary protection to shut down equipment before design pressures are reached.

This fracture stimulation equipment for the activities outlined in this EIR will require approximately 10 truckloads plus an additional 15 trucks for associated camp facilities accommodating up to 50 personnel. For a full, 15 stage shale fracture stimulation an additional 40 trailers of proppant and 4 trailers of additives will be required. A vertical well requires approximately one third of the quantity of proppant and additives that is required for a horizontal well.

A wireline perforation truck will also be required to conduct perforations prior to each fracture stimulation stage. A coiled tubing unit, consisting of a reel of tubing mounted on a truck and the associated wellhead equipment to run the tubing into the wellbore, is also likely to be on location during the stimulation to assist with operational requirements. It can be used to clean out sand plugs and assist with placing treatments.

It is anticipated that the fracture stimulation equipment would operate for blocks of approximately 4 - 8 weeks during which 2 - 4 wells would be fractured. At each well, operations would typically involve a two-day set-up, one day per zone stimulated and two days to rig-down and demobilise to the next well.

An example of a stimulation spread from the Coober and Beetaloo Basin is provided in **Plate 7 & Plate 8**.



Plate 7: Fracture stimulation operations at Beach Energy's Holdfast-1 well in 2011 (Cooper Basin)



Plate 8: Fracture Stimulation Operations at Origin Energy's Amungee NW – 1H (Beetaloo Basin – Northern Territory). Note the temporary ponds in the background for stimulation activities. The ponds on the left were used for drilling purposes.

5.3.2 Fracture Stimulation Design Factors

The fracture stimulation design process uses data collected during drilling and logging to design the treatment for each individual well. Data from each formation on reservoir parameters, lithology variations and stress contrast between layers is processed using stimulation software to develop a design which optimizes fracture length, fracture conductivity and fracture height within the target reservoir formation. Given the lack of information available in deeper areas of the Boorthanna Trough, vertical wells with detailed logging suites will be completed to characterize the reservoir and complete geomechanical analysis. This information will be used to inform the fracture design process and incorporated into and proposed horizontal application.

Detailed considerations that influence the fracture modelling investigation and final design of the fracture stimulation include:

- Depth and thickness of the target zone
- Lithology of target and bounding layers
- Formation boundaries (as identified from seismic data)
- Thickness underlying formations and rock strength
- Thickness of 'seals' (aquitard layers) above and below the target reservoir formation
- Maximum horizontal stress across all layers (target and bounding)
- Stress field analysis to determine the maximum principal stress direction and the minimum principle stress direction
- Bulk density, elastic properties and compressibility
- Bedding planes, jointing and mineralization

- Porosity and permeability
- Pore fluid saturations and properties (e.g. density, water salinity)
- Well performance data, including flow rates, Formation pressure and produced fluid properties.

Prior to a hydraulic stimulation treatment, a fracture model is constructed to investigate, predict and optimise the fracture geometry (An example of a typical workflow is provided **Figure 22**). Various pumping schedules are input into the model to evaluate the simulated fracture geometry. Economics are optimised by designing a treatment that maintains the fracture height within the target formation. The fracture stimulation treatment is therefore designed very carefully and the operation itself is closely managed and monitored in real time to ensure the treatment is executed as designed and the fracture growth stays within the target unit and does not extend into non-target formations. An example of a simulated treatment is provided in **Figure 23** and **Figure 24**.

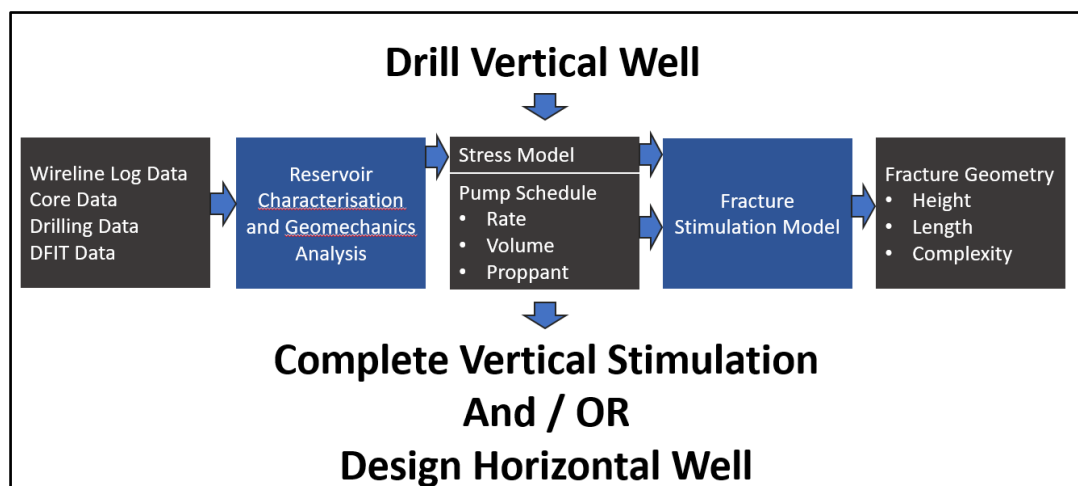


Figure 22: Example of Fracture Stimulation Work Flow for exploration and appraisal

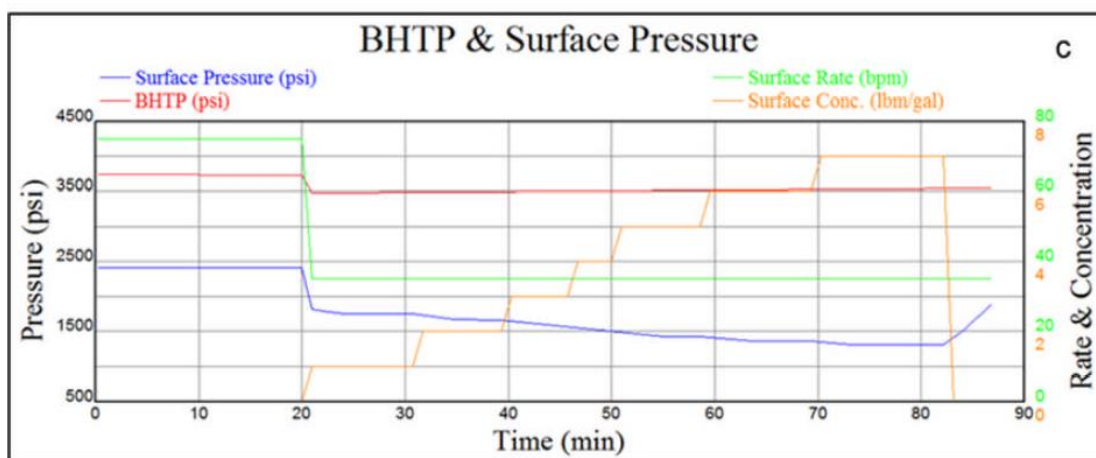


Figure 23: Example of fracture stimulation model

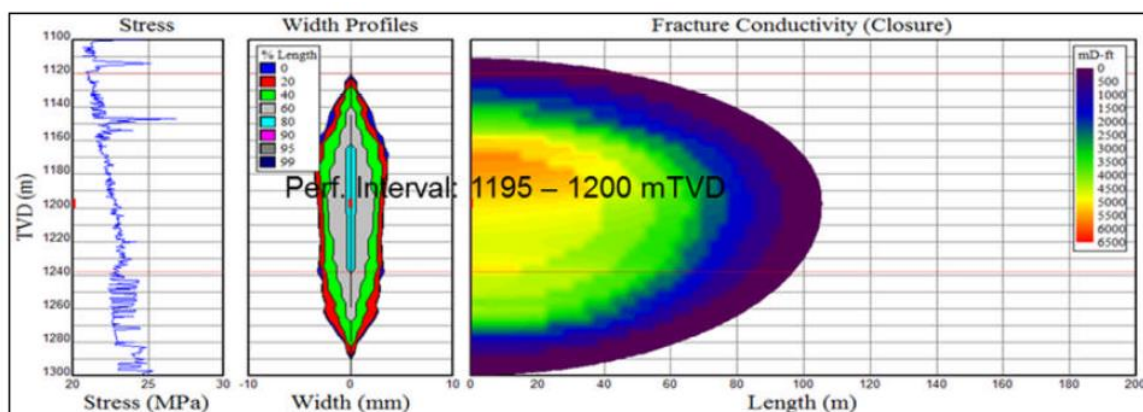


Figure 24 Example of modelled fracture geometry

During the fracture stimulation operation itself, parameters are monitored in real time (notably surface

pressure, bottom hole pressure, net pressure, injection rate and proppant concentration) to ensure that the treatment is proceeding as designed. If an unexpected response is seen, one or more variables may be altered.

5.4 Fracturing Fluids

Water is the main component of fracture stimulation treatments and forms the vast majority of the fluid injected during fracturing operations, typically around 97%. The proppant is the next largest constituent. Proppant is a granular material, typically sand or small ceramic beads which is mixed in with the fracturing fluids to prop open the fractures and allow hydrocarbons to flow to the well.

In addition to water and proppant, a range of other additives (approximately 0.5%) are necessary to ensure successful fracture stimulation. Chemical additives include acid, buffers, biocides, surfactants, iron control agents, corrosion and scale inhibitors, crosslinkers, friction reducers, gelling agents and gel breakers. Several of these ingredients are essential to maintaining well integrity.

Each fracture stimulation treatment is different and there isn't a one-size-fits-all formula for the volumes of each additive. Although service providers may have a number of compounds that can be used in a stimulation fluid, any single operation may only use a few of the additives listed above pending the properties required for the specific application.

The overall percentages of additives in a typical fracturing operation are shown in Figure 25.

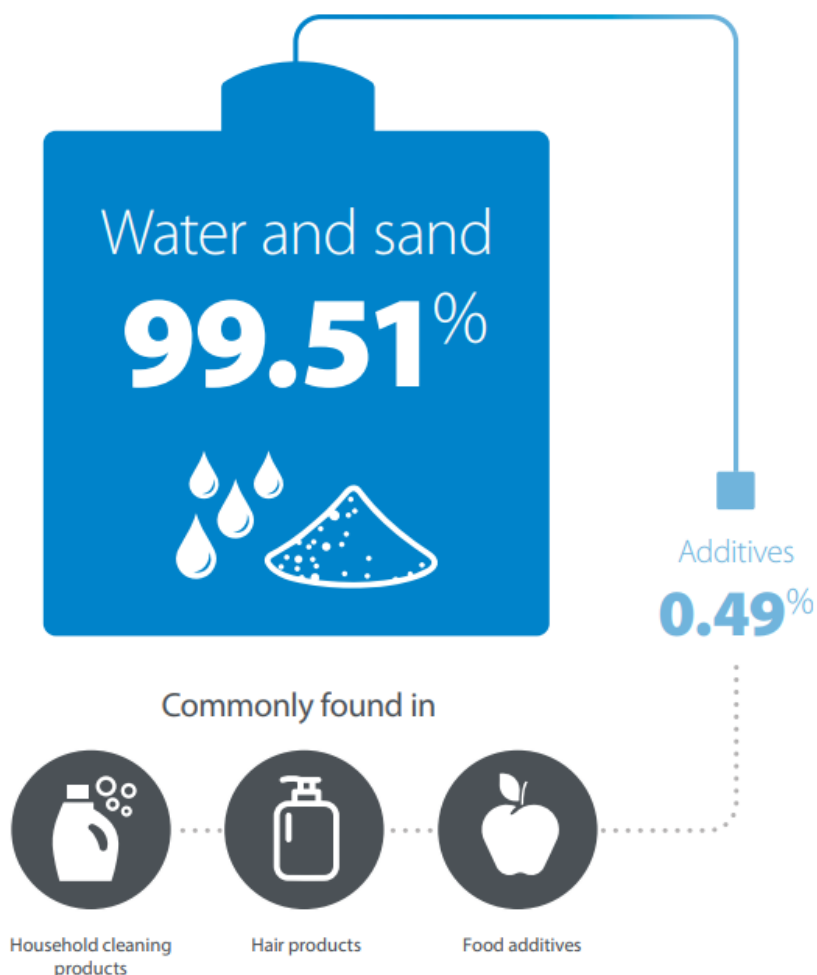


Figure 25: Example of overall percentages of additives in a fracturing operation (DEM 2017)

As discussed in Section 5.3, the fracturing fluid injected into the well is not uniform throughout the fracturing process. Each task performed during the fracturing operation will use fluid with additives specifically designed for the task. For example, acid is pumped in the initial acid injection phase to clean the well bore. In following phases, the fluid designed to propagate the fractures is injected, initially without proppant, and then proppant is added to the fluid to enter the fractures and hold them open.

Gelling agents, or viscosifiers, are used during these phases to increase the viscosity of the fluid and help

carry the proppant. Gel breakers and surfactants are added to aid in recovery of the injected fluids from the formation.

Fracturing fluids are a carefully formulated product. The design of the fluid is varied based on the characteristics of the reservoir being fractured and the fracture stimulation design for the particular well. The design of the fluids must take into account depth, temperatures, pressures, reservoir geology and chemistry, scale build-up, bacteria growth, proppant transport, iron content and fluid stability and breakdown requirements.

The types and purposes of additives expected to be used in the fracture stimulation of shale targets in the Arkaringa Basin are summarised in **Table 5**. The specific compounds used in a given stimulation operation will vary depending on service provider, source water quality and site-specific characteristics of the target formation. Further detail on these additives and their constituents is provided in Appendix 5 Table A5-1. Links to Safety Data Sheets (SDSs), which contain detailed information about each additive are also provided in Appendix 5, Table A5-3.

Additive	Purpose
Acid / Solvent	Removes scale and cleans wellbore prior to fracturing treatment
Buffer / Acid Additive	Acid used to adjust the pH of the base fluid and Iron control additive in acid
Biocide	Prevents or limits growth of bacteria that can cause formation of hydrogen sulphide and can physically plug flow of oil and gas into the well
Buffer	Used to adjust the pH of the base fluid
Crosslink Agent	A delayed crosslinker for the gelling agent.
Iron Control Agent	Helps to sequester dissolved iron in spent acid
Friction Reducer	Allows fracture fluid to move down the wellbore with the least amount of resistance
Corrosion Inhibitor	Prevents acid from causing damage to the wellbore and pumping equipment
Crosslinker	A non-delayed crosslink agent that maintains fluid viscosity as temperature increases
Surfactant / Penetrating Agent	Allows for increased matrix penetration of the acid resulting in lower breakdown pressures.
Proppant	Holds open fracture to allow oil and gas to flow to well
Scale Inhibitor	Prevents buildup of certain materials (i.e. scale) on sides of well casing and surface equipment
Surfactant	Aids in recovery of water used during fracturing
Gelling Agent / Viscosifier	Gelling agent for developing viscosity
Breaker / Deviscosifier	Agent used to degrade viscosity

Table 5: Additives in typical fracture stimulation fluids

Fluid additive information provided in Appendix 5 Table A5-1. There are a number of providers available in Australia including Schlumberger, Haliburton and Baker Hughes who contract fracture stimulation equipment and additives. Fracture stimulation providers may have their own proprietary stimulation compounds, which are generally from the same group of chemicals but with different amounts of, or slightly different, active ingredients. Where appropriate, detailed additives proposed for use in fracture stimulation operations would be provided to DEM as part of the activity approval process (see Section 2.5), along with a demonstration that the level of risk posed by these additives is consistent with this EIR.

A number of other websites also provide information on fracturing fluid additives and are listed in Appendix 5 Table A5-3, including websites for the fracture stimulation service providers currently operating in

Australia.

Most of the chemicals used in fracture fluids are found within products that are used in the home or in industry, as indicated in Appendix 5 Table A5-1. While many of the additives used in the fracturing process are hazardous when in their concentrated product form, they are diluted by the water and are present in fracturing fluids in relatively low concentrations. However, even in low concentrations some of these additives need to be handled with care to avoid any potential for impacts on human health or the environment.

SAPEX is aiming to keep utilisation of chemicals to the lowest level possible, and will safely manage the use of chemicals and fuels and contain recovered stimulation fluids to minimise the environmental footprint of the stimulation activities.

The following strategies will be implemented:

- Pumping as low a concentration of chemicals as is needed to perform the treatment.
- Requiring that the material handling and safety aspects of these additives, as managed by the contractor, are in accordance with SDSs and relevant standards and guidelines including AS1940, EPA guidelines and the Australian Dangerous Goods Code (where relevant).
- Auditing the contractor's management systems and conduct site inspections to assess the contractor's compliance.
- On-site supervision to monitor conduct of the treatments and ensure any spills are reported and remediated.
- Containment of recovered flow back fluids in lined ponds, as discussed in Section 5.8, for evaporation of fluid.
- Monitoring and sampling of returned fluids during the exploration stage. Once the treatment is placed, it is estimated that less than 50% returns to the surface (King 2012). Much of the fracture fluid remains trapped in the rock underground and some of the additives may become adsorbed to the surface of the rock.
- Management of ponds to ensure integrity of containment.
- Removal of pond liner to a licensed waste facility following evaporation.
- Rehabilitation of pond sites post activities.

SAPEX will investigate methods to further reduce chemical utilisation and incorporate findings during the monitoring of flow back fluids as part of SAPEX's commitment to continuous improvement.

BTEX in Fracturing Additives

Fracturing fluid additives containing the volatile aromatic compounds benzene, toluene, ethylbenzene and xylene (collectively referred to as BTEX) have been identified as a potential concern in some areas where fracture stimulation operations are carried out much closer to water supply aquifers.

Although the level of risk posed by additives containing BTEX is relatively low in the Arckaringa Basin (e.g. the target petroleum reservoirs can naturally contain BTEX) it is not proposed to use additives where BTEX is present in significant quantities. Some additives in the acid blend (e.g. hydrochloric acid, corrosion inhibitor and acid penetrating agent) can contain trace levels of BTEX, however the dilution of the acid blend by subsequent stages of the fracture stimulation would result in very low levels, which would be below drinking water guidelines. Suppliers and fracturing contractors have been working to ensure that levels of BTEX in fracturing fluids are reduced as far as practicable and are not at significant levels.

5.5 Fracture Height Growth and Fracture Monitoring

Fracture modelling is the main method for predicting fracture geometry, using specialist software which requires site specific input data for calibration, as discussed above in Section 5.3.2. Some of the different measurement techniques which can be used to obtain data for modelling of fracture geometry and orientation are summarised in **Table 6**. Relevant measurement techniques include microseismic, surface tiltmeters, proppant tracers, chemical tracers and sonic anisotropy logging are discussed below. The implementation of diagnostic tools will be assessed on a case by case basis with a more detailed program included in the submissions to DEM during the activity notification process.

Group	Diagnostic	Main Limitations	Ability to Estimate						
			Length	Height	Width	Azimuth	Dip	Volume	Conductivity
Indirect	Net Pressure Analysis	Modelling assumptions from reservoir description							
	Well Testing	Need accurate permeability and pressure							
	Production Analysis	Need accurate permeability and pressure							
Direct, near wellbore	Proppant Tracers	Depth of investigate (1 to 2 feet)							
	Temperature Logging	Thermal conductivity of rock layers skews results							
	Production Logging	Only determines which zones contribute to production							
	Borehole Imaging Logging	Run only in open hole - information at wellbore only							
	Downhole Video	Only info about which perforations contribute							
	Sonic Anisotropy	Depth of investigate (1 to 2 feet)							
	Caliper Logging	Open hole, results depend on borehole quality							
Direct, far field	Surface Tiltmeter Mapping	Resolution decreases with depth							
	Downhole Offset Tiltmeter Mapping	Resolution decrease with offset well distance							
	Microseismic Mapping	May not work in all formations							
	Treatment Well Tiltmeters	Frac length must be calculated from height and width							

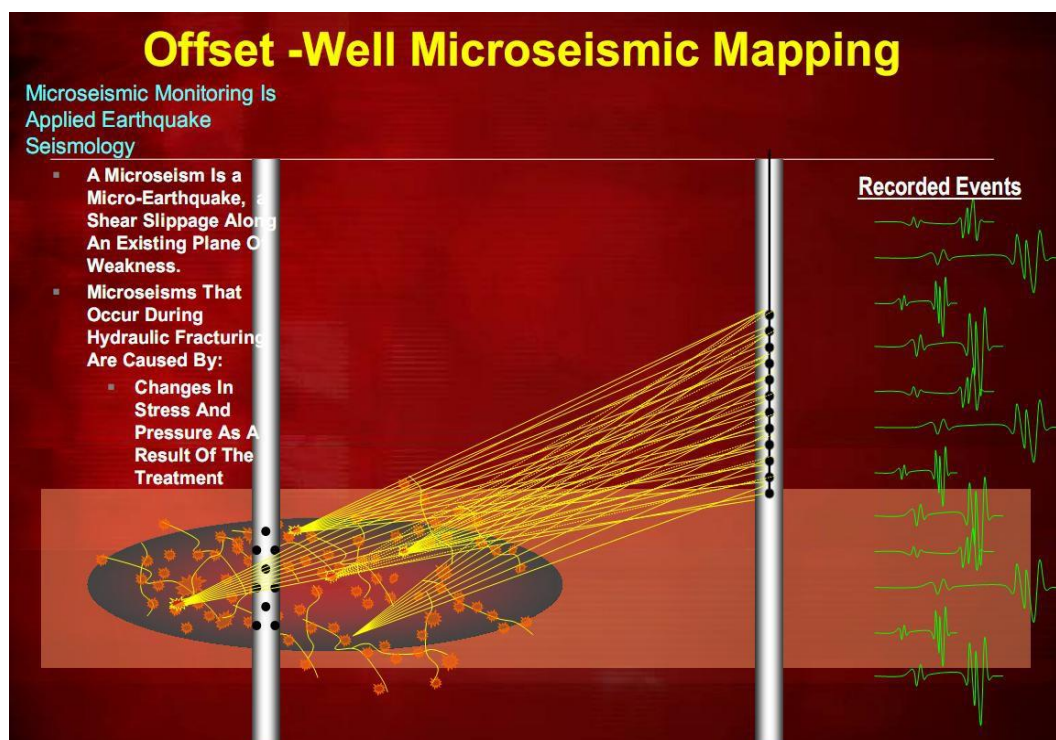
Will Determine
 May Determine
 Cannot Determine

Table 6: Parameters measured by various diagnostic tools

Micro-seismic Monitoring

The technique used to monitor fracture growth is called micro-seismic mapping. The process involves placing a sensitive set of listening devices (geophones) in an adjacent monitoring bore during the stimulation of the target well. During the fracture stimulation, small rock movements cause acoustic energy to be released, which can be detected by geophones. The location of these events is calculated and used to map the fracture propagation. An illustration of the technique is provided below (**Figure 26**). The number of movements detected depends upon the reservoir and surrounding rock along with the distance from the fracture to the geophones.

The economic feasibility of microseismic monitoring is dependent on the presence of a suitable offset wellbore located within close proximity to the wellbore stimulated (approximately 300 – 800m).



From Pinnacle: Kevin Fisher, Oil and Gas Shale Developer, Houston May 2009

Figure 26: Schematic of micro-seismic monitoring of fracture stimulation treatment

Tiltmeter Surveys

Surface tiltmeters measure surface deformation during a fracture treatment. In an environment where complex fracture geometries are possible, surface tiltmeters can provide valuable information on the fracture azimuth and dip from the nano-radian resolution. Further details on surface tiltmeter theory associated with hydraulic fracture mapping can be found in Siebrits *et al.* (2000), Wright and Conant (1995), and Wright *et al.* (1998).

Proppant Tracers

Proppant tracing along with spectral gamma ray logging have been used extensively in the industry to determine vertical height growth in hydraulic fracturing (Anderson *et al.* 1986; Holditch, Holcomb and Rahim 1993; Reis, Fisher and Holcomb 1996, Willis 1991). Three stable isotopes of radioactive ceramic bead tracers can be used during the treatments. The fracture height, near wellbore proppant concentrations, and associated propped widths are then estimated post-treatment using spectral and gamma ray logging tools. The three isotopes, scandium, iridium, and antimony, can be used at different portion of the treatments to identify where different fluid has gone. The three radioactive isotopes have a short half-life (measured in days) and rapidly decay to environmentally safe levels. Any use of Proppant Tracers will be completed in compliance with the 'Radiation and Control Act 1982' and the 'Radiation and Control (Ionising Radiation) Regulations 2015'.

Chemical Tracers

Chemical fracturing tracers (CFTs) are non-hazardous organic compounds used to chemically mark individual stage fracturing fluids in a multi-zone completed well. These compounds are added to the fracturing fluids at approximately 1 part per million (ppm) throughout all fluid segments of an individual fracture stage, with the exception of pre-pads and flushes. Upon commencing flowback, individual samples can be collected from the treated well. These flowback samples are then analysed using a spectrometer analysis procedure which automatically identifies and quantifies the flowback concentrations for each chemical tracer from the treatment well or any tracers in fractured offset wells. Using mass balance computations, these recovered chemical tracer concentrations can then be converted into corresponding fracturing fluid volumes recovered.

The computed fracturing fluid volumes recovered can subsequently be divided by the fracturing fluid volumes pumped to determine the flowback efficiencies for each fracturing stage. Chemical tracer technology has been used in the industry for a significant period, and further details can be found in Asadi *et al.* (2002, 2006, 2008), Leonard *et al.* (2007) and King and Leonard (2011).

Sonic Anisotropy Logging

While sonic logging tools have been used extensively in the petroleum industry since the 1950s, they have also recently been applied to measuring hydraulic fracture height growth. Typically, pre and post fracture treatment dipole sonic logs are run and then compared to identify changes in sonic amplitude or stress anisotropy caused by the induced near well bore fracture. Further detail can be found in Beryushev *et al.* (2006), Tcherkashnev *et al.* (2006), De Almeida *et al.* (2008), Nikitin *et al.* (2009), Scott *et al.* (2010) and Velez *et al.* (2013).

Production and Temperature Logging

Temperature logging is a simple tool involving use of a thermometer to identify where the fluids are entering the wellbore or moving within the casing, Temperature logging can also be used to detect fluid movement behind the casing. Depending upon the well, a temperature log may also be used to determine fracture height and identify perforations contributing to production.

A production log is more advanced and incorporates tools to measure temperature, pressure, fluid density and flow. However, a production log is not used as a direct tool for hydraulic fracture analysis other than determining the amount of production from various zones.

5.6 Post-Stimulation Completion

Immediately following fracture stimulation, dependent on the zone access and stimulation technique used, isolation plugs used to separate the fracture stimulation stages will be drilled out with coiled tubing or an equivalent. During this process excess well fluids will be directed to the lined pit, constructed adjacent to the flare pit.

The tubing string is another set of steel pipe installed in the well bore with an anchor arrangement at the bottom that attaches it to the production casing, sealing the space between the tubing and the production casing such that the void space between the two sets of pipe can be filled with protective brine and be monitored for any breach of the tubing integrity. In the event there is a breach, the tubing string can be recovered and replaced.

5.7 Flowback and Initial Production Testing

Following installation of the tubing string the well will be opened and flow will commence. As the initial flow back will be predominantly recovered stimulation fluid, production will be directed to a tank or a lined pond adjacent to the flare pit (see Section 5.8 for a description of ponds). A pump is generally installed on oil wells (typically using a workover rig to install a pump downhole) and the well is then put on production. Due to the lack of existing production facilities, a separator tank and production tank will likely be installed at the well and any produced oil trucked offsite. Produced water disposal will be to a lined pond.

If wells produce a significant quantity of gas, a three-phase separator may be used to separate oil, gas and water. Any produced gas will be sent to a flare during flow back on production testing. This is however unlikely in the Arckaringa Basin as the target source rocks are oil prone and are believed to be within the black – volatile oil generation windows.

During the flow back period the rate of production of the recovered fracture fluid diminishes. It is expected that approximately 40 - 50% of the injected fluid will be recovered, based on experience from shales in the US which indicates that a significant proportion of the injected fluid remains trapped underground with generally less than 50% of the placed fluid returning to surface (King 2012). At the end of the test, the remaining fluid will be allowed to evaporate. Pond liners will be removed and disposed of to an appropriately licensed waste disposal facility.

Initial production testing is covered by the existing Arckaringa Basin Exploration Drilling Activities SEO (Sapex 2013).

Additive Concentrations in Flowback

Chemical returning from a well after fracturing treatment are usually a fraction (e.g. 20% or less for chemicals and about 40% for polymers) of what was pumped down the well (King 2012, Friedman 1986, Howard 2009) and fluid disposal plans are tailored accordingly. Polymers decompose quickly at reservoir temperature, biocides are spent on organic demand and degrade, and surfactants are absorbed on rock surfaces (King 2012). Consequently, many of the compounds that are identified as potentially hazardous on their SDS, such as buffers or biocides, are effectively neutralised or present at significantly reduced concentrations in the flowback fluid. The flowback fluid may also contain salts that were dissolved from the geological strata underground.

5.8 Temporary Holding Ponds

All ponds that are to receive water for stimulation and recovered flowback fluids will be lined and fenced. The construction will utilise both excavation and bunding to raise the sides of the ponds above ground level to prevent surface water runoff into the pond's ash shown in **Plate 10**. Above ground storage ponds may also be employed as shown in **Plate 8** and **Plate 9**. The temporary water holding ponds will be constructed and start filling approximately one to two months in advance of the planned stimulation date.

A smaller lined pond may also be constructed, adjacent to the flare pit, to receive fluids associated with post stimulation clean-out and completion activities. Initial flow back of the well, prior to diversion of the well stream to the separator, will also be directed to this pond. If and as required, water from this clean up pond can be transferred to the larger temporary holding ponds with pumping equipment. It is expected that between 10% and 20% of the injected volume may flow back in this early clean out stage and the pond and transfer equipment will be designed for this load.

As discussed above, it is expected that a significant proportion of the injected fluid will remain trapped underground and less than 50% of the placed fluid will returning to the surface.

SAPEX will construct a number of ponds (approximately 50 by 30m and 2 – 3m deep) at each well site for water storage (**Plate 9**) with regard to EPA Guideline 509/14 Wastewater Lagoon Construction. Any temporary pond that has the potential to be used for stimulation fluid flowback will be constructed with the

following considerations:

- a) All ponds are to be lined with a suitable UV stabilised polyethylene material. All liners must be constructed to the manufactures recommend installation method and be welded and checked for joint adherence and leak tested prior to being placed in operation, and
- b) Regular water balance calculations and visual inspections are made to ensure any loss of significant volumes from recovered fluid ponds is detected.

These will be progressively rehabilitated as operations progress. Where necessary, some of these ponds will be retained for longer term as flow back may be required for approximately three to six months to understand longer term well performance.

If the ponds containing stored stimulation flowback fluid are to be used for a period greater than one year, a more stringent leak detection method will be employed.

The area required to accommodate the water holding ponds results in the well lease being larger than a lease required for drilling a typical petroleum well (in the order of 200m by 200m compared to 120m by 100m).

The pond sites will be rehabilitated once the wells are successfully stimulated and tested.



Plate 9: Example of above ground storage tanks in the Cooper Basin.



Plate 10: Example of a temporary water holding pond**5.9 Water Use**

To fracture stimulate the thick shale intervals, each fracture stimulation treatments will require approximately 0.4 - 1.2 megalitres (ML). In a vertical well it is anticipated one to five zones may be fracture stimulated.

In a horizontal well, with a length of 2,500m (Length may range from 1,000 – 3,000m), stimulation treatments are likely to be placed every 100m requiring 25 treatments in the well.

Consequently, fracture stimulation of a vertical well would require in the order of 0.4 – 6.0 ML of water, and a horizontal well may require up to 30 ML.

To minimise trucking of water, water will be obtained, where possible, from shallow water wells, drilled to a depth of approximately 200 - 250m, within the lease area of each of the exploration wells. Drilling, productivity and water quality uncertainties encountered while drilling for water for previous exploration wells may make it necessary for SAPEX to seek the landowner's permission to obtain water from existing bores.

The drilling of water wells and extraction of groundwater in the region (which is within the Far North Prescribed Wells Area) is regulated under the Natural Resources Management Act. A licence is generally required to use groundwater; however, some existing blanket authorisations apply for taking of groundwater for drilling, constructing or testing petroleum exploration wells. A well construction permit from the DEW will be required for any water well drilled, including bores installed to monitor aquifers, irrespective of licensing requirements.

SAPEX will liaise with the DEW to ensure that appropriate authorisations are in place for drilling and extraction of groundwater. Landowners will be consulted regarding water well locations and water use and proposed water supply wells will be reviewed to ensure that their use does not impact adversely on existing users of groundwater.

Water use for fracture stimulation will be in accordance with the Far North Prescribed Wells Area Water Allocation Plan, and applicable guidelines such as the API guidelines (API 2010).

5.10 Other Aspects of Fracture Stimulation Operations

This section provides detail on aspects that are specifically relevant to the fracture stimulation process.

Further aspects of drilling and well operations such as preparation of the well lease, drilling, casing and cementing of the well, camps, well operation and monitoring, well abandonment and well lease restoration are covered by the Arckaringa Basin Exploration Drilling Activities Environmental Impact Report (SAPEX 2007 and 2013) and Arckaringa Basin Exploration Drilling Activities Statement of Environmental Objectives (SAPEX 2007 and 2013) and are not re-visited in this document.

5.10.1 Waste Management

A range of wastes are generated during fracture stimulation operations. Typical wastes are summarised in **Table 7**.

Waste	Management
Domestic Waste	
Sewage and grey water	Sewage and wastewater to be managed in accordance with the requirements of the <i>South Australia Public Health (Wastewater) Regulations 2013</i> , which requires that the wastewater disposal system must either comply with the SA Health On-Site Wastewater Systems Code to be to the satisfaction of the Department of Health and comply with the most current version of the <i>Environmental Protection (Water Quality) Policy 20015</i> – Clause 17.
Food waste and paper	Collected (may be compacted) for disposal to approved landfill.

Plastic, glass and cans	Collected at the site for disposal to approved landfill or recycling where possible.
Industrial Waste	
Workshop waste (rags, filters)	Approved landfill.
Chemical bags and cardboard packaging materials	Compacted and collected at site for disposal to licensed facility.
Scrap metals	Collected in designated skip for recycling or to licensed facility.
Used chemical and fuel drums	Collected in designated skip for return to supplier or recycling.
Chemical wastes	Approved landfill or return to supplier.
Flowback fluids	Held in lined ponds for evaporation, with off-site disposal of liner to licensed facility.
Timber pallets (skids)	Recycled or to licensed disposal facility.
Vehicle tyres	Shredded and disposed to approved landfill.

Table 7: Typical wastes and disposal methods

Waste management practices will be guided by the principles of the waste hierarchy (i.e. avoid, reduce, reuse, recycle, recover, treat, dispose).

Generation of domestic waste (e.g. food waste, paper, plastics, cans and glass) will be limited as most domestic waste handling would occur at the camp, which would be managed under the parameters of the Exploration Drilling Activities SEO (SAPEX 2007 and 2013). Any domestic waste at the well site would be stored on site in secure bins or skips. Recyclable materials will be segregated for transport to a recycling facility where practicable. Other materials will be transported to a licensed waste disposal facility.

All industrial solid wastes at the site will be collected in designated skips for eventual recycling or disposal to an appropriately licensed facility. All wastes generated will be segregated on-site and, where feasible, reused or recycled. All waste would be transported to a licensed waste management facility in appropriate containers (e.g. drums or covered skips) by a licensed waste contractor where appropriate.

5.10.2 Hazardous Materials Storage

During fracture stimulation operations, average diesel usage will be approximately 11,500L per day. Sufficient fuel for three to five treatments will be on site (pending the completion design). Fracturing additives required for the fracture stimulation operation (see Section 5.4) will also be stored on site. Fuel and chemicals would be stored and handled, with appropriate secondary containment, in accordance with relevant guidelines and legislation (e.g. Australian Dangerous Goods Code, AS 1940 and EPA guideline 080/16 Bunding and Spill Management).

5.10.3 Spills and Emergency Response

Appropriate spill containment and clean-up equipment would be maintained on site, including acid spill kits and hydrocarbon spill kits. Any spill that occurred would be contained, reported and cleaned up by treatment in-situ where appropriate, or removal off-site for treatment or disposal. A spill response and emergency response plan would be in place detailing actions to be taken to minimise the impacts of accidents and incidents.

Minor spills in lined bunded areas are generally treated in situ in accordance with EPA guidelines. The main method of treatment and disposal of hydrocarbon contaminated soil resulting from spills outside of bunded areas is removal for temporary storage in a designated bunded area. The contaminated soil is then transported by a licensed regulated waste contractor to a suitable EPA licensed facility for treatment or disposal. (see Section 7 for further discussion).

5.10.4 Clean-up and Rehabilitation

Following the completion of fracture stimulation activities, all waste materials would be removed off site as discussed in Section 5.10.1. Once the ponds containing flowback fluids have had the contents and liner removed and the ponds are no longer required, they would be backfilled and re-profiled to match pre-existing surface contours, and the surface ripped/scarified to promote revegetation.

Site clean-up and rehabilitation and well abandonment (when required) would be carried out under the parameters established in the Exploration Drilling Activities SEO (SAPEX 2007 and 2013). Standard criteria have been established under the Petroleum and Geothermal Energy Act to measure the successful rehabilitation of abandoned well sites (PIRSA 2009).

6 Environmental Impact Assessment

This section discusses potential environmental impacts related to the fracture stimulation process in shale reservoirs in the Arckaringa Basin. The discussion is supported by an environmental risk assessment, which is summarised in Section 7. This risk assessment quantifies the level of risk based on an assessment of the likelihood and consequences of hazardous events occurring.

Sections 6.1 to 6.5 provide a detailed discussion of aspects of the environment that are potentially (or commonly perceived to be) impacted by fracture stimulation activities. Reference is made to the results of the risk assessment where relevant throughout the discussion.

The key aspects discussed are:

- Aquifers, where the potential hazards are mainly related to injection of fracture stimulation fluids into the target formations
- Soil, shallow groundwater, surface water and fauna, where the potential hazards are mainly related to storage and handling of fuel, chemicals and flowback fluids
- Other issues such as public safety and risk, cultural heritage, noise and air emissions, radioactivity and seismicity, where the potential hazards are related to a more general range of site activities.

The risk assessment summary table (**Table 11**) in Section 7 provides a summary of the key hazards, management measures and resulting level of risk.

6.1 Aquifers

The potential or perceived hazards to aquifers resulting from fracture stimulation activities in the Arckaringa Basin are discussed below. They include:

- Leakage to aquifers due to loss of well integrity
- Fracture propagation into overlying Great Artesian Basin (GAB) aquifers including disruption of natural fractures supporting springs at surface (note springs are an EPBC listed threatened community).
- Leakage to GAB aquifers through geologic media
- Impact on Permian aquifer potential including cross flow between aquifers
- Lateral migration of injected fluid in the Permian section
- Fracture propagation between Permian pressure cells / aquifers that are normally isolated
- Groundwater impacts from water use.

6.1.1 Leakage to aquifers due to loss of well integrity

A loss of well integrity could result in the leakage of fracturing fluids or hydrocarbons to aquifers or production of aquifer water when the well is flowed. The risk is reduced to as low as possible in the well design process and managed through operational monitoring during each step in the process. In particular:

- The well design and construction provide the mechanical integrity that reduces this risk to as low as possible
- Pressure testing confirms that production casing meets designed pressure specification
- Cement bond logs confirm the integrity of cement that fills the casing-wellbore space and prevents migration
- Pressure safety trip out systems during the fracture stimulation prevent pressure limits of the surface pipework and downhole casing equipment being exceeded
- Pressure monitoring during the fracture stimulation provides confirmation that the stimulation has not resulted in a well integrity issue

These items are discussed below.

Well design

As indicated in Section 5.2, the well design and construction process provides the mechanical integrity of the well bore for the operational conditions and life of the well. The process ensures that casing, well head and production equipment are designed to meet the stresses and loads associated with the temperature, pressures and fluids that may be pumped into and produced from the well. Standard design safety factors are applied to the pipe strength in this process to allow for the temperature environment and the potential pressures and loads on the casing.

New casing is installed on every new well. The casing, production and well head equipment is purchased

from suppliers that have demonstrated to SAPEX their ability to supply the materials that meet or exceed the design specification with appropriate supporting certification documents.

Well construction

As detailed previously, during construction of the well the casing strings are cemented into the ground. As shown in **Figure 20**, the GAB aquifers are isolated behind at least two strings of casing and cement. In addition to anchoring the casing string into the bore, the cement provides a barrier to fluid migration between the casing and borehole isolating aquifers and hydrocarbon bearing intervals.

Well site supervision by experienced personnel ensures that installation of casing, tubing and well head equipment is correctly undertaken to minimise the chance of inadvertent errors such as over tightening of threads which may lead to premature failure.

Cement design, casing centralisation in the well bore and correct cement pumping procedures are important in ensuring good quality cementing and isolation of the formations.

In the unlikely event there is a high-pressure release into a confined aquifer due to well failure, potential impacts are discussed in Jacobs (2016) and presented by Malavazos (2016). Jacobs (2016) modelled contaminant migration using initial pressure head equal to a pressure release of 14,000psi over a 2-day period to assess the maximum potential impact that will be observed. Based on these assumptions, the contaminate migrated 60m from the well bore in 1 month after the event, and up to 80m in 1 year. The risks are assessed to be moderate by definition of the reports risk matrix, these risks will be further reduced given the GAB will be isolated behind multiple strings of casing.

In an actual case, pressure monitoring of the wells will detect any reduction in well pressure and will activate remedial procedures reducing the pressure head generated through the pressure release.

Pressure testing and cement bond logs

Prior to the stimulation treatment, the wellbore is pressure tested to confirm the pressure integrity of the casing and the cement at the base of the well. Water is injected into the well and the pressure increased to the maximum design pressure.

Additionally, a cement bond log is run prior to stimulation to characterise the quality of the cement behind the casing. The log may assist with understanding stimulation and production results in the event that unexpected production characteristics develop. If the cement bond log (or other logs) indicates that it is required, a remedial cement treatment can be applied to the relevant casing to minimise the risk of communication with aquifers.

It is considered that there is a negligible chance that the production casing cement quality (and other isolation methods that may be applied in the optimisation of the production casing well design) and the intermediate casing cement quality would both be of sufficiently poor quality to enable fracture stimulation fluids to be pumped from the target reservoirs into the GAB which are 500m or more above the Stuart Range Formation (expected interburden in PEL123, thickness increases north into PEL122). The Boorthanna Formation is Stratigraphically below the Stuart Range Formation and therefore deeper again than the depths mentioned above.

Pressure protection during stimulation

In order to ensure that the pumping equipment does not generate pressures which exceed the design pressure of the casing and wellhead equipment, controls are fitted to the pumping equipment that will shut down the pumps once a pre-set operational maximum pressure is reached.

Monitoring during fracture stimulation

Monitoring of injection pressures is carried out during fracture stimulation and indicates whether there are any issues with surface equipment or the well. In the event the injection pressure does not appear to be correct, the stimulation treatment will be suspended and the data reviewed to assess the cause.

Summary

The likelihood of aquifers or springs being impacted by leakage during fracture stimulation of a properly constructed and operated well is very low. The level of risk to aquifers has been assessed as low (see **Table 11**).

6.1.2 Fracture propagation into overlying GAB aquifers including disruption of natural fractures supporting springs at surface

If growth of fractures out of the target formations and into overlying fresh water aquifers occurred, it could result in contamination of these aquifers or establish a conduit from the aquifer to the wellbore such that, during production operations, water would be recovered to surface.

Based on extensive fracture height growth monitoring in shale plays in the United States and the stress contrasts and separation distances observed in the formations intersected in the Arckaringa Basin (as discussed in Section 5), it is considered improbable that this type of connection can be established.

Origin (2017) suggests insitu stress contrasts have the most significant effect on fracture height growth. Perkins and Kern 1961, Simonson et al. 1978, Voegele et al. 1983, Palmer and Luiskuty 1985, Warpinski et al. 1982, Fescher et al. 2011 and Warpinski et al. (1982) gathered observations from experimental testing at sites that were mined back to allow fracture to be studied. Here, they confirmed height growth is indeed impeded by lithology contrasts where in-situ stresses differ. Fischer et al. (2011) summarise these mechanisms by which material property contrasts limit fracture height growth:

- The effect of a fracture approaching an interface with modulus contrast
- The effect of modulus on the width of the fracture and the resulting impact on flow resistance caused
- The difference in fracture toughness between layers.

Secondary controls on fracture height growth include inelastic forms of energy dissipation such as shear failure, bed slip and plastic deformation.

Monitoring of many fracture stimulation treatments in shale plays in the United States has shown that typical height growth of fractures is less than 200 - 300m (Fisher and Warpinski 2011). **Figure 27** is a plot of the upper extent of the fracture treatment, the perforation depth and lower extent of the fracture treatment plotted against target zone depth (decreasing depth to the right) for more than 300 wells in the Eagle Ford shale in Texas. The Eagle Ford data shows no occurrence of height growth sufficient to intersect an aquifer located more than 400 m above the fracture stimulation zone in at least 250 treatments, representing less than a 0.5% chance of occurrence.

The Eagle Ford data is used here as an analogue to estimate stimulation height growth for fracture stimulation of shales in the area. The Eagle Ford data is presented here because the shale source rock is most comparable with the Arckaringa Targets.

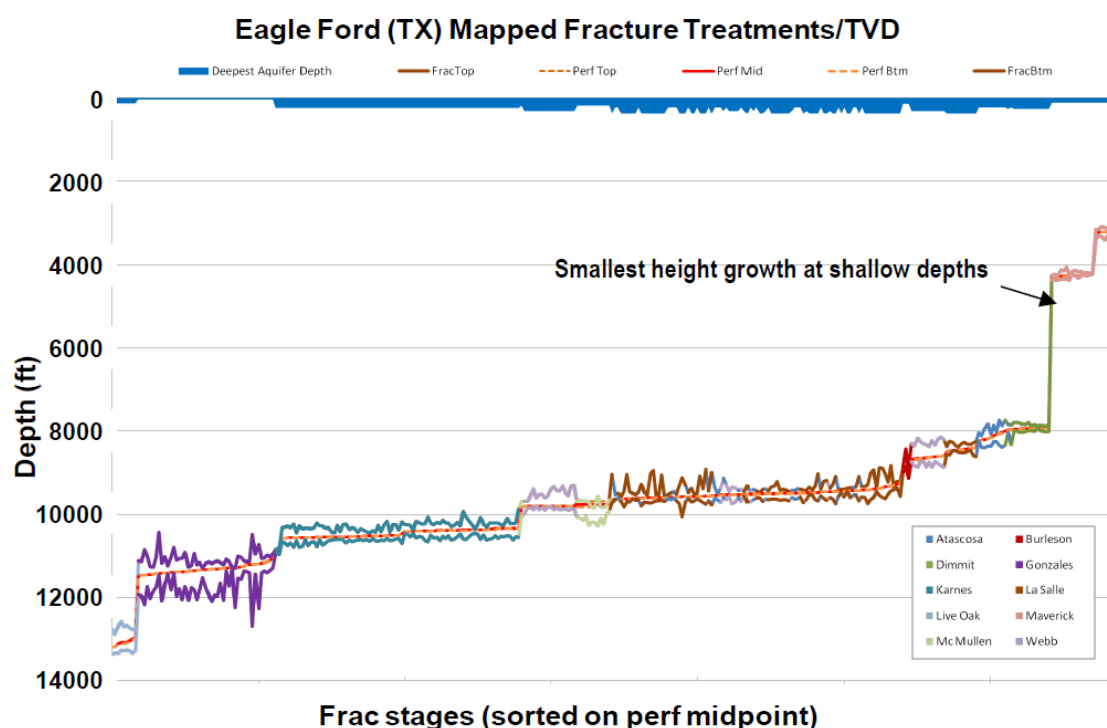


Figure 27: Typical fracture height growth measured during shale gas stimulation in the Eagle Ford (USA) – note smallest height growth occurs at shallow depths

For comparative purposes, **Figure 28** provides stimulation height growth data for fracture stimulation treatments completed in unconventional wells in South Australia's Cooper Basin. The wells targeted Permian shales and tight sands over large intervals (Approx. 1,300m) at depths of approximately 3,500m. The database includes 34 stages with the following key characteristics:

- Average height above mid perforation: 155m
- Average height below mid perforation: 88m
- Maximum height above mid perforation: 293m
- Maximum height below mid perforation: 249m

These numbers represent the maximum estimates based on measurements of where micro seismic picked up noise. This doesn't necessarily mean that the fracture propagated and is connected to where the noise was measured. It's expected the stress regime of the target Arkcaringa formations will be similar to the Cooper Basin target rocks although the injection volumes and pressure should be significantly lower.

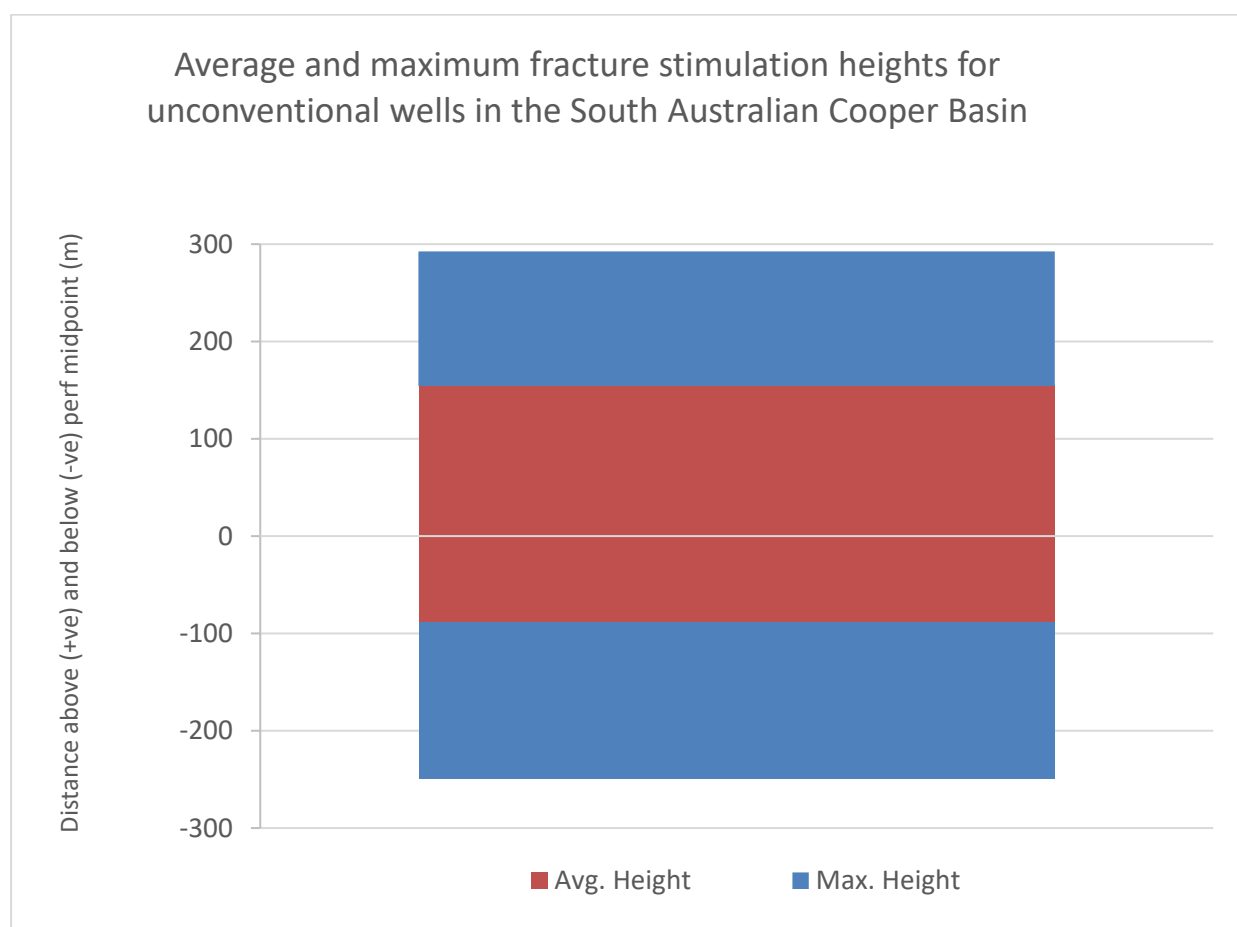


Figure 28: Cooper Basin fracture stimulation observed propagation heights from microseismic monitoring in unconventional wells

As discussed in Section 4.3.2, stratigraphically above the Stuart Range Formation is the Mount Toondina Formation. The basal unit of the Mount Toondina Formation is described as a conformable (occasionally disconformable) contact with the underlying Stuart Range Formation consisting of marine shales with interbedded limestones forming a low permeability layer and potential aquitard. At the Boorthanna 1 well (located in the north of PEL123), the lower Mount Toondina Unit is up to 200m thick and consists predominantly of Siltstone/Shale interbedded with fine sandstone (Total thickness of unit is approx. 600m). In the unlikely event, a fracture propagated outside of the target Stuart Range Formation, the stress contrasts within the lower Mount Toondina Formation and the thickness of low permeability sediments will act as a barrier preventing any impact with the overlying GAB formations as shown in **Figure 29**.

Existing data indicates the most prospective zone within the Stuart Range Formation is at the base which will form the likely target for any fracture stimulation. Within the project area, the Stuart Range Formation has been interpreted to be up to 250m thick allowing additional low permeability isolation above the treatment areas.

Further significant limitation on the potential transport of oil / contaminants from the Stuart Range Formation into the overlying GAB aquifers exist including:

- Fracture Stimulation will likely target the lower Stuart Range Formation leaving significant thickness of low permeability shales overlying treatment area
- Stress contrasts and low permeability siltstone/Shales within the lower Mount Toondina Formation will act as a geological barrier between the target area and the overlying GAB
- In PEL123 where the target Stuart Range Formation is shallowest, the GAB sediments (Cadna-Owie Formation) subcrop at surface and are generally weathered. Drillhole data indicates it's common for clay lenses to form throughout the weathered sections causing isolated, stagnant aquifers of high salt content
- In the exploration and appraisal stage, each stimulation treatment will be modelled as discussed in Section 5.3.2 and shown in **Figure 22**. The model will incorporate site specific data collected during the drilling of the vertical well to characterise the reservoir and complete geomechanical analysis
- Fracture stimulation height growth tends to be higher in deeper stimulations when compared with shallow treatments as shown in **Figure 27**.
- Under production conditions, the flow will be from the aquifer to the well ensuring that further fluids do not cross flow into the aquifer.
- The Upper Mount Toondina Formation is not targeted in the area for aquifer purposes
- Flow from the aquifer production would be identified at the well by the elevated water production rates and analysis of the water chemistry.
- The pressure gradients once flowback commences, which would result in fluids moving towards the well rather than away from the treatment zone, meaning that injected fracturing fluids flow to the well and are recovered at the surface.
- When the well is shut-in or decommissioned the aquifer will continue to flow to the lower zones until the pressure in the two zones equilibrates.

The Boorthanna Formation is stratigraphically below the Stuart Range Formation and therefore has additional stress boundaries and geological separation between the GAB and target zones. These include:

- The stress contrasts and low permeability Shales within the Stuart Range Formation will act as a geological barrier between the target area and the overlying GAB
- Intraformational shales and mudstones throughout the Boorthanna Formation will form stress contrasts and geological barriers between the target formation and the overlying GAB
- The Boorthanna Formation is geologically separated from production bores in the Billa Kalinna Sub Basin described in Section 4.8.2 by a basement high feature shown in cross section B – B' in **Figure 16**)

The level of risk posed by fracture propagation into overlying freshwater aquifers has been assessed as low (see Table 8). Therefore, the level of risk posed to natural fractures supporting surface springs charged water is low.

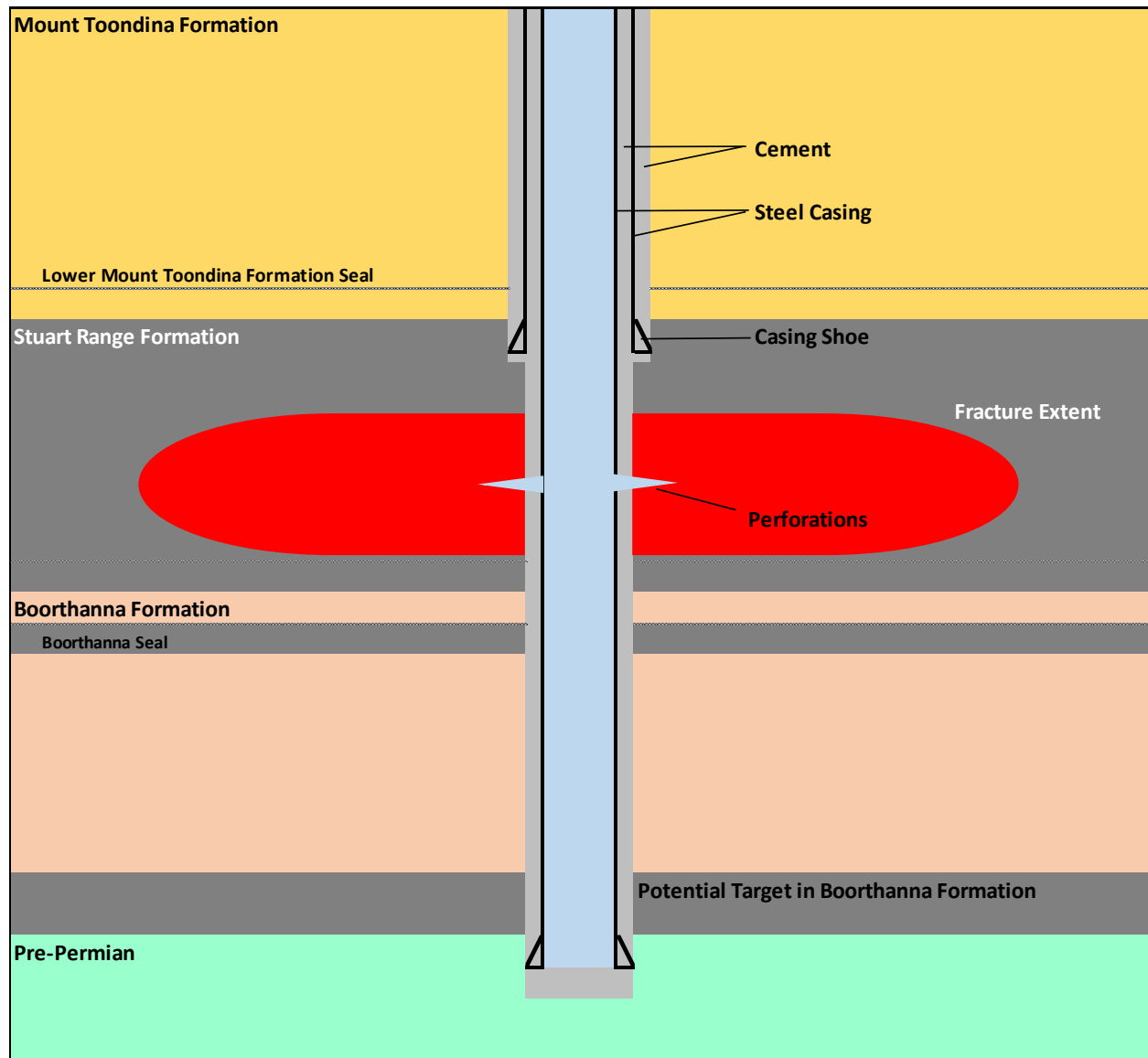


Figure 29: Indicative Stuart Range Formation Fracture Stimulation schematic showing stratigraphy, fracture extent and geological control provided by adjacent formations

6.1.3 Leakage of injected fluid to GAB aquifers through overlying strata or faults

Leakage of stimulation fluids to aquifers through the overlying strata is not considered a significant hazard for fracture stimulation.

The rate of flow through low permeability aquitard overlying the hydraulic fracture would be very slow and result in negligible net movement away from the treatment. Pressure gradients to potentially drive such leakage would typically exist only during the stimulation operation, and once flowback commences, the pressure gradient underground will result in fluids moving towards the well rather than away from the fracture stimulation.

The nearest aquifers of any significance are the sandstone units of the Jurassic Great Artesian Basin. As discussed in Section 6.1.1 and 6.1.2, the Permian target intervals are separated from the GAB by a minimum 500m of limited permeability Upper Stuart Range Formation and Lower Mt Toondina Formation.

In the unlikely event a contaminant could leak through the overlying strata, potential impacts are modelled by Jacobs (2016) and presented by Malavazos (2016). The model assumes a pressure head equal to 14,000 psi to be constant for a period of 7 days to simulate the maximum release of contaminants. The results indicate the distance of contaminant migration is 2 m up to 1 year after the contamination event and the risks are assessed to be very low (by definition of the reports risk matrix).

As discussed in Section 6.1.1, pressure monitoring of the wells will detect any reduction in well pressure which will activate remedial procedures.

The presence of inter formation faults may result in migration of fluids but there is very low probability of this in the Arckaringa Basin. In particular:

- the pressure differential between the GAB and the Permian formations indicates that the intervals are not currently connected by faults
- the seismic information, as discussed in Section 4.4 has not detected large scale faults that connect the GAB to the target zones.

In the unlikely event a fault was impacted, Jacobs (2016) modelled fluid travel within a fault/single fracture resulting from unintended fluid escape during fracture stimulation and concluded the risks to be low (by definition of the reports risk matrix). A 5,000psi release was assumed in a 45° fault with aperture of 0.01mm. The distance of contaminant migration after one day of escape was simulated to be approximately 350m from the well bore. Jacobs (2016) concludes that it's most unlikely that high pressure release into a fracture could migrate into shallow economic aquifers before a leak is detected and stopped.

The level of risk posed by leakage into overlying GAB aquifers has been assessed as low (see **Table 11**).

6.1.4 Impact on Permian aquifer potential including cross flow between aquifers

The impact of fracture stimulation operations on the aquifer potential of the Permian reservoirs themselves (i.e. the target formations for fracturing) is not considered to be significant.

The sandstone units of the Permian Boorthanna Formation and Mt Toondina Formation are not generally targeted for aquifer purposes within PEL122 and PEL123. As discussed in Section 4.6, the Boorthanna Formation is used as a water supply for pastoralists and major mining complexes south of PEL123. DEWNR (2013) demonstrates water extraction is within the Billa Kalina Sub-Basin. The Boorthanna Formation aquifer within the Billa Kalina Sub Basin occurs in isolated semi discontinuous pods, this is discussed in greater detail in Section 4.5.

As discussed in Section 6.1.2, the geology within the target area will be assessed via a vertical well to confirm the offset between aquifers and hydrocarbon bearing formations. The stimulation modelling process will incorporate this into the design to minimise risks associated with Permian aquifers and potential impact from the stimulation process. This is also an important commercial driver as any impact on an aquifer will result in water flowing into the wellbore which may affect the economics of the well. Even if it was considered the treatment may affect these aquifers, the units are not considered to be suitable for use for the following reasons:

- if water is present, it is expected the environmental values of waters per the *Environmental Protection (Water Quality) Policy 2015* be sufficient to preclude use of the water for livestock activities within the project area due to a high TDS value.
- depth of the zones requires expensive drilling for water users and is not commercially viable.
- Permian aquifers are overlain by the GAB Formations, this is the likely target for any water use

The level of risk has been assessed as low (see **Table 11**).

6.1.5 Lateral migration of injected fluid in the Permian section

Lateral migration of any significant quantities of injected fluids away from the fracture treatment zone is considered highly unlikely, as once the fracture stimulation treatment has been completed, the well is flowed back, creating a pressure differential and a flow path from the end of the fracture treatment to the well. This pressure differential increases into the production phase of the well as production of reservoir fluids continues. Consequently, injected fluids would flow back to the well. A pressure gradient to drive lateral migration would likely not exist.

Where the Boorthanna Formation aquifers as discussed in Section 4.8.2, a geological barrier in the form of a basement high separates the Boorthanna Trough from the Billa Kalina Sub Basin as shown in cross section B – B' in **Figure 16**.

The level of risk has been assessed as low (see **Table 11**).

6.1.6 Groundwater impacts from water use

Water extraction for fracture stimulation will be undertaken within the regulatory framework of the Natural Resources Management Act. As discussed in Section 5.9, SAPEX will liaise with the DEW to ensure that

appropriate authorisations are in place for drilling and extraction of groundwater. Landowners will be consulted regarding water well locations and water use and proposed water supply wells will be assessed to ensure that their use does not impact adversely on existing users of groundwater.

As discussed in Section 5.9, water use for fracture stimulation will be in accordance with the Far North Prescribed Wells Area Water Allocation Plan, and broadly applicable guidelines such as APPEA and API guidelines (APPEA 2011; API 2010).

The level of risk from water extraction for fracture stimulation has been assessed as low, based on minor level impacts being possible (see **Table 11**).

6.2 Soil and shallow groundwater

Potential impacts to soil and shallow groundwater arise mainly from:

- spills or leaks from the storage and handling of fuel or chemicals
- spills or leaks from the sourcing and storage of water in preparation for stimulation
- spills or leaks from handling and storage of flowback fluids at the surface
- storage and transport of waste.

Improper storage and handling of fuel, chemicals and flowback fluids has the potential to result in localised contamination of soil and groundwater.

In order to minimise this risk, chemicals on site will be stored and handled in accordance with relevant standards and guidelines. Bulk fuel and chemicals will be stored with appropriate secondary containment as required. Any spills from chemical handling would be immediately cleaned up and contaminated material removed off-site for appropriate treatment or disposal.

As discussed in Section 5.8, temporary storage ponds, lined with suitable UV stabilised polyethylene material (or equivalent), will be used to contain the water for fracture stimulation and the fluids recovered during flowback. Quality control during construction of the ponds is important in preparing a suitable base for the lining material to minimise risk of liner breaches. Fencing prevents large fauna and livestock from entering the ponds and damaging the liners. Regular monitoring of the pond and fence condition, operating the ponds below maximum fill levels (allowing freeboard for rain events and wave action) and construction with above-ground bunding to prevent surface runoff into the ponds all minimise the risk of seepage or release from the pond.

The water sourced for fracture stimulation may be brackish or saline. Chemicals are not added to the stored water; however, it is desirable to prevent release of the water to soil and potentially to shallower groundwater systems. Should a pond leak develop while these ponds are being used to contain pre-stimulation water, the short-term nature of utilisation, the absence of added chemicals and the remoteness from sensitive receptors or sensitive land uses indicate that there will be negligible to minor impacts on the soil and shallow groundwater and this risk is assessed to be low.

If a spill or leak from a pond occurs while it contains flowback fluids, containment and clean-up measures would be implemented. The pond can be decommissioned by pumping fluid out of the pond to an alternative pond on the lease (re-lining or re-instating one of the pre-stimulation water ponds if required). Where necessary and possible, escaped fluid may be recovered, for example with a drainage channel to collect the fluid which would then be pumped back to an alternative pond. In the event of a major spill or leak, affected areas would be fenced off and assessed, rehabilitated and monitored, in consultation with DEM and EPA where appropriate.

The water table in much of the region is generally absent due to the Bulldog Shale (Aquitard) sub cropping at surface. In PEL123 where the underlying Cadna-Owie Formation sub crops at surface, shallow groundwater is expected to be predominantly saline as discussed in Section 4.5. There is very low population density and very limited use of shallow groundwater. Many of the fracturing fluid additives are biodegradable and would be expected to break down over time if a spill or leak occurred. The rate of transport of any spilt contaminants to shallow groundwater (if present) is also likely to be limited by the low rainfall and high evaporation in the region. Consequently, minor seepage from a pond, if it occurred, would be expected to have a low level, localised impact. A large release (e.g. due to pond failure) could affect a larger area and result in a moderate level consequence, but is considered unlikely given the construction, lining, operation and monitoring of the ponds that will be undertaken (as discussed above).

Fracture stimulation requires the injection of fluids into the wellbore. An equipment failure or leak could result in fracturing fluid being released to the lease area. Surface pipework, valving and pumping equipment

required for the treatment must have a valid certification for the pressure rating. Once set up for the fracture stimulation the equipment is pressure tested to ensure integrity and pressure trip out devices are present to shut down pumps before equipment limitations are reached (Section 6.1.1). The design, pressure test and shut down systems reduce the risk of leaks to a very low level. In the unlikely event of a failure, the equipment is quickly shut down from the control van, reducing the volume of the spill to minor amounts.

Storage of waste and transport to licensed disposal facilities will be undertaken in accordance with relevant legislation and guidelines. Waste generation will be minimised where practicable, waste will be stored securely and licensed waste contractors will be used for waste transport.

Other potential impacts to soil (e.g. soil disturbance, erosion) are localised and generally short term. These are principally a result of well lease preparation activities that would be conducted under the Exploration Drilling Activities SEO (SAPEX 2007 and 2013). Site rehabilitation, including remediation of these impacts would also be carried out in accordance with the requirements of the Exploration Drilling Activities SEO (SAPEX 2007 and 2013), as discussed in Section 5.10.4.

The level of risk to soil and shallow groundwater has been assessed as low for most of these potential hazards. For a major leak or spill, while unlikely, the risk ranking is medium due to the assumed consequence (see Table 8).

6.3 Surface Water

Potential impacts to surface water arise mainly from:

- spills or leaks from the storage and handling of fuel or chemicals
- storage and transport of waste
- spills or leaks from handling and storage of flowback fluids at the surface
- flooding of well leases during fracture stimulation operations.

Measures to ensure safe handling and storage of fuel, chemicals and flowback fluids will be implemented, as discussed in Section 6.2, including secondary containment, lining, spill response and clean-up. Similarly, secure storage and handling of waste will be implemented as discussed in Section 6.2.

Several of the additives in the fracturing fluids (particularly biocides) have relatively high toxicity to aquatic organisms, particularly in fracturing fluids that have only just been mixed, where the additives have not been used and degraded. Although many of these additives are biodegradable and would be expected to break down over time, a release or spill to surface waters of large volumes of fluids containing these additives would require significant dilution to reduce levels of contaminants to below harmful levels and could result in impacts beyond the immediate area of operations.

The potential mechanisms for such an escape of large volumes of fracturing fluids to surface water include structural failure of ponds holding flowback fluids (due to overfilling and erosion of the pond walls) or significant flooding such that a pond is inundated.

Construction of the ponds with a polyethylene liner, operation with appropriate allowance for rain events, construction of pond walls higher than the surface grade to prevent surface water drainage to the pond, contouring surface drainage around the ponds and ongoing monitoring of pond condition reduce the risk of structural failure such that it is a very unlikely event. Selection of appropriate well site and pond locations will also ensure that the consequences of a potential pond failure are minimised (e.g. ponds would not be located in close proximity to a significant watercourse such that failure would result in direct release to these watercourses).

To mitigate the risk of fluid release due to flood inundation, well leases will not be located in areas where frequent flooding is likely. If well leases are to be located in areas where infrequent minor flooding may occur, measures will be undertaken to ensure that ponds are not vulnerable to flooding (e.g. ponds may be located on higher ground out of the floodplain and/or pond walls constructed higher above grade at these locations).

Flooding of the well lease while fracture stimulation is being carried out could result in localised contamination from fuel and chemicals held on site. Short term (1 - 2 weeks), shallow and localised flooding due to localised high rainfall events is unlikely to result in significant risk as the stimulation activity is ceased in advance of storm weather and materials would be appropriately secured.

Prior to undertaking fracture stimulation operations, site-specific assessments against the SEO will be submitted to DEM to demonstrate that the environmental objectives can be met, including the SEO

requirement to avoid contamination of surface waters. The site-specific assessments will indicate risks identified at individual well locations and management strategies required to mitigate these to meet the objectives.

The mitigation measures discussed above, particularly in regard to the location of ponds and well sites, indicate that the likelihood of release of flowback fluid to surface water can be reduced to a very low level.

The level of risk to surface water has been assessed as low for most of these potential hazards. For a major leak or spill to surface water due to pond failure, while this is an unlikely event, the potential level of consequence has been assessed to be major, which results in a medium risk (see **Table 11**).

6.4 Stock, Wildlife and Vegetation

Potential impacts to stock and native fauna arise mainly from:

- spills or leaks from the storage and handling of fuel or chemicals
- spills or leaks of flowback fluids
- interaction with fluid storage ponds
- use of roads and movement of vehicles and heavy machinery
- activity outside designated / approved areas
- storage and transport of waste.

Measures to ensure safe handling and storage of fuel, chemical and flowback fluids will be implemented, as discussed in Section 6.2, including secondary containment, lining, spill response and clean-up.

Access to fuel and chemicals and flowback fluids held in ponds presents a potential hazard to stock and to some native fauna. Stock access to chemicals and fuel will be prevented by storing and handling them in designated areas free from rubbish or waste that may attract fauna, manning of well sites while fracturing activities are being undertaken and immediate containment and clean-up if any spills occur. Stock-proof fencing will be erected around ponds to prevent stock from accessing flowback fluids. Drilling sumps will be fenced following drilling (which is standard practice). Regular inspections will be carried out to ensure the integrity of the fences. Where an issue with fauna egress from a pond arises SAPEX will investigate opportunities for managing access to the ponds, this may include trialling escape ladders, small fauna fencing or other options.

The presence of temporary ponds for holding flowback fluids has the potential to attract birds. Due to the nature of the ponds (relatively steep sided and lined with plastic, with no 'beaches', vegetation or food sources) visitation by birds is expected to be restricted to relatively small numbers for relatively short periods of time. Concentration data for fracturing fluids to be injected and available toxicity information (e.g. SDS information provided by the stimulation service provider) indicate that the concentration of additives of highest concern for fauna (e.g. biocides) is expected to be below levels that pose a significant risk for birds coming into short term contact with flowback fluids.

As discussed in Section 5.7, many of the additives in the fracturing fluids are used or degraded in the process (including biocides) or remain in the formation and would return at a fraction of what was pumped down the well. The pH of the flowback fluids is expected to be relatively neutral, as acids are neutralised in the fracturing process (see Section 5.4). Water quality data reported in Beach (2012) support this, with recorded pH of 6.2 - 7.7. Ponds will be temporary and will be rehabilitated following removal of liner.

As a consequence, the presence of the ponds is not expected have a significant impact on birds. SAPEX intends to conduct further investigation to confirm this, including ongoing testing of flowback fluid composition. The ongoing inspection and monitoring of the ponds would also detect bird mortality if it occurs. If necessary, additional measures to discourage bird use will be implemented, which may include installation of flagging or other devices to discourage bird presence.

Plastic lined ponds with relatively steep sides have the potential to trap stock and native fauna. Escape mechanisms will be installed during pond construction, as discussed above fencing will also prevent larger animals from entering the ponds. Based on experience with similar ponds used for holding raw water for drilling or fracturing or for treatment of produced formation water, entrapment of fauna in ponds in the Arckaringa Basin is a very rare occurrence. As noted above, the presence of these ponds is temporary.

As discussed previously, a pond breach could result in a significant release of fluid. The construction, operation and monitoring of the ponds reduces the likelihood that this outcome will occur to a low level. In the event that a pond breach occurs before stimulation, the brackish (or saline) water may affect vegetation in the area of the spill (should it extend beyond the cleared lease area).

During flowback, the returned fluid in the pond will consist of degraded fracture fluids and dissolved ions from the geological strata and traces of hydrocarbons. As there is less returned fluid than injected water, pond operating levels can be significantly reduced and the risk of pond failure reduced further. A spill of flowback fluid associated with a pond breach may affect vegetation (should it extend beyond the lease area) and indirectly stock and fauna that may enter to feed. The spill area can be fenced to prevent stock and fauna entry. If, and as appropriate, drainage channels may be required to drain and gather spilt fluids and pump back to other holding ponds, and further assessment, rehabilitation and monitoring may be undertaken, as discussed in Section 6.2.

Fracture stimulation operations may result in a short term and localised increase in traffic volumes, which could increase the risk of collisions with stock and native fauna. Measures to mitigate the risks are part of standard operating procedures for SAPEX and include speed restrictions, monitoring of speeds in industry vehicles, driver education programs and restriction of transport movements to daylight hours as far as practicable.

Activities outside defined / approved areas have the potential to impact vegetation and fauna. All activities will be confined to the cleared well lease, with signage and fencing (where required) installed to delineate approved areas and any restricted areas. If flora of conservation significance is present in the vicinity it will be flagged and/or fenced off where necessary to prevent disturbance.

A high standard of waste management will be implemented to avoid impacts to flora and fauna. In particular, secure systems will be used for storage and transport (e.g. covered bins in a designated area) to prevent wind-blown litter or birds and dingoes accessing waste. (See section 5.10.1)

Based on the above discussion, impacts to native fauna and flora (including rare or threatened species) are expected to be minimal. Site-specific risks will be addressed in initial scouting and site assessment conducted under the Exploration Drilling Activities SEO (SAPEX 2007 and 2013) and in assessments submitted to DEM prior to undertaking fracture stimulation operations. These assessments must demonstrate that the objectives with respect to vegetation, stock and native fauna identified in the SEO will be met while undertaking the proposed work at the specific well location.

The level of risk has been assessed as low for these potential hazards. A medium risk is assigned for a major leak or spill; although it is unlikely to occur, the consequence is moderate (see **Table 11**).

6.5 Other Issues

6.5.1 Public Safety and Risk

Potential impacts to public safety and risk arise mainly from:

- unauthorised access resulting in exposure to site hazards during operations
- unauthorised access to fluid storage ponds
- bushfire as a result of activities
- use of roads and movement of vehicles and heavy machinery.

Fracture stimulation activities will be carried out at established well leases where public access is restricted. Lease access is further restricted to only necessary personnel during pressure pumping activities.

Most sites are also expected to be relatively remote from public roads and accessed from roads with no public access. Measures such as signage and fencing will be in place at the well lease to warn of the hazards at the site and restrict access into the site. Potentially hazardous areas such as sumps and ponds will be securely fenced with warning signs in place.

The population density in the area is very low. Fracture stimulation activities (and drilling activities in general) would not be carried out in close proximity to pastoral station residences or the William Creek township.

Fires are generally not a frequent occurrence in the Arckaringa Basin. Fires have occurred from lightning strikes at various times. In order to manage the risk of initiating fires, activities will be confined to the cleared well lease and combustible material will be cleared from around the flare pit. Firefighting equipment will be maintained in the area as appropriate, and the requirements of the Fire and Emergency Services Act will be complied with.

Fracture stimulation operations may result in a short term and localised increase in traffic volumes. The

existing road and track network in the Arckaringa Basin is mostly used for cattle station operations, and hardly ever used by the oil and gas industry. The incremental change will be minor in general with increased vehicular traffic during Fracture Stimulation operations being manageable. Where appropriate, measures to mitigate the risks to the public will be put in place including signage, speed restrictions, monitoring of speeds in industry vehicles, education programs and ongoing maintenance of roads and tracks.

The level of risk to public safety has been assessed as low for most of these potential hazards. A medium ranking has been assessed for road use (see **Table 11**).

6.5.2 Potential Impact to Existing Users

Potential impacts to existing users of water resources within PEL122 & PEL123 mainly arise from:

- Loss of water source due to contamination or depressurisation of water aquifers

A large portion of the area within PEL123 is within a zone where the Great Artesian Basin outcrops at surface and therefore does not form an artesian aquifer. Development of pastoral water bores within this area is minimal due to poor yields and high salinity water as discussed in Section 4.5.

This along with risk mitigation strategies to minimise impacts on surrounding aquifers discussed in Section 6.1 reduces the level of risk to existing users to low for these potential hazards (see **Table 11**).

6.5.3 Cultural Heritage

Potential impacts to cultural heritage arise mainly from activities occurring outside designated / approved areas.

Work Area Clearances with the native title claimant groups are carried out prior to undertaking any exploration or production activities in the Arckaringa Basin. Fracture stimulation operations are undertaken on a prepared well lease, within the area cleared by the Work Area Clearance party. Signage and fencing (where required) are installed to delineate approved areas and any restricted areas. If sites of cultural heritage significance are present in the vicinity they may be flagged and/or fenced off where necessary to prevent disturbance. In addition, procedures are in place to deal with the incidental discovery of cultural heritage material.

Consequently, significant impacts to cultural heritage are not likely to occur and the level of risk has been assessed as low (see **Table 11**).

6.5.4 Noise and Air Emissions

Potential impacts associated with noise and air emissions include:

- Reduction in local air quality
- Generation of greenhouse gases
- Disturbance to native fauna
- Disturbance to the local community.

Noise and air emissions from the well sites during fracture stimulation will be localised and short term and are not likely to have a significant noise or air quality impact. The sites will not be in close proximity to residences (e.g. station homesteads or William Creek). Equipment will be operated and maintained in accordance with specifications in order to minimise noise and air emissions. Flaring during production testing would be kept to minimum length of time necessary to establish resource and production parameters.

All greenhouse gas emissions will be reported in accordance with the requirements of the National Greenhouse and Energy Reporting Act (NGER Act).

The level of risk from noise and air emissions has been assessed as low (see **Table 11**).

6.5.5 Radioactivity

The potential for radioactivity resulting from Naturally Occurring Radioactive Materials (NORM) that are brought to the surface is perceived as a potential issue for fracture stimulation activities.

Based on previous experience with Cooper Basin petroleum operations, levels of radioactivity associated with NORM in flowback of fracture stimulation fluids are not expected to be significant and are expected to

be well below any levels of concern. NORM is usually only a potential issue when they are concentrated (e.g. by the formation of mineral scales or sludges over time in tanks, piping and facilities).

Radioactive tracers (proppant beads impregnated with isotopes), if used are generally retained in formation along with the remainder of the proppant. They have a short half-life and rapidly degrade. Very little is returned to surface and if so, would be a very low concentration and would not be in solution (it would settle into the lined pit with any proppant flushed from the well). SAPEX will monitor flowback where radioactive tracers are used to ensure that radiation levels are well below any levels of concern. All radioactive materials will be handled in accordance with relevant legislation and guidelines.

Chemical tracers, if used, are non-hazardous and are injected in very low concentrations) around 1 part per million in each stage). In flowback, they are expected to be less than 250 parts per billion in total within the flowback fluids.

The level of risk has been assessed as low (see **Table 11**).

6.5.6 Seismicity

The induction of seismic events (i.e. micro-earthquakes) as a result of fracture stimulation is sometimes perceived as a potential issue. It is not considered that a credible risk is presented by fracture stimulation of shale oil/gas targets in the Arckaringa Basin.

Fracture stimulation has been carried out in the Cooper Basin for over 40 years without any issues related to seismicity. Fracture stimulation of the Holdfast-1 well in PEL218 in 2011 did not register on the seismic monitoring equipment at Geodynamics' nearby Habanero site. Micro-seismic monitoring may be used at some well locations as part of the resource assessment and will be available to delineate seismic response.

Drummond (2016) concluded issues of concern flagged by the public can be mitigated through the use of leading industry practice. Key points relating to seismicity summarised by Drummond (2016) include:

- The water volumes used during hydrofracturing are typically small compared to other uses in rural and regional areas. The volumes injected during hydrofracturing are insufficient to cause significant earthquakes; indeed, the science underpinning hydrofracturing indicates that the earthquakes should be very small, consistent with observations
- Environmental issues associated with the surface footprint of hydrofracturing activities are not linked with induced seismicity
- Seismicity induced by deliberate hydrofracturing usually has zero or negative magnitudes. It will not be felt and will not be damaging. Larger earthquakes can occur through the reactivation of faults by reinjecting large volumes of waste water. This can be mitigated through management of formation pressures.

Note for the purposes of this report, hydrofracturing and fracture stimulation are one in the same.

Drummond (2016) provides a table that captures parameters for induced seismicity using numerous references and case studies to form conclusions. Based on available data, in the unlikely event fracturing of intact rock caused an earthquake, maximum magnitudes are usually $M \leq 0$ and occur within a few 100s of meters of the well spreading radially with time. In the unlikely event a fracture stimulation causes fault reactivation, maximum magnitudes are usually $M \leq 0$ in shales and typically occur at the edges of the fractured volume. Such events occur in linear patterns 100s of metres long aligned with existing faults that are usually optimally or near optimally aligned with stress fields.

In both occasions, it's highly unlikely the seismic event will be felt at surface given. In addition to the absence of significant risk posed by fracture stimulation operations, there is very low population density and little infrastructure that would be sensitive to small seismic events.

The level of risk has been assessed as low (Table 11).

6.5.7 Cumulative Impacts

Cumulative impacts of fracture stimulation of wells in the context of the Arckaringa Basin and the existing environment are not considered to be significant. Any impacts will generally be isolated, short term and will affect a very small proportion of the region.

6.5.8 Economic Impact

Certain identified environmental risks have potential for negative economic impact on stakeholders. Application of the measures discussed above to minimise the environmental risk also minimises the economic risk.

There are a number of potential economic benefits for landholders, the community and the State resulting from fracture stimulation and production from the Arckaringa Basin including:

- Well access routes would be rehabilitated in the event of an unsuccessful well but may be of use to landholders and may save construction costs to the landholder.
- Improved access routes, less affected by flood or heavy localised rain events, may be established and be beneficial to stakeholders.
- Increased utilisation of Coober Pedy and William Creek food, fuel and lodgings which has direct impact to owners and potential indirect impact to users if services were to be expanded or augmented.
- Increased utilisation of indigenous land owner crews to undertake clearance surveys associated with activities.
- Potential for royalties to be paid if exploration and appraisal are successful and project economics favourable which benefits State and traditional land owners.
- Potential enhancements to infrastructure or increased maintenance such as roads, airstrips and communication, dependent on success and on-going activity.
- Increased understanding of the geological zones under the ground provides information for other licensees in the area once data becomes open file.

7 Environmental Risk Assessment

SAPEX has undertaken an environmental risk assessment of fracture stimulation of shale oil/gas reservoirs in the Arckaringa Basin. This section summarises the process and results of the assessment.

Environmental risk is the chance of something happening that will result in impact to an aspect of the environment. Risk is measured in terms of the consequences of an event and their likelihood.

Given appropriate management measures (i.e. those identified in Section 6), most risks can be avoided or reduced to a level that is as low as reasonably practical (ALARP). This is a risk of something happening that is considered to have a minimal impact and which will recover. However, in some cases there may still be 'residual' risks that remain after management measures have been implemented.

An environmental risk assessment of SAPEX's proposed fracture stimulation activities has been undertaken to evaluate the level of environmental risk associated with various activities. It provides a framework for assessing risk management priorities and options based on the level of each assessed risk. The risk assessment is described in this section.

The environmental risk assessment was conducted using methodology based on AS/NZ 31000:2009 *Risk Management* and HB 203:2006 *Environmental Risk Management – Principles and Process*. Where appropriate, the risk matrix was updated to align with SAPEX's current safety systems.

The first stage of the risk assessment involved identifying the activities that may be a source of risk (hazards) and the possible associated environmental impacts (consequences).

Once the consequences were identified in Section Environmental Impact Assessment, the severity of the consequences (**Table 8**) and the likelihood of the consequences occurring (**Table 9**) were allotted. A risk matrix (**Table 10**) was then used to undertake an environmental risk assessment of each consequence and determine a risk ranking. Results of the risk assessment are presented in **Table 11**.

Each phase of the risk assessment process is further discussed in the following sections.

7.1 Hazards and Consequences

Primary environmental hazards and the key potential environmental consequences associated with fracture stimulations operations in the Arckaringa Basin are identified in Sections 6.

To determine the level of risk associated with various hazards and potential consequences, both the likelihood and severity of hazards, and their associated consequences, have to be considered. Categories of likelihood and severity have been determined using subjective estimates of whether or not a particular event or outcome will occur.

Fracture Stimulation operations have been undertaken in the Cooper and Eromanga basins for many years and as a result the environmental hazards and existing management measures are generally well understood. As a consequence, the likelihood and severity of consequences of the majority of fracture stimulation activities can be confidently predicted based on past experience in other South Australian basins and professional judgement.

Both the likelihood and severity of consequences have been assessed in the context of the management practices that are currently applied to reduce the level of risk associated with identified hazards and potential consequences.

7.1.1 Severity of Consequences

Environmental consequences can be categorised from negligible to catastrophic (**Table 7**). These consequences are adapted from the definitions in AS/NZS 31000:2009 but have been expanded to incorporate impacts to environmental values such as flora, fauna and biomass and the socio-economic environment.

Category of Effect	Qualitative Description of Environmental Effects	
	Natural environment	Socio-economic environment
Negligible	Possible incidental impacts to flora & fauna in a locally affected land system but no ecological consequence. Possible incidental impacts to aquifers associated with the oil and gas formation without ecological consequence.	Community is aware of operations and concerns have been addressed
Minor	Changes to the abundance or biomass of biota, and existing soil and/or water quality in the affected land system, but no changes to biodiversity or ecological function. Aquifers have a small amount of exposure from other sources of fluids, negligible volume movement in or out of formations or aquifers. No measurable change to aquifer water quality or pressure in local area.	Temporary disturbance to the community.
Moderate	Changes to the abundance or biomass of biota, and existing soil and/or water quality in the affected land system, with local changes to biodiversity but no loss of ecological function. Detectable change to aquifer water quality and pressure in the local area.	Longer term disturbance able to be managed with communication to affected community
Major	Substantial changes to the abundance or biomass of biota, existing soil and/or water quality in the affected land system with significant change to biodiversity and change of ecological function. Eventual recovery of ecosystem possible, but not necessarily to the same pre-incident conditions. Substantial changes to aquifer water quality and pressure in the local area (i.e. local drawdown adjacent to the oil and gas well or field).	Significant effect which can be mitigated by extensive rehabilitation and negotiation with community
Catastrophic	Irreversible and irrecoverable changes to abundance/biomass or aquifers in the affected area. Loss of biodiversity on a regional scale. Loss of ecological functioning with little prospect of recovery to pre-incident conditions. Widespread effect of reduction in aquifer pressure (i.e. reduced flow from bores in locations remote from operations). Contamination of aquifers remote from operations.	Significant and long lasting negative economic and social effects.

Table 8: Severity of consequences

The distinction between temporary and long-term impact depends on many factors but is ultimately a value judgement based on scientific evaluation and the level of community acceptance. These factors are generally related to climatic events, differing terrain units, vegetation units and timing of activities/operations. Dependent on these factors, a general guideline is that the community should expect recovery from fracture stimulation activity impacts in the north of South Australia after about five to ten years when current techniques are employed. Impacts that are irreversible or are expected to take significantly longer to recover are defined as 'long-term impacts'.

7.1.2 Likelihood of occurrence

The likelihood of potential environmental consequences occurring was qualitatively assessed and categorised according to the criteria outlined in **Table 9**. Where appropriate, definitions were updated to match SAPEX's current safety management system. This table is based on Table 4(A) of HB 203:2006 (AS/NZS 2009).

Likelihood	Description
Almost certain	The event is expected to occur in most circumstances
Likely	Will probably occur in most circumstances
Possible	Might occur at some time
Unlikely	Could occur at some time
Rare	Occurs only in exceptional circumstances

Table 9: Assessment of likelihood

7.2 Risk Assessment

The level of risk has been determined by combining the likelihood and the severity of consequences using a risk matrix. **Table 10** shows the risk matrix that has been used in this risk assessment.

This matrix is based on example matrices provided in AS/NZ 31000:2009 and supporting documentation.

		SEVERITY OF CONSEQUENCE				
		Negligible Effect	Minor Effect	Moderate Effect	Major Effect	Catastrophic Effect
LIKELIHOOD	Almost certain	MEDIUM	HIGH	HIGH	VERY HIGH	VERY HIGH
	Likely	LOW	MEDIUM	HIGH	VERY HIGH	VERY HIGH
	Possible	LOW	MEDIUM	HIGH	HIGH	VERY HIGH
	Unlikely	LOW	LOW	MEDIUM	HIGH	HIGH
	Rare	LOW	LOW	MEDIUM	MEDIUM	HIGH

Table 10: Risk matrix

The objective of the risk assessment process is to separate the minor acceptable risks from the major risks and to provide data to assist in the evaluation and management of risks.

A summary of the risk levels for fracture stimulation activities is provided in **Table 11**. This risk assessment takes into account the mitigation methods and practices described earlier within this EIR.

Risks are generally considered acceptable if they fall into the low category without any further mitigation measures, and 'tolerable' if they fall into the medium risk category and are managed to reduce the risk to a level 'as low as reasonably practicable'. Risk reduction measures must be applied to reduce high risks to tolerable levels.

The results of the risk assessment indicate that the risk levels for fracture stimulation activities are classified as either 'Low' or 'Medium'. No high or very high risks were identified. This indicates that with appropriate planning and management (in accordance with previous sections of this EIR), environmental risks are not at an unacceptable level.

A summary of the level of environmental risk for fracture stimulation activities is provided in **Table 11** below. The level of risk has been assessed based on the assumption that the management measures outlined in this EIR will be in place.

Table 11: Risk assessment for fracture stimulation of shale oil and gas targets in the Arckaringa Basin, South Australia

Risk Event / Hazard	Potential Environmental Impacts	Control Measures / Comment	Consequence	Likelihood	Residual Risk
Injection of fracture stimulation fluid					
Loss of well integrity	Leakage to aquifers Contamination of soil, groundwater and surface water Emissions to the atmosphere	Aquifers isolated behind multiple casing strings, cemented in place. New casing and wellhead installed. Casing and wellhead designed to meet pressure, temperature, operational stresses and loads. Design reviewed by independent engineering firm if necessary.	Moderate	Rare	Medium
	Injury / danger to health and safety of employees, contractors and possibly the public	Cement bond logs run to confirm quality of cement. Well pressure tested prior to stimulation. High pressure stimulation equipment has valid certifications, is properly secured and is pressure tested once set-up, prior to commencement of stimulation. Stimulation pumping pressures do not exceed design safety factors. Trip systems to shut off pumping units during stimulation. Injection pressures are monitored and compared to expected fracture initiation pressure. Well control equipment used during coiled tubing, wireline and workover activities. Ongoing well integrity monitoring. Emergency response plan in place and drills conducted.	Major	Rare	Medium
Fracture propagation into overlying GAB aquifers including disruption of natural fractures supporting springs at surface.	Contamination of aquifers Indirect adverse impacts to groundwater users Disruption of natural fracture supporting springs at surface	Fracture design (including pressures, injection rate, fluid makeup and proppant concentration) undertaken to provide confidence that the fracture treatment will not impact on overlying GAB aquifers Fracture stimulation treatments modelled prior to all operations Significant physical separation between targets and overlying GAB aquifers (~500m+ thick Mt Toondina Formation & Stuart Range Formation between targets zones and the overlying GAB). Fracture height growth in shales in US is not more than 200 - 300m, this is re-enforced by height growth data from stimulation treatments completed in the Cooper Basin. Fracture height data show growth tends to be smaller at shallower depths. Fractures unlikely to propagate beyond the lower Mt Toondina Formation into the GAB due to stress contrast between these layers. Implementation of monitoring programs and fracture geometry diagnostic tools reviewed during site-specific assessments against the stated environmental objective aquifer impacts Additional consultation with both State and Federal Government Agencies is required within 5km trigger zones around springs.	Minor	Rare	Low
Leakage to GAB aquifers through geologic media	Contamination of aquifers Indirect adverse impacts to groundwater users	Target intervals separated from overlying GAB aquifers by approximately 500m of limited permeability Mt Toondina Formation and the upper Stuart Range Formation. Once on production, the pressure gradient underground will results fluids moving towards the well rather than migrating either upwards or laterally away from the fracture stimulation	Minor	Unlikely	Low

Risk Event / Hazard	Potential Environmental Impacts	Control Measures / Comment	Consequence	Likelihood	Residual Risk
Injection of fluid into Permian section	Impact on Permian aquifers potential	Water influx is detrimental to the success of an unconventional well, in the event significant flows are encountered from Permian aquifers the well will be shut in or decommissioned at completion of production testing.	Minor	Unlikely	Low
Lateral migration of injected fluid in the Permian section	Impact on Permian aquifers potential	Due to low permeability of the target formations, fracture stimulation fluid highly unlikely to migrate any significant distance beyond the stimulation treatment. Once on production, pressure gradient underground will result in fluids moving towards the well rather than migrating either upwards or laterally away from the fracture stimulation.	Minor	Unlikely	Low
Fracture propagation into Permian aquifers	Contamination of aquifers Indirect adverse impacts to groundwater users Cross flow between aquifers	Fracture design (including pressures, injection rate, fluid makeup and proppant concentration) undertaken to limit impact on Permian aquifers Fracture stimulation treatments modelled prior to all operations Implementation of fracture geometry diagnostic tools reviewed during site-specific assessments against the stated environmental objective aquifer impacts Due to the low permeability of target formations, fractures unlikely to propagate any significant distance beyond the stimulation treatment. Once on production, pressure gradient underground will result in fluids moving towards the well rather than migrating either upwards or laterally away from the fracture stimulation. Water influx is detrimental to the success of an unconventional well, in the event significant flows are encountered the well will be shut in or decommissioned at completion of production testing.	Minor	Unlikely	Low
Water supply / use	Drawdown of artesian and sub-artesian aquifers Adverse impact on groundwater users Impact on groundwater dependent ecosystems	Water extraction in compliance with licensing and water allocations where applicable. Water supply wells reviewed to ensure that their use does not impact adversely on existing users of groundwater. Relatively few water supply bores in the area and shallow aquifers are often unsuitable for stock or domestic use. Monitoring of water extraction volumes.	Minor	Possible	Medium

Risk Event / Hazard	Potential Environmental Impacts	Control Measures / Comment	Consequence	Likelihood	Residual Risk
Storage and handling of fuel, chemicals and fracturing / flowback fluids					
Leak of brackish or saline pre-stimulation water from holding ponds	Localised salinization of soil, surface water and groundwater Indirect impacts to flora and vegetation	Quality control on pond construction and liner installation to minimise risk of compromised liner integrity. Pond liners prevent pond wall erosion. Maximum pond fill level not exceeded (allow for rain events and wave effects). Ponds with above-ground walls / bunds to prevent surface runoff into ponds. Pond operation monitored (e.g. pond wall integrity) and repair undertaken if required. Adequate freeboard maintained (to allow for rain events and wave effects) and above-ground walls / bunds to prevent entry to surface runoff. Water balance method used for leak detection (incorporating inflow, evaporation, fluid levels and measurement uncertainty). No chemicals added to pre-stimulation water in ponds.	Minor	Unlikely	Low
Minor spill / leak from hazardous material storage and handling (e.g. several litres)	Localised contamination of soil, surface water and groundwater Access to contaminants by stock and wildlife Indirect impacts to flora and vegetation	Handling and storage in accordance with relevant International Standards Organisation standards, relevant SDS and State regulatory requirements, All bunded areas to comply with Australian Standard AS 1940, and EPA guideline 080/16 Bunding and Spill Management. Fracturing additives contained in units with appropriate secondary containment. Emergency/spill response procedures in place with immediate clean up and remediation of spills. Personnel trained in correct procedures for use of materials, including refuelling and clean-up procedures.	Minor	Unlikely	Low
Major spill / leak from hazardous material storage and handling (e.g. entire contents of refuelling tank)	Contamination of soil, surface water and groundwater Access to contaminants by stock and wildlife Indirect impacts to flora and vegetation	Bulk fuel storage with appropriate secondary containment system. Refuelling undertaken with appropriate drip capture systems. Suitable facilities present to contain potential spills when handling fuel and chemicals. Clean-up materials and wastes appropriately contained for off-site disposal to a licensed waste management facility. Clean up of large spills will be in accordance with the National Environmental Protection (Assessment of Site Contamination) Measure (1999) amended in 2013 and relevant SA EPA guidelines	Moderate	Unlikely	Medium

Risk Event / Hazard	Potential Environmental Impacts	Control Measures / Comment	Consequence	Likelihood	Residual Risk
Minor leak or spill to ground from surface handling / storage of flowback fluids	Localised contamination of soil and/or groundwater Access to spilt contaminants by stock and wildlife Indirect impacts to flora and vegetation	Routine inspections of flowback storage area and pipelines. High pressure stimulation equipment has valid certifications, is pressure tested once set-up (prior to commencement of stimulation) and trip systems prevent operation above design pressure limits. Flowback lines from the wellhead rated and pressure tested to appropriate pressure. Emergency shut-down system installed on well-head.	Minor	Unlikely	Low
Major leak or spill to ground from surface handling / storage of flowback fluids (e.g. pond wall failure)	Contamination of soil and/or groundwater Access to spilt contaminants by stock and wildlife Indirect impacts to flora and vegetation	Flowback fluids securely contained in ponds lined with UV stabilised material. Quality control on pond construction and liner installation to minimise risk of compromised liner integrity. Pond liners capable of withstanding expected operating conditions. Pond liners prevent pond wall erosion. Water balance method used for leak detection (incorporating inflow, evaporation, fluid levels and measurement uncertainty). Maximum pond fill level not exceeded (allow for rain events and wave effects). Bunded areas must have sufficient freeboard (e.g. to hold a 1:25 year, 24hr rainfall event) On flowback ponds will be filled to significantly less than capacity as flowback is expected to be 30 - 40% of initial clean water storage volume. Ponds with above-ground walls / bunds to prevent surface runoff into ponds. Pond operation monitored (e.g. pond wall integrity) and repair / remediation / decommissioning undertaken where appropriate (e.g. if leak evident, create drainage channel, recover fluid, repair or decommission pond). Spills / leaks cleaned up and remediated. Additional fencing installed where necessary to prevent stock access. Chemical utilisation during stimulation kept to the lowest possible to achieve necessary stimulation outcome. Lower toxicity chemicals investigated and used where practicable and suited to the stimulation design required. Note: Water table, where present, is generally not close to the surface and is expected to be predominantly saline, with very limited and scattered use of shallow unconfined groundwater. This further mitigates the level of risk. All bunded areas to comply with Australian Standard AS 1940, and EPA guideline 080/16 Bunding and Spill Management	Moderate	Unlikely	Medium

Risk Event / Hazard	Potential Environmental Impacts	Control Measures / Comment	Consequence	Likelihood	Residual Risk
Minor leak or spill of flowback fluids to surface water	Localised contamination of surface water Localised death or injury to aquatic fauna	Chemical utilisation during stimulation kept to the lowest possible to achieve necessary stimulation outcome. Lower toxicity chemical additives used where practicable and suited to the stimulation design required.	Minor	Unlikely	Low
Major leak or spill of flowback fluids to surface water (e.g. if pond fails and contents reach surface water or flood overtops ponds)	Contamination of surface water Death or injury to aquatic fauna	Many of the fracturing fluid additives are used or degraded in the reservoir and at surface in the flowback pond. Flowback fluid securely contained in lined ponds, as discussed above: ▪ Ponds lined with UV stabilised material ▪ Quality control during construction to minimise risk of compromise to integrity of liner ▪ Monitoring of pond operation (freeboard) to maintain pond integrity ▪ Spills / leaks cleaned up and remediated ▪ Ponds with above-ground walls / bunds to prevent surface runoff into ponds Water balance method used for leak detection (incorporating inflow, evaporation, fluid levels and measurement uncertainty). Bunded areas must have sufficient freeboard (e.g. to hold a 1:25 year, 24hr rainfall event) All bunded areas to comply with Australian Standard AS 1940, and EPA guideline 080/16 Bunding and Spill Management Adequate freeboard maintained (to allow for rain events and wave effects) and above-ground walls / bunds to prevent entry to surface runoff. Well sites and pond locations selected to ensure that the consequences of a potential pond failure are minimised (e.g. ponds would not be located in close proximity to significant watercourses such that failure would result in direct release to these watercourses). Well leases located on higher ground as far as practicable. Where well leases have potential for infrequent flooding, measures will be undertaken to ensure ponds are not vulnerable to flooding (e.g. ponds on higher ground, construction of higher pond walls, and removal of flowback fluids off-site either during testing or at completion of operations). Implementation of additional management measures as identified by site-specific assessments against the stated environmental objective to avoid surface water impacts.	Moderate	Unlikely	Medium

Risk Event / Hazard	Potential Environmental Impacts	Control Measures / Comment	Consequence	Likelihood	Residual Risk
Flooding of well leases during fracture stimulation operations	Contamination of surface water Death or injury to fauna	Well leases located on higher ground as far as practicable. Handling and storage in accordance with relevant International Standards Organisation standards, relevant SDS and State regulatory requirements). Emergency/spill response procedures in place with immediate clean up and remediation of spills. Measures discussed above implemented to ensure ponds are secure from flooding. Flowback fluids will be monitored closely where ponds are located in areas where there is any potential of flooding.	Moderate	Unlikely	Medium
Interaction of stock or native fauna with storage ponds	Death or injury of fauna or stock	Ponds securely fenced to exclude stock and large native fauna. Pond construction to minimise attractiveness to birds i.e. relatively steep sides and lined with suitable polyethylene material, with no 'beaches' or vegetation. Many of the fracturing fluid additives are biodegradable. Routine surveillance monitoring will be undertaken to detect incursions. Ongoing inspection and monitoring of ponds would detect fauna mortality (if it occurred). Bird deterrent measures will be introduced if bird mortality incidents are observed. Ponds will be temporary and will be rehabilitated following removal of liner.	Minor	Unlikely	Low
Personnel and third-party access to storage ponds	Injury / danger to health and safety of employees, contractors and possibly the public	Ponds securely fenced. Signage in place to warn of access restrictions. Access to sites restricted during operations. Sites will be attended by an operator during and after fracturing operations.	Moderate	Rare	Medium

Risk Event / Hazard	Potential Environmental Impacts	Control Measures / Comment	Consequence	Likelihood	Residual Risk
General issues					
Activity outside designated / approved areas	Damage to significant vegetation Degradation of fauna habitat Damage to cultural heritage sites	Activities confined to existing cleared areas (e.g. access roads, prepared well lease) within area subject to environmental assessment and Work Area Clearance for cultural heritage. Approved work areas and restricted areas clearly delineated on site. Training and induction for all personnel to educate them on the importance of remaining within designated / approved areas. If flora with significant conservation value is present in the vicinity of the well site, it will be flagged and/or fenced off where necessary to prevent disturbance. Cultural heritage sites or exclusion zones in the vicinity of the well site will be flagged and / or fenced off to prevent disturbance where necessary.	Minor	Unlikely	Low
Air emissions	Reduction in local air quality Generation of greenhouse gas emissions	Equipment operated and maintained in accordance with manufacturer specifications. Remote location of well sites. Fracturing would not be carried out in close proximity to William Creek or pastoral station residences. Note: Greenhouse gas emissions recorded and reported in accordance with NGER requirements.	Minor	Unlikely	Low
Noise emissions	Disturbance to native fauna Disturbance to local community	Equipment operated and maintained in accordance with manufacturer specifications. Remote location of well sites. Fracturing would not be carried out in close proximity to William Creek or pastoral station residences. Landowners notified of location of operations and appropriate consultation and mitigation measures implemented, if required, to ensure that no reasonable complaints are received.	Minor	Unlikely	Low

Risk Event / Hazard	Potential Environmental Impacts	Control Measures / Comment	Consequence	Likelihood	Residual Risk
Bushfire (resulting from activities)	Loss of vegetation and habitat Disturbance, injury or death of fauna Atmospheric pollution Damage to infrastructure Disruption to land use Danger to health and safety of employees, contractors and possibly the public	Activities undertaken on cleared well lease. Combustible materials cleared from area surrounding flare. Firefighting equipment available as appropriate for location and use. Fire and Emergency Services Act requirements will be complied with (e.g. permits for 'hot work' on total fire ban days).	Moderate	Rare	Medium
Seismicity	Ground disturbance	Low background seismic hazard and lack of major faulting in the central Boorthanna Trough. Micro-seismic monitoring may be used at some well locations as part of the resource assessment and will be available to delineate seismic response.	Negligible	Rare	Low
Radioactivity from Naturally Occurring Radioactive Materials (NORM) in flowback fluids	Danger to health and safety of employees, contractors and possibly the public Contamination of soil and/or groundwater Contamination of surface water resources	Flowback ponds polyethylene lined to prevent soil and groundwater contamination. Monitoring planned at current well sites and fracturing operations to confirm expectation that levels of radioactivity are within acceptable limits. Flowback monitored where radioactive proppant tracers are used to ensure radiation levels are well below and levels of concern If NORM above the natural background levels were to occur, appropriate measures for handling and disposal of pond liners and contents remaining after evaporation would be implemented.	Minor	Unlikely	Low
Light emissions	Disturbance to local community Disturbance to native fauna	Minimise lighting where possible.	Minor	Unlikely	Low
Use of roads; movement of heavy machinery and vehicles along roads and access tracks	Injury or death of stock or fauna Dust generation Noise generation Damage to third party infrastructure Degradation of public roads and tracks Disturbance to cultural heritage sites	Existing access roads, cleared well lease and turn-a-rounds used. Dust control measures (e.g. water spraying) implemented if dust generation becomes a problem e.g. near sensitive sites. Undertake vehicle and equipment washdown using a risk-based approach before entering the Arkaringa Basin or after operating in areas of weed infestations Speed restrictions and appropriate signage to reduce speed and increase awareness of hazards. Driver awareness training for all personnel. Traffic and journey management procedures followed.	Minor	Unlikely	Low
	Introduction and / or spread of weeds	Liaise with road authorities regarding arrangements and responsibilities for road maintenance and undertake maintenance where required.	Moderate	Rare	Medium
	Road hazard / disturbance to local road users		Major	Rare	Medium

Risk Event / Hazard	Potential Environmental Impacts	Control Measures / Comment	Consequence	Likelihood	Residual Risk
Storage of waste and transport to landfill	Localised contamination of soil, surface water and groundwater Damage to vegetation and habitat Attraction of scavenging animals (native / pest species) and access to contaminants by stock and wildlife Litter / loss of visual amenity	Waste generation minimised (e.g. reduce, reuse and recycle). Waste removed off-site and disposed of at appropriately licensed waste handling facility. High standards of 'housekeeping' implemented. Secure systems used for storage and transport of waste (e.g. covered bins in designated area for waste collection and storage prior to transport). Hazardous wastes handled in accordance with relevant legislation and standards. Licensed contractors used for waste transport.	Minor	Unlikely	Low

8 Environmental Management Framework

Fracture stimulation activities will be undertaken in accordance with SAPEX's Health, Safety and Environment Management System (HSEMS). The HSEMS is a key tool in the management of SAPEX and associated contractors' environmental responsibilities, issues and risks.

The HSEMS also provides a framework for the coordinated and consistent management of environmental issues by ensuring the:

- establishment of environmental policy
- identification of environmental risks and legal and other requirements relevant to the operations
- setting of appropriate environmental objectives and targets
- delineation of responsibilities
- establishment of a structure and program to implement environmental policy and achieve objectives and targets, including the development of procedures or guidelines for specific activities and education and induction programs
- facilitation of planning, control monitoring, corrective action, auditing and review of activities to ensure that the requirements and aspirations of the environmental policy are achieved.

Key components of the HSEMS are discussed in the following sections.

8.1 Environmental Objectives

Environmental objectives have been developed based on the information and issues identified in this document. These objectives have been designed to provide a clear guide for the management of environmental issues and are detailed in the accompanying Statement of Environmental Objectives.

8.2 Responsibilities

Environmental management and compliance will be the responsibility of all personnel. The indicative organisation and responsibilities for personnel overseeing environmental management are detailed in Table 9. The exact nature and title of these roles may vary and positions may be amalgamated or the responsibilities shared under a modified arrangement.

The overall responsibility for environmental compliance lies with SAPEX. SAPEX will maintain a high level of on-site supervision. The fracture stimulation contractor and individuals will also be responsible and accountable through their conditions of employment or contract. The training of all personnel will ensure that each individual is aware of their environmental responsibility.

Role	Responsibility
SAPEX Executive Management	Licence holders Hold overall responsibility for SAPEX activities and environmental management
SAPEX Project Manager	Responsible for co-ordinating the management of the activities, including all environmental aspects Responsible for overall implementation of EHS Responsible for the overseeing and fulfilling of commitments contained in EIR and SEO Overall responsibility for reporting on environmental performance and due diligence Co-ordinates environmental incident internal reporting and investigation Incident notification to Authorities
SAPEX Environment & Safety Personnel	Oversees EIR and SEO implementation Monitors the activities of construction contractors and assesses compliance with the SEO Coordinates the monitoring and audit program Environmental internal reporting and incident investigation

Role	Responsibility
SAPEX Site Representative	Directly responsible for on-site management, including all environmental aspects Responsible for the overseeing and fulfilling of commitments contained in EIR and SEO Reports to SAPEX Project Manager on environmental performance and due diligence Environmental internal reporting and incident investigation
Fracture stimulation contractor	Responsible for ensuring that works meet regulatory requirements and all environmental objectives contained in the SEO pertinent to the stimulation operations (e.g. not including sourcing water for stimulation, construction of lined ponds and flowback and testing operations) Directly responsible for the overseeing and fulfilling of commitments contained in relevant approvals, EIR and SEO Responsible for ensuring adequate resources are provided for constructing and maintaining environmental controls Inspection of work area to ensure appropriate environmental management Environmental internal reporting and incident investigation

Table 12: Indicative roles and responsibilities

8.3 Environmental Management Procedure

All SAPEX employees and contractors are responsible for ensuring compliance with the SAPEX Environmental Management Procedure (EMP) and associated environmental legislation. The EMP is comprised of a number of levels of documentation (including plans and procedures) that form the framework for the management of the environment in which SAPEX operates. The EMP covers all activities undertaken by SAPEX in Australia including exploration, drilling and well operations, and production.

SAPEX conducts periodic environmental audits to assess the appropriateness of the EMP to meeting SAPEX's policy, legislative requirements and environmental objective commitments and whether the EMP has been properly implemented and maintained.

8.4 Job Safety Analysis and Permit to Work

Job Safety Analysis (JSA) is a process used to identify hazards associated with a job, by assessing the risks and implementing control measures to ensure the job can be conducted in a safe manner. SAPEX conducts JSAs for tasks where a work procedure does not exist, where the task has not previously been conducted by the personnel assigned to the task, or where additional hazards are present.

8.5 Induction and Training

Prior to the start of field operations all field personnel will be required to undertake an environmental induction to ensure they understand their role in protecting the environment. This induction will be part of a general induction process which also includes safety procedures. Site specific environmental requirements will be documented in the work program or work instruction.

A record of induction and attendees will be maintained.

8.6 Emergency Response and Contingency Planning

In the course of normal operations, there is always the potential for environmental incidents and accidents to occur. To manage these incidents, emergency response plans will be developed to guide actions to be taken to minimise the impacts of accidents and incidents. Emergency response plans will be reviewed and updated on a regular basis to incorporate new information arising from any incidents, near misses and hazards and emergency response simulation training sessions. These plans will also include the facilitation of fire danger season restrictions and requirements.

Emergency response drills will also be undertaken at regular intervals to ensure that personnel are familiar with the plans and the types of emergencies to which it applies, and that there will be a rapid and effective response in the event of a real emergency occurring.

8.7 Environmental Monitoring and Audits

Ongoing monitoring and auditing of fracture stimulation operations will be undertaken to determine whether significant environmental risks are being managed, minimised and where reasonably possible, eliminated.

Monitoring programs where applicable will be designed to assess:

- compliance with regulatory requirements (particularly the Statement of Environmental Objectives)
- integrity of bunding and containment systems
- integrity of ponds and pond liners
- site contamination
- groundwater quality
- aquifer water level / aquifer pressure
- site revegetation following completion and any restoration
- potential future problems.

8.8 Incident Management, Recording and Corrective Actions

SAPEX and its contractors have a system in place to record environmental incidents, near misses and hazards, track the implementation and close out of corrective actions, and allow analysis of such incidents to identify areas requiring improvement. The system also provides a mechanism for recording 'reportable' incidents, as defined under the *Petroleum and Geothermal Energy Act 2000* and associated regulations.

8.9 Reporting

Internal and external reporting procedures will be implemented to ensure that environmental issues and / or incidents are appropriately responded to. A key component of the internal reporting will be contractors' progress and incident reports to SAPEX.

External reporting (e.g. incidents, annual reports) will be carried out in accordance with Petroleum and Geothermal Energy Act requirements and the SEO. Annual reports are available for public viewing on the DEM website.

9 Consultation

SAPEX will conduct targeted consultation with relevant interested parties during planning for fracture stimulation activities. This consultation will assist SAPEX in identifying potential impacts and the best form of mitigation or management measures.

SAPEX is committed to maintaining effective communication and good relations with all stakeholders.

9.1 Key Stakeholders

The following stakeholders have been identified as having a direct interest in SAPEX's activities in the Arckaringa Basin:

- State regulatory agencies
- Landholders
- Local government
- Native title / Aboriginal groups

Stakeholder consultation carried out for the development of this EIR is summarised in **Table 13**. Where future stakeholder consultation is planned but had not been undertaken at the time of writing, the entry has been left blank. A major part of the consultation is the public consultation process under the Petroleum and Geothermal Energy Act that is by DEM. The submissions received during the public consultation on the EIR and SEO are contained in Appendix 6 and Appendix 7, along with SAPEX's responses.

Organisation/Agency	Consultation Method(s)	Comment
Regulatory Authority		
Department for Energy and Mines (DEM)	Presentation at DEM Offices in Adelaide on 30 th October 2017	5 attendees. Draft EIR/SEO provided on 1 November 2017
South Australia Environment Protection Authority (EPA)	Presentation at DEM Offices in Adelaide on 30 th October 2017	2 attendees. Draft EIR/SEO provided on 1 November 2017
State Government Departments		
Department for Environment and Water (DEW)	Presentation at DEM Offices in Adelaide on 30 th October 2017	3 attendees. Draft EIR/SEO provided on 1 November 2017
	Discussion at DEM offices in Adelaide on 8 th August 2018	1 attendee from DEW. 3 Attendees from DEM.
Department for Transport, Energy & Infrastructure (DTEI)	Presentation at DEM Offices in Adelaide on 30 th October 2017	0 attendees. Draft EIR/SEO provided on 1 November 2017
South Australian Arid Lands Natural Resources Management Group	Board meeting at SAAL-NRM Offices in Port Augusta on 22 nd February 2018	13 attendees. Link to draft EIR/SEO provided
Safe Work SA	Contact made via Email 11 th October 2017 – No response	Draft EIR/SEO provided on 8 November 2017
Commonwealth Government		
Department of Defence	Meeting in Woomera with DOD personnel on 20 September 2017 Email follow up on the 4 th October 2017	Draft EIR/SEO provided on 29 November 2017
Local Government		
District Council of Coober Pedy	Community consultation session held at the council chambers on the 7 th March 2018. Presentation provided by Tri-Star and DEM	Approximately 50 attendees. Draft EIR/SEO provided to council on 29 November 2017
Heritage / Native Title		
The Arabana People's Native Title Group	Presentation in Port Augusta on 3 rd November 2017	11 attendees. Draft EIR/SEO provided on 6 th November 2017

Antakirinja Matu-Yankunytjajara People	Meeting in Adelaide with AMYAC on 17 th April 2018	AMYAC briefed on exploration plans within Arabana area
Other Stakeholders		
Wilderness Society	Meeting at Conservation SA office in Adelaide on 16 th January 2018	1 attendee. Draft EIR/SEO not provided. Access available during public consultation
Conservation SA	Meeting at Conservation SA office in Adelaide on 16 th January 2018	1 attendee. Draft EIR/SEO not provided. Access available during public consultation
South Australia Chambers of Mines and Energy (SACOME)	Meeting in Adelaide on 31 st November 2017	1 attendee. Draft EIR/SEO not provided
Cooper Pedy Community	Pop-up information booth set up in Cooper Pedy on the 17 th & 18 th April 2018	Booth manned by 4 Tri-Star personnel
Pastoral Interests		
Anna Creek Station	Meeting at Nilpinna Station with Williams Cattle Company on 31 st August 2017	Draft EIR/SEO provided on 9 th November 2017
Nilpinna Station	Meeting at Nilpinna Station with Williams Cattle Company on 31 st August 2017	Draft EIR/SEO provided on 9 th November 2017
Mount Barry Station	Meeting at Mt Barry Station with Williams Cattle Company on 19 th September 2017	Draft EIR/SEO provided on 9 th November 2017
Stuart Creek Station	Contact made via Email 11 th October 2017 – No response	Draft EIR/SEO provided on 8 November 2017
Billa Kalina Station	Contact made via Email 25 th September 2017 – request for meeting denied	Draft EIR/SEO provided on 9 th November 2017

Table 13: Table of Stakeholder consultation

9.2 Landholder Consultation

Landholders (land owners or occupiers) within the SAPEX PEL122 & PEL123 will be informed of the proposed exploration activities and the management of these activities will be discussed. Close liaison will be carried out with landholders directly affected by drilling activities to ensure that activities are planned and carried out to minimise impacts to land use activities. Land occupiers will be formally notified prior to entry for exploration activities in accordance with Petroleum Act requirements and SAPEX will continue to work closely with landholders throughout the duration of its exploration programs.

A list of landholders in PEL122 & PEL123 are provided in Appendix 4. These landholders were provided with an information pack prepared by SAPEX that explained the proposed stimulation activities and the draft EIR and SEO documents. Pastoralists in key areas (Mount Barry, Nilpinna & Anna Creek) were met with personally for additional discussion regarding the proposed program and application of fracture stimulation to target formations.

9.3 On-going Consultation

SAPEX aims to continue to engage stakeholders for the duration of its exploration activities to ensure that all potential concerns are identified and appropriately addressed. Stakeholder correspondence will be registered and documented to ensure that issues are appropriately addressed.

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11 Abbreviations

AARD	Department of Premier & Cabinet - Aboriginal Affairs & Reconciliation Division
ADG Code	Australian Dangerous Goods Code
ANZECC	Australian and New Zealand Environment and Conservation Council
AS 1940	Australian Standard AS 1940 <i>Storage and Handling of Flammable and Combustible Liquids</i>
atm	Atmosphere (unit of pressure); 1atm = 101.325kPa = 101325Pa = 1.01325bar = 14.69595psi)
bar	Unit of pressure (1bar = 100kPa = 14.50377psi)
bbl	Barrels (1 bbl = 159 litres)
BDBSA	Biological Databases of South Australia
BOM	Bureau of Meteorology
BTEX	Benzene, toluene, ethylbenzene, xylene
CSG	Coal seam gas
°C	Degrees Centigrade
DEH	Department for Environment and Heritage (South Australia) [replaced by DEWNR]
DEE	Department of the Environment and Energy
DEM	Department for Energy and Mines (Formerly DPC–ERD)
DESWPC	Department of Sustainability, Environment, Water, Population and Communities
DEWNR	Department of Environment, Water and Natural Resources [formerly DWLBC and DEH]
DEW	Department for Environment and Water (Formerly DEWNR)
DFW	Department for Water (South Australia) (part of DEW as of 1 July 2012)
DPC – ERD	Department of the Premier and Cabinet, Energy Resources Division [formerly DMITRE]
DPTI	Department of Planning, Transport and Infrastructure (South Australia) [formerly DTEI]
DTEI	Department of Transport, Energy and Infrastructure (South Australia) [replaced by DPTI]
DWLBC	Department of Water, Land & Biodiversity Conservation (South Australia) [replaced by DEWNR]
EIR	Environmental Impact Report prepared in accordance with Section 97 of the South Australian <i>Petroleum and Geothermal Energy Act 2000</i> and Regulation 10.
EMS	Environmental Management System
EPA	Environment Protection Authority (South Australia)
EPBC Act	<i>Environment Protection and Biodiversity Conservation Act 1999</i> (Commonwealth)
Far North PWA	<i>Far North Prescribed Well Are Water Allocation Plan</i>
GAB	Great Artesian Basin
GIS	Geographic Information System
GL	Gigalitre (10 ⁹ litres)
h	hours
ha	hectares
kg	kilogram

kL	kilolitre (10 ³ litres)
km	kilometre
kPa	Kilopascal (1000Pa = 1kPa)
L	litre
LPG	Liquefied Petroleum Gas
m	metre
m ³	cubic metre (= 10 ³ litres or one kilolitre)
mg	milligram
ML	megalitre (10 ⁶ litres)
mPa	Megapascal (1,000,000Pa = 1000kPa = 10bar)
MNES	Matter of National Environmental Significance
Native Vegetation Council	A council established under the South Australian Native Vegetation Act 1991 to assess vegetation clearance applications.
NEPM	National Environmental Protection (Assessment of Site Contamination) Measures 2013
NGER Act	<i>National Greenhouse and Energy Reporting Act 2007 (Commonwealth)</i>
NGERS	National Greenhouse and Energy Reporting System
NORM	Naturally Occurring Radioactive Materials
NPW Act	<i>National Parks and Wildlife Act 1972 (South Australia)</i>
Pa	Pascal (measure of pressure; 1psi = 1.450377×10 ⁻⁴ Pa)
PAH	Polycyclic Aromatic Hydrocarbon
Permian	geological age term
PEL	Petroleum Exploration Licence
PIRSA	Department of Primary Industries and Regions SA [formerly Department of Primary Industries and Resources, South Australia [replaced by DMITRE]]
PFW	Produced Formation Water (also known as co-produced water)
ppm	Parts per million
psi	pounds per square inch (1psi = 6.8948kpa)
Ramsar wetland	A Wetland of International Importance listed under the Ramsar Convention (held in Ramsar, Iran 1971).
RNE	Register of the National Estate
s	seconds
SCB	Soil Conservation Board
SEB	Significant Environmental Benefit
SEO	Statement of Environmental Objectives

12 Glossary

Acidising – treatment of oil-bearing limestone or carbonate formations with a solution of hydrochloric acid or other chemicals to increase production. The acid is forced under pressure into the formation where it enlarges the flow channels by dissolving the limestone.

Aeolian – Carried, deposited by the wind.

Aquitard – A bed of low permeability adjacent to an aquifer.

Basin centred gas – Regionally pervasive gas accumulation in the centre of a hydrocarbon-rich basin that exhibits low permeability, abnormal pressure and gas saturation.

Biocide – Chemical compound that can kill living organisms (typically targeted at microorganisms).

Blow-out or Kickback – when well pressure exceeds the ability of the wellhead valves to control it. Oil or gas flow freely at the surface.

Borehole – a narrow shaft bored into the ground.

Borrow pit – Surface excavation for the extraction of materials such as sand or clay.

Bund – An earth, rock or concrete wall constructed to prevent the inflow or outflow of liquids.

Casing annulus – Space between the casing and any piping, tubing or casing surrounding it.

Casing Strings – steel tubing that lines a well after it has been drilled. It is formed from sections of steel tube that have been screwed together. A long section of connected oilfield pipe that is lowered into a wellbore and cemented into place.

Cement bond log – The output from an acoustic tool that is lowered down an oil or gas well to evaluate the integrity of the bond of the cement to the casing and formation.

Coiled tubing – A long, continuous length of pipe wound on a spool. The pipe is straightened prior to pushing into a wellbore and rewound to coil the pipe back onto the transport and storage spool.

Coiled tubing unit – The package of equipment required to run a coiled tubing operation. Basic components include the coiled tubing reel to store and transport the coiled tubing string, the injector head to provide the tractive effort to run and retrieve the coiled tubing string, the control cabin and the power pack that generates the power required by the other components.

Continuous play – a gas reservoir where the reservoir rock is charged with gas everywhere, rather than being concentrated in conventional traps.

Conventional gas – natural gas trapped in underground structures in highly permeable sandstones.

Coring – The process of cutting out a long cylindrical section of rock, known as a core sample or core, from a geological formation by core drilling.

Drill Pipe – lengths of steel pipe screwed together to form a continuous pipe extending from the drilling rig to the drilling bit at the bottom of the hole. Rotation of the drill pipe and bit causes the bit to bore through the rock.

Drill Stem Tests – conventional method of testing a formation to determine potential productivity before installing production casing in a well. A testing tool is attached to the bottom of the drill pipe and placed opposite the formation to be tested which has been isolated by placing packers above and below the formation. Fluids in the formation are allowed to flow up through the drill pipe by establishing an open connection between the formation and the surface.

Ephemeral – Existing for only a short time, often dependent upon climatic influences.

Flowback – Fluids that are injected during fracture stimulation and flow back up the well from the reservoir to the surface after the pressure is released.

Forb – A herbaceous flowering plant (not including grasses, sedges or rushes).

Fracturing fluids – The mixture of water and additives injected into a well during fracture stimulation.

Gathering line – A pipeline used to relay fluids such as raw gas, condensate or oil from a well to a processing plant.

Gibber – Small to medium weathered rounded stones that form a relatively flat extensive pavements on plains and gentle slopes. The narrow spaces between stones have soil infill. The stones are concentrated on the surface by their gradual downward movement as the soil that once separated them in the vertical dimension has been removed by wind and gentle water erosion.

Lithology – Description of the physical characteristics of a rock such as colour, texture, grain size or composition.

Microseismic monitoring – The passive observation of very small-scale seismic events which occur in the ground as a result of human activities or industrial processes such as mining, oil and gas production, enhanced geothermal operations or underground gas storage.

Overpressure – Subsurface pressure that is abnormally high, exceeding hydrostatic pressure at a given depth.

Perforating – The process of punching holes in the casing or liner of an oil or gas well to connect it to the reservoir.

Permeability – A measure of the ease of flow of fluids through a rock.

Porosity – A porous medium (such as rock or sediment) describes the fraction of void space in the material, where the void may contain, for example, air, water or hydrocarbons.

Production Casing – steel pipe threaded together and cemented into a well to prevent the wall of the hole from collapsing and to provide a means of extracting oil/gas from the well.

Produced Formation Water (PFW) – water associated with oil and gas reservoirs that is produced along with the oil and gas.

Production Fluid – The mixture of oil, gas and water that flows to the surface of an oil or gas well from a reservoir.

Proppant – Particles (e.g. sand grains, resin-coated sand or high-strength ceramic material) mixed with fracturing fluid to hold fractures open after a fracture stimulation treatment.

Ramsar wetland – A Wetland of International Importance listed under the Ramsar Convention (held in Ramsar, Iran 1971).

Ripping – The use of machinery to rake or shallow plough soil to relieve compaction and aerate soil.

Stimulation – Fracture stimulation of a well, which involves pumping fluid, largely water, to create or enhance fractures in the rock and increase permeability in the reservoir.

Stratigraphy – The study of rock layers and layering (stratification)

Tectonic – Relating to, causing, or resulting from structural deformation of the earth's crust.

Tight gas – Natural gas which is difficult to access because of the low permeability of the rock containing the gas.

Tiltmeter – An instrument used to measure slight changes in the inclination of the earth's surface.

Unconventional gas – Natural gas that is trapped in lower permeability reservoirs, rather than on underground structures such as anticlines and highly permeable sandstones.

Viscosifiers - An additive that increases the viscosity of a fluid. Viscosity of a fluid is its resistance to flow, or in everyday terms, its “thickness”.

Well Head – The part of an oil or gas well which terminates at the surface, where oil or gas can be withdrawn. Steel equipment installed at the surface of the well containing an assembly of heavy-duty hangers and seals. The wellhead is used to support the weight of the casing strings hung from it and to contain the well pressure.

Wireline unit – The equipment used to lower a wire or cable into an oil or gas well to conduct operations in the well.

Zone – An interval or unit of rock differentiated from surrounding rocks on the basis of its fossil content or other features, such as faults or fractures. Often used to describe a layer of reservoir rock that contains oil or gas.

Appendix 1:

Land Systems in PEL 122 and 123

Land Systems in PEL122 and PEL123

This document provides a detailed description of the land systems in PEL122 and PEL123 that are briefly discussed in the EIR. The descriptions are taken from land system descriptions in relevant Soil Conservation Board District Plans.

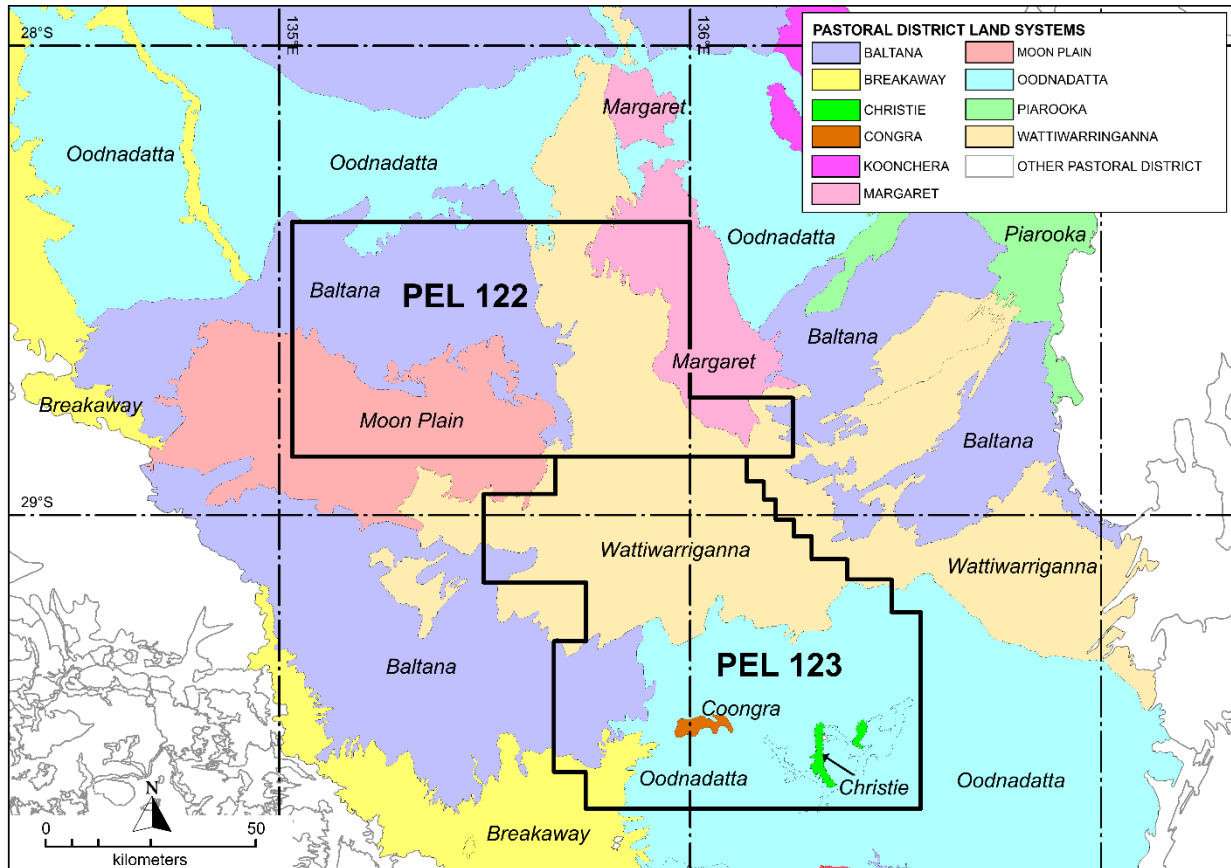


Table A1: Land system summary

Name	Dominant landforms	IBRA Region	
		Stony Plains	Simpson Strzelecki Dunefields
Baltana	Stony plain, drainage lines/watercourses	X	
Breakaway	Breakaways and stony hills, drainage lines/watercourses	X	
Christie	Stony plain	X	
Coongra	Stony plain, stony hills, drainage lines/watercourses	X	
Moon Plain	Moon plain, drainage lines/watercourses	X	
Margaret	Ranges, tableland, stony plain (footslopes)	X	
Oodnadatta	Stony plain, drainage lines/watercourses, stony hills	X	
Wattiwarriganna	Dunes, swales, drainage lines/watercourses, GAB springs		X

General Land System Descriptions from SCB District Plans⁵

Baltana Land System

The Baltana land system occupies a large area to the east and south of the Stuart Range on McDouall Peak station. It also occurs on Billa Kalina Station.

This land system has formed where erosion of the silcrete capping has exposed the softer Bulldog Shale which has mixed with alluvium from the ranges. This has resulted in the formation of extensive undulating plains with numerous gilgais and some areas of sandsheet. This is known locally as "moon" or "loomy" country. It has distinct similarities with the nearby Oodnadatta land system. Soils, which include silts, sands and grey clays, are covered with a lag of silcrete and quartzite gibbers. The soils comprise brown saline clay which separates it from the softer grey clays of the Moon Plain land system.

No perennial species truly dominate the vegetation on plains and there are often large bare areas, which support ephemeral species following rain, between patches of perennial vegetation. The dominant plant species on the plains are Oodnadatta saltbush, bladder saltbush, neverfail, Mitchell grasses, Flinders grass, button grass, Cooper clover, pale poverty-bush, tangled poverty-bush and samphires (glassworts).

Creeks and watercourses have alluvial sand and cracking clay soils and contain large amounts of shales and gypsum and support very little vegetation. Prickly wattle is the dominant species in the creeks with coolibah, cottonbush and silky browntop also common. Verbena and Cooper clover grow following good rains. Old man saltbush occurs in swamps and some creeks.

Plains, watercourses and run-on flats are all dominated by chenopod low shrublands. Bladder saltbush, woolly bluebush, barley Mitchell grass, neverfail and pale poverty-bush are common on plains with brown clay or silty soils. Watercourses with brown cracking clays and alluvial sands support cottonbush and showy groundsel. Run-on flats have saline grey-brown clays and are characterised by black bluebush, cottonbush, samphire, showy groundsel and swamp canegrass, with barley Mitchell grass and neverfail occurring where gilgais are present.

Sandsheets have formed in some areas from residual yellow sands deposited on the underlying gibber plain. These areas support low open shrublands with Sturt's pigface prominent in the vegetation. Elegant wattle (prickly wattle) and bladder saltbush also occur here.

Breakaway

This land system has formed from an eroding basement of Bulldog Shale. Eroding shales and silcretes have resulted in mixtures of silcrete gibber, grey shales and other variously coloured hard and soft shales. The various colours result from the amount of leaching of iron from the shales, with red coloured shales containing more iron and paler ones containing less.

Vegetation of all land units except broad watercourses is dominated by chenopod low shrubland. Tall shrublands of bastard mulga, mulga, northern myall and emubushes are also common. Clay soils over silicified shales of tablelands and low hills are dominated by bladder saltbush, low bluebush and three-winged bluebush, sometimes with mulga and sennas. Vegetation of footslopes also includes bristly sea-heath and samphires, reflecting the more saline nature of the soils, and has fewer trees and tall shrubs.

Solonized red duplex soils of plains support bladder saltbush, low bluebush, samphire and bristly sea-heath, but also have barley Mitchell grass in the gilgais. Alluvial soils of smaller watercourses support bladder saltbush, cottonbush, spiny saltbush, round-leaf emubush, native apricot and showy groundsel. Larger watercourses have mulga or coolibah woodland, with marpoo and bullock bush also present.

⁵ Information taken from the Kingoonya, Marla - Oodnadatta and Marree Soil Conservation Boards' District Plans.

Christie Land System

The Christie land system is an ancient system formed from granitic and gneissic rocks as well as quartz bedrock and silcrete, with silcrete often present on hilltops. It has very limited occurrence in the PELs (south-eastern corner of PEL 123) and is widespread in the western half of the Kingoonya SCB district.

Mulga scrub dominates on shallow stony sandy loams and stony earthy sands on outwash slopes. Tall shrublands of crimson turkey-bush, green turkey-bush, round-leaf emubush, three-wing bluebush and cassias are also present, often with an understorey of perennial grasses including woollybutt and bandicoot grass. Chenopod low shrublands dominate three land units within this land system; silcrete rises with shallow stony sandy loams, silcrete rises with shallow calcareous loams, and valley plains with sandy earth soils. Bladder saltbush and low bluebush are common in all three of these units, with black bluebush joining them on valley plains. Round-leaf emubush and cassias occur in both units featuring silcrete rises, with pearl bluebush present on calcareous soils, and three-wing bluebush and silky bluebush present on non-calcareous soils. Mulga scrub is also found on shallow alluvial sands of watercourses, with dead finish and spiny saltbush.

Coongra

This land system consists of vast sandstone and shale covered slopes, plateaus and plains dominated by bladder saltbush. Undulating stony tablelands with gilgais are dissected by an extensive drainage system although much of the initial drainage is into gilgais. Stones are rounded or angular and range in size from 3 to 30cm in diameter and these form an erosion resistant layer unless they are disturbed.

The slopes are treeless except for the occasional rock emubush tall shrubs. Sparse mulga occurs along shallow creek lines, with this species accompanied or replaced by gidgea on the eastern side of the land system. Coolibahs occur with river red gums along the larger watercourses, often with an understorey of Australian cupgrass.

On the tableland's bladder saltbush grows in association with the perennial grasses like the Mitchell grasses, native millet, katoora, the perennial shrub bristly sea-heath and occasional rock everlastings. Understorey plants include mulga grass, bottlewashers and bogan flea. The majority of perennial plants growing here are the same as those growing on the Oodnadatta land system, with the major difference being that Oodnadatta saltbush is uncommon in the Coongra land system and is a dominant plant in the Oodnadatta land system.

After rain, the Coongra land system is very productive, growing a wide variety of annual, ephemeral and short-lived perennials, even in dry times. This system is relatively productive due to its perennial plant component.

Moon Plain

This land system occurs north-west of Coober Pedy. Its dominant feature is an undulating plain with soft grey cracking gypseous clay soils which generally lack any cover of gibber or other stones. This soil type separates it from the heavier brown clays of the Baltana land system, which it abuts to the west, south and east. The Moon Plain has little drainage and becomes very boggy after rain. However, two major drainage lines run through this system and provide drainage following very heavy rain. They also provide a habitat for the majority of perennial shrubs found in this land system.

The Moon Plain has very little plant cover in most years, with only a few perennial species present. Mitchell grasses and neverfail are two of the few perennial grasses found on the Plain, together with annual and pop saltbushes, mulka grass, pale poverty-bush, tangled poverty-bush, Blacks copperburr and buckbush.

Several species of samphire are common in the drainage lines, along with prickly wattle, old man saltbush, lignum, swamp canegrass and a few stunted coolibahs. Annual saltbush, pop saltbush, limestone bottlewashers, Darling pea, mulka grass, buckbush and various copperburr's also occur. Numerous ephemerals, including Cooper clover, flourish after good soaking rains of more than 50mm.

Margaret

This is a small land system located 100 km west of Lake Eyre North. It consists of rugged ranges with deep gorges, a deeply dissected plateau on top of the range, and long-lasting rock holes. The slopes of

the range are rough and rocky. These ranges were once part of an inland sea and tidal ripple marks can be seen on rocks at the top of the range. The stripping process of the ancient soils is far more advanced here than in the Breakaway land system, although residual formations of up to 50 m or more above the level of the surrounding Oodnadatta land system are present. Soils may be up to several metres in depth.

The footslopes of this land system can be separated from the adjoining Oodnadatta land system by the presence of ferruginous rather than quartzite gibbers in the Margaret land system.

The upper parts of creeks which begin in the ranges support the northern form of the river red gum, but this tree is replaced by coolibah when the creeks leave the ranges and become wider and the soils are sandier. The creeks also support dead finish and chenopod shrubs and perennial grasses which include lemon-scented grass, cotton grass and swamp wanderrie, often on skeletal rocky soils. The steep rocky gorges at the head of many of the creeks support mountain wanderrie and spinifex on shallower soils.

An undulating gibber tableland occurs on top of the range, with clay soils and numerous deep drainage lines. This tableland is covered with bladder saltbush, short-winged copperburr, salt copperburr and Mitchell grasses and is similar to the Oodnadatta land system, but lacks the Oodnadatta saltbush.

Steep hill slopes support a tall open shrubland of bastard mulga, mulga, emubushes, sennas, silver tails and perennial sunray, with other daisies, paper daisies and mulga grass. The lower undulating footslopes surrounding the ranges contain gilgais and support numerous chenopods (dominated by Oodnadatta saltbush), mulga grass, Mitchell grasses and other vegetation similar to the Oodnadatta land system.

Oodnadatta

The Oodnadatta land system is the largest and most extensive land system found in the Marla - Oodnadatta Soil Conservation District. This extremely extensive land system extends from Dalhousie southward along the western side of Lake Eyre and into the south-west of the Marree SCD.

This land system is comprised of extensive undulating plains with a lag of silcrete and quartzite gibbers with numerous gilgais and occasional plateaus. It has an extensive drainage system with large braided creeks such as the Neales and Arckaringa Creek.

As for similar tableland land systems, the major soils are the duplex loams over clays of the gibber "shelf" areas, and the self-mulching clays of the gibber-free gilgais. Gibber soils are saline and dispersive, being either deep red clays or clay loams. Much of the soil salinity is now thought to have arisen through vertical leakage at the margins of the Great Artesian Basin, which this land system follows. Gilgais have much lower salinity. Gibber cover may be derived from silcrete or gypcrete, and there are areas with a very high gypseous content south of Lake Eyre South

Gilgais are the most productive component of this land system due to the combination of water run-on from shelves, cracking clays which do not seal until much of the profile has been wetted and the lower salinity. They are able to trap water run-off from the impervious stony flats which surround them. This water is then retained for extended periods by the clayey soil. Gilgais vary in size from only a few metres to approximately 10 metres in diameter and may be irregular in shape. The densest vegetation occurs in gilgais and on gilgai fringes or along watercourses. The stony shelves between the gilgais are often bare or covered only with a few bindyis or sparsely distributed samphire.

Gilgais support perennial low shrubs, Oodnadatta saltbush and / or samphire depending on salinity, and perennial grasses particularly native millet, barley Mitchell grass and katoora. Other common species include fairy grass, neverfail, plains lantern-bush, five-minute grass, bladder saltbush and occasionally cottonbush. The irrigation from adjoining shelves results in dense growth of ephemerals after rain, particularly windmill grasses, Australian cup-grass, Flinders grasses and bottlewasher. The edges of gilgais support perennial shrubs such as bladder saltbush and bristly seaheath. Trees and tall shrubs are usually absent, whether because of limited water storage, salinity or excessive gypsum at depth.

Predominantly perennial plants such as bladder saltbush, katoora, neverfail, bristly sea-heath and rock everlasting grow on the less productive gilgai fringes. A sparse scattering of ephemeral herbs and forbs occur after winter rainfall.

Gibber areas between gilgais are by comparison almost unvegetated. Ephemerals appear after major rains which are sufficiently heavy to leach salts out of the upper soil profile. Such rains have to be major and prolonged, since the gibber soil surface seals rapidly when wet and most water runs off into gilgais.

Low hills and escarpments, (jump-ups) have gypseous clay loam soils, without gilgai formation. Bladder saltbush, low bluebush, black bluebush, harlequin fuchsia-bush typically occur. Annual species include Tate's bindyi, spear grass, kerosene / mulga grass, and common and jointed bottlewasher.

Gidgee is common along creek lines in northern parts of the land system and mulga grows along creek lines throughout the land system. Coolibah grows along the larger watercourses, sometimes in association with river red gums.

Alluvial soils of watercourses support coolibah, river red gum, Broughton willow, prickly wattle and gidgea, and mineritchie in the north of the District. The shrub layer is dominated by old man saltbush, cottonbush and lignum with an understorey of grasses which may include swamp canegrass, neverfail, Mitchell grasses, silky brown tops, and perennial cupgrass. Cooper clover and verbine are common in wet seasons. The sandy floodouts adjacent to the creek support gidgea, coolibah and Mitchell grasses. Claypans with heavy brown clays are generally bare other than at their margins.

Numerous mound springs occur in this land system. Springs vary from active with visible flows to extinct and include the whole range between the two extremes. Mound springs often support dense grasslands of common reed when they are not subject to persistent grazing. Prolonged grazing removes the common reed and the more resilient but much smaller bore-drain sedge replaces it.

Wattiwarriganna

The Wattiwarriganna land system is formed from a series of large parallel sand ridges overlying an older gibber plain, with swales usually containing a gibber pavement. Dunes are generally from 100 m to 500 m apart and up to 10 m in height.

The quartzite and silcrete gibbers are gravel rather than scree size because they have been sorted as they travelled further from their source. Numerous large watercourses dissect the land system. Dunes usually have deep red sandy soils, although dunes in this land system on Billa Kalina Station are generally paler. Sandy or clay-loam soils occur in the swales, which are generally flat, but may contain low sandy or calcareous clay rises. The swamps have brown clay, or cracking grey or brown clay, or yellow or red sandyloam soils. Numerous large watercourses dissect the land system.

Vegetation of the dunes is dominated by a hummock grassland of sandhill canegrass or a tall shrubland of horse mulga. Marpoo occurs in isolated stands and narrow-leaved hopbush is also moderately common. Few understorey species grow under or near these two shrubs. Silver needlebush also occurs as scattered plants and mulga occurs on some dune footslopes. The understorey includes tall kerosene grass, buckbush and cattle bush.

Interdune corridors include both sandy flats and claypans. Sandy flats support low shrublands of Sturts pigface, cottonbush, low bluebush, bladder saltbush, emubushes, sennas and neverfail, with mulga grass dominant in the understorey. Some claypans support swamp canegrass, old man saltbush, cottonbush, neverfail and lignum. Blue rod is common at claypan margins.

Larger watercourses are usually lined with coolibah, with marpoo, old man saltbush, cottonbush, sennas, samphire, neverfail, cupgrasses, silky browntop and swamp canegrass all present in the understorey. Cane-grass (swamp cane-grass) is common at some swamps and claypans. Swamps have similar understorey vegetation to watercourses but usually lack the associated riparian woodlands.

Several mound springs occur within this land system and support their characteristic vegetation including common reed, bore-drain sedge, cutting grass, bare twig rush, sea rush and salt couch.

Appendix 2:

Rare or Threatened Species Recorded in PELs 122 and 123

Rare or Threatened Species Recorded in PELs 122 and 123

A search of the Commonwealth Environment Protection and Biodiversity Conservation (EPBC) online database (DEE 2017) and the South Australian Department of Environment, Water and Natural Resources (DEW) Biological Databases of South Australia (DEW 2017) has identified the following rare or threatened flora and fauna species as being recorded or predicted to occur in, or within 20 km of, PEL 122 and 123.

Where an entry in the table is based on a predicted occurrence in the EPBC database rather than an actual record, it has been marked with an asterisk (*).

Table A2: Rare or Threatened Species in PELs 122 and 123

Species Name	Common Name	Conservation Status	
		C'with (EPBC)	SA (NPW Act)
Mammals			
<i>Dasyurus cristicauda</i>	Crest-tailed Mulgara (Ampurta)	Vulnerable	
<i>Petrogale lateralis</i> (McDonnell Ranges race)	Black-footed Rock-wallaby	Vulnerable	Endangered
<i>Pseudomys australis</i>	Plains mouse	Vulnerable	Vulnerable
<i>Taphozous hilli</i>	Hill's Sheath-tailed Bat		Rare
<i>Trichosurus vulpecula</i>	Common Brushtail Possum		Rare
Reptiles			
<i>Aspidites ramsayi</i>	Woma		Rare
<i>Ophidiocephalus taeniatus</i>	Bronzeback Legless Lizard	Vulnerable	Rare
Birds			
<i>Actitis hypoleucos</i>	Common Sandpiper		Rare
<i>Amytornis modestus</i>	Thick-billed Grasswren	Vulnerable	
<i>Anas rhynchotis</i>	Australasian Shoveler		Rare
<i>Aphelocephala pectoralis</i>	Chestnut-breasted Whiteface		Rare
<i>Ardeotis australis</i>	Australian Bustard		Vulnerable
<i>Biziura lobata</i>	Musk Duck		Rare
<i>Burhinus grallarius</i>	Bush Stonecurlew		Rare
<i>Calidris ferruginea</i>	Curlew Sandpiper	Critically endangered	
<i>Calidris melanotos</i>	Pectoral Sandpiper		Rare
<i>Charadrius mongolus</i>	Lesser Sand Plover	Endangered	Rare
<i>Cladorhynchus leucocephalus</i>	Banded Stilt		Vulnerable
<i>Elanus scriptus</i>	Letter-winged Kite		Rare
<i>Epthianura crocea</i>	Yellow Chat		Endangered
<i>Falco hypoleucos</i>	Grey Falcon		Rare
<i>Falco peregrinus</i>	Peregrine Falcon		Rare
<i>Grus rubicunda</i>	Brolga		Vulnerable
<i>Hamirostra melanosternon</i>	Black-breasted Buzzard		Rare
<i>Neophema chrysostoma</i>	Blue-winged Parrot		Vulnerable

Species Name	Common Name	Conservation Status	
		C'wlth (EPBC)	SA (NPW Act)
<i>Numenius phaeopus</i>	Whimbrel		Rare
<i>Pedionomus torquatus</i> *	Plains-wanderer	Critically endangered	Endangered
<i>Pezoporus occidentalis</i> *	Night Parrot	Endangered	Endangered
<i>Phaps histrionica</i>	Flock Bronzewing		Rare
<i>Phaps histrionica</i>	Flock Bronzewing		Rare
<i>Plegadis falcinellus</i>	Glossy Ibis		Rare
<i>Porzana tabuensis</i>	Spotless Crake		Rare
<i>Porzana tabuensis</i>	Spotless Crake		Rare
<i>Stictonetta naevosa</i>	Freckled Duck		Vulnerable
<i>Tringa glareola</i>	Wood Sandpiper		Rare
<i>Xenus cinereus</i>	Terek Sandpiper		Rare
Flora			
<i>Althaea australis</i>	Australian Mallow		Vulnerable
<i>Aristida arida</i>			Rare
<i>Atriplex eichleri</i>	Eichler's Saltbush		Rare
<i>Atriplex humifusa</i>			Vulnerable
<i>Atriplex morrisii</i>			Vulnerable
<i>Austrostipa nullanulla</i>	Club Spear-grass		Vulnerable
<i>Austrostipa vickeryana</i>	Vickery's Spear-grass		Rare
<i>Bergia occulpetala</i>			Vulnerable
<i>Brachyscome eriogona</i>			Rare
<i>Calocephalus sonderi</i>	Pale Beauty-heads		Rare
<i>Cyperus dactyloides</i>			Vulnerable
<i>Eleocharis papillosa</i>	Dwarf Desert Spike-rush	Vulnerable	Rare
<i>Eleocharis plana</i>	Flat Spike-rush		Rare
<i>Embadium johnstonii</i>	Johnston's Slipper-plant		Rare
<i>Embadium stagnense</i>	Arcoona Slipper-plant		Rare
<i>Eragrostis lacunaria</i>	Purple Love-grass		Rare
<i>Eremophila pentaptera</i>			Rare
<i>Eryngium vesiculosum</i>	Prostrate Blue Devil		Rare
<i>Frankenia cinerea</i>			Rare
<i>Frankenia cupularis</i>			Rare
<i>Frankenia plicata</i>		Endangered	Vulnerable
<i>Gilesia biniflora</i>	Western Tar-vine		Rare
<i>Goodenia anfracta</i>			Rare
<i>Goodenia chambersii</i>			Rare
<i>Goodenia valdentata</i>	Davenport Range Goodenia		Rare
<i>Hemichroa mesembryanthema</i>	Pigface Hemichroa		Vulnerable
<i>Maireana melanocarpa</i>	Black-fruit Bluebush		Rare
<i>Nicotiana truncata</i>			Rare

Species Name	Common Name	Conservation Status	
		C'wlth (EPBC)	SA (NPW Act)
<i>Ophioglossum polyphyllum</i>	Large Adder's-tongue		Rare
<i>Orobanche cernua</i> var. <i>australiana</i>	Australian Broomrape		Rare
<i>Osteocarpum acropterum</i> var. <i>deminutum</i>	Wingless Bonefruit		Rare
<i>Poa fax</i>	Scaly Poa		Rare
<i>Ptilotus barkeri</i>	Barker's Mulla		Rare
<i>Santalum spicatum</i>	Sandalwood		Vulnerable
<i>Sclerolaena blackiana</i>	Black's Bindyi		Rare
<i>Senecio gypsicola</i>	Gypsum Groundsel		Rare
<i>Stemodia</i> sp. <i>haegii</i> (J.Z.Weber 9055)	Haegi's Stemodia		Rare
<i>Swainsona minutiflora</i>	Small-flower Swainson-pea		Vulnerable
<i>Swainsona oligophylla</i>			Rare
<i>Tecticornia cupuliformis</i>			Vulnerable
<i>Wurmbea nilpinna</i>			Vulnerable
<i>Wurmbea stellata</i>	Star Nancy		Rare
<i>Zygophyllum crassissimum</i>	Thick Twinleaf		Rare
<i>Zygophyllum humillimum</i>	Small-fruit Twinleaf		Rare
<i>Zygophyllum hybridum</i>			Rare

* indicates that a species was predicted to occur by the EPBC Protected Matters Search Tool but has not actually been recorded in PELs

References

DEE (2017). EPBC Act Protected Matters Search Tool. <http://www.environment.gov.au/epbc/protected-matters-search-tool>. Department of the Environment and Energy, Canberra. Searched November 2017.

DEWNR (2017). Biological Databases of South Australia (BDBSA). Department for Environment, Water and Natural Resources. Data extracted November 2017. Recordset number DEWNRBDBSA171108-1.

Appendix 3:

Priority Plant Species

Priority Plant Species

Petroleum exploration activities often require the clearance of vegetation to facilitate access to areas of interest. Where possible the clearance of vegetation is avoided, however when clearance is required it is important that steps be taken to minimise the clearing of important species.

To assist with determining which plant species should be avoided or minimally cleared, four categories of conservation priority have been defined for the Arckaringa Basin. These conservation priorities take into account characteristics such as longevity, growth rate, regeneration rate and abundance, and any State or Commonwealth listing.

These priorities provide a general guide; however, the significance of some species will depend to some extent on the species' location and the characteristics of the land form in which it is located. Site specific assessments will be used to refine the priorities for a given activity or location.

The conservation priorities are as follows:

Table A3-1: Conservation Priorities

Priority	Typical Plant Type/Characteristics ⁷	Clearance
Priority 1	Long time to reach maturity Slow growth rate Poor regeneration from seed or rootstock May be uncommon State or Commonwealth listed species	Avoid clearance of mature trees Avoid clearance of listed species (unless appropriate permits and approvals in place). Very high conservation priority
Priority 2	Long time to reach maturity Slow growth rate May be relatively uncommon May regenerate from seed &/or rootstock	Avoid clearance wherever possible High conservation priority
Priority 3	Short to moderate time to maturity Moderate growth rate Regenerates from seed &/or rootstock Relatively abundant	Clear only the minimum necessary Moderate conservation priority
Priority 4	Short time to maturity Fast growth rate Good regeneration from seed &/or rootstock Abundant Short-lived annuals and ephemerals generally fall in this category	May be cleared if necessary Low conservation priority

The following table provides some examples of plant species in each category of priority.

Prior to the commencement of activities, relevant personnel are provided with information (e.g. information sheets or environmental management documentation, including photographs where relevant) to assist in the identification and management of the priority plant species present at the location.

⁶ A specific plant species may not necessarily exhibit all of these characteristics

Table A3-2: Examples of plant species for each conservation priority

Priority	Common Name	Scientific Name
Priority 1	Western Myall River Red Gum Coolibah Black Oak	<i>Acacia papyrocarpa</i> <i>Eucalyptus camaldulensis</i> <i>Eucalyptus coolabah</i> <i>Casuarina pauper</i>
Priority 2	Mulga Dead Finish Old Man Saltbush Bluebush Bullock Bush White Cypress-pine	<i>Acacia aneura</i> <i>Acacia tetragonophylla</i> <i>Atriplex nummularia</i> <i>Maireana sedifolia</i> <i>Alectryon oleifolius ssp. canescens</i> <i>Callitris glaucophylla</i>
Priority 3	Tar Bush Samphire	<i>Eremophila glabra</i> <i>Tecticornia sp.</i>
Priority 4	Sandhill Canegrass Most grasses	<i>Zygochloa paradoxa</i> Graminae sp.

Appendix 4:

List of Relevant Land Owners

Relevant Land Owners in PEL122 & PEL123

Table A4-1: Pastoral Leases

Property Name	Contact Details
Mt Barry	<i>Details removed from public version</i>
Nilpinna	
Anna Creek	
Billa Kalina	
Stuarts Creek	

Table A4-3: Native Title Groups

Name	Contact Details
Arabana People	<i>Detail removed from the public version</i>

Appendix 5:

Listing of Fracturing Additives and Constituents

1 Fracturing Fluid Additives

The following table lists chemicals which may be used in a fracture stimulation.

Table A5-1: Fracturing fluid additives Source Santos (2015)

Chemical Name	CAS RN	Common Use
Organic		
2-Bromo-2-nitro-1,3-propanediol	52-51-7	Preservative agent, antibacterial soap, skin cleansing wipes, hand wash and body shampoo and microbial; treatment in water systems
Acetic Acid	64-19-7	Additive in food industry, processed fruit, cheese, meat and poultry, descaling agent
Food Red 10	3734-67-6	Food dye
Red No. 2	915-67-3	Dye
Violet 12	6625-46-3	Air freshener, commercial pH indicator solution
Citric Acid	77-92-9	Food agent for sour taste, fruit juice, dishwasher cleaner, all-purpose cleaner, hand soap
Ethylene Glycol Monobutyl Ether	111-76-2	Cleaning products, cosmetics, liquid soaps, paint removal gel, citrus household cleaner, sterilizing wipes, commercial lubricating oil
Glycerine	56-81-5	Solvent, sweetener, filler in food, laundry stain remover, antimicrobial soap, toothpaste, lipstick
Glyoxal	107-22-2	Cross linker in paper and textile industries
Isopropanol	67-63-0	Solvent, medical grade disinfectant, tape head cleaner, hops extract used for beer, air freshener
Methanol	67-56-1	Windscreen washer fluid, wastewater treatment, alternative fuel blends, liquid hand soap, furniture finisher, windscreen washer concentrate, hops extract
Xanthan Gum	11138-66-2	Thickening agent in salad dressings, sauces, ice-creams
Quaternary Amine	-*	Disinfectants, surfactants, fabric softeners, antistatic agents, and wood preservation
Alcohols, C12-16, ethoxylated	68551-12-2	Laundry detergents, surface cleaners, cosmetics and for use in agriculture, textiles and paint, car wash liquid, air freshener
Polyacrylate	-*	Absorbent material in nappies, laundry detergent glass cleaning solution, dishwashing detergent, children's bath water additive
Quaternary Amine	-*	Disinfectants, surfactants, fabric softeners, anti-static agents, wood preservation, industrial and commercial water acidity neutralizing solution
Alcohol (1)	-*	Scouring agent for textiles, commercial defoamer
Amine	-*	Disinfectants, surfactants, fabric softeners, anti-static agents, wood preservation, commercial bathroom cleaner, medical rinsing solution, photography print ink
Polyacrylamide copolymer	-*	Soil conditioner in the horticulture and agriculture industries, flocculator in potable water treatment, mulch binder, dust control agent
Terpene	-*	Natural agricultural pesticides, laundry soap, furniture oil, grease stripper, paint, ink, gum removal

Chemical Name	CAS RN	Common Use
Ether Compound	.*	Air freshener, food flavouring agents
Oxyalkylated polymer	.*	Demulsifiers, flotation agents
Phenolic compound	.*	Plastic and textile generation, detergents
Glycol compound	.*	Foods, cosmetics, and oral hygiene products as solvent, preservative and moisture retaining agent
Hydroxypropyl guar	39421-75-5	Thickener is cosmetics, baked goods, ice cream, toothpaste, sauces, fabric softener, hair straightening aid, shampoo, body lotion, shaving cream
Benzaldehyde	100-52-7	Almond flavouring in food
Cinnamaldehyde	104-55-2	Food flavour, herbicide, cancer treatment, antimicrobial
Diethylene glycol	111-46-6	Moisture retainer in tobacco, cork, ink glue, cosmetics. Used in brake fluids
Alkyl phenol alkoxylates	.*	Metal soldering flux, commercial and industrial cleaners and degreasers
Glycol ether	.*	Pharmaceuticals, sunscreens, cosmetics, inks, dyes, water based paints, degreasers, cleaners, aerosol paints and adhesives
Choline chloride	67-48-1	Feed additive for chickens
Ethylene glycol	107-21-1	Antifreeze, household cleaners, deicing, caulk
Acrylonitrile	107-13-1	Plastic manufacture
Alcohols, C6-C12, Ethoxylated propoxylated	68937-66-6	Household and industrial and institutional cleaners, paints and coatings, pulp and paper, textile processing
Alcohols, C10-C16, Ethoxylated propoxylated	69227-22-1	Household and industrial and institutional cleaners, paints and coatings, pulp and paper, textile processing
Polyethylene glycol	25322-68-3	Laxatives, medications
Inorganic		
Ammonium Sulfate	7783-20-2	Soil fertiliser
Chlorous Acid, Sodium Salt	7758-19-2	Bleaching and stripping of textiles, pulp, and paper
Crystalline Silica, Quartz	14808-60-7	Sand and gravel, cat litter, tile mortar, arts and crafts, ceramic glaze
Disodium Octaborate Tetrahydrate	12008-41-2	Antiseptic, insecticide, flame retardant
Hydrochloric Acid	7647-01-0	Leather processing, purification of common salt, household cleaning
Potassium Carbonate	584-08-7	Soap, glass, china, food additive
Silica Gel	112926-00-8	Mouthwash, toothpaste, powdered sugars

Chemical Name	CAS RN	Common Use
Sodium Carbonate	497-19-8	Laundry detergent, dishwashing liquid, toothpaste, pool pH additive
Sodium Chloride	7647-14-5	Food grade salt, laundry detergent, aquarium fish medication, ice melting product
Sodium Hydroxide	1310-73-2	Laundry detergent, toothpaste, cocoa, milk products, chocolate
Sodium Hypochlorite	7681-52-9	Household bleach, disinfectant, water treatment, endodontics, eczema treatment
Sodium Iodide	7681-82-5	Light bulbs, infant food
Sodium Persulfate	7775-27-1	Bleach, metal etching, soil conditioner, detergent
Sodium Sulfate	7757-82-6	Dishwasher detergent, laundry detergent, liquid hand soap, toothpaste
Aluminum oxide	1344-28-1	Paint, pigment, plastic filler, water/gas purification
Aluminum silicate	1302-76-7	Blanket felt, paper or boards
Crystalline Silica, cristobalite	14464-46-1	Glass, optical fibers for telecommunications
Iron oxide	112926-00-8	Pigments in paint coatings, coloured concretes
Silica Dioxide	112926-00-8	Cement, glass, optical fibers for telecommunications, porcelain, earthenware
Titanium Dioxide	13463-67-7	Sunscreen, food colouring, paint pigments
Borate salts	-*	Agricultural plant food, fertilizer, industrial glass manufacturing additive
Almandite and pyrope garnet	1302-62-1	Gemstone, grit blasting
EDTA / Copper chelate	-*	Fertiliser, water softeners, shampoos, food preservatives
Sodium bisulfite	7631-90-5	Food preservative, swimming pool chemical
<i>Note: " -* " = chemical not disclosed for reasons of confidentiality</i>		

1.1 Indicative Overall Percentage of Additives

The indicative overall percentages of additives in a typical fracturing operation on a well in the Cooper Basin is shown below.

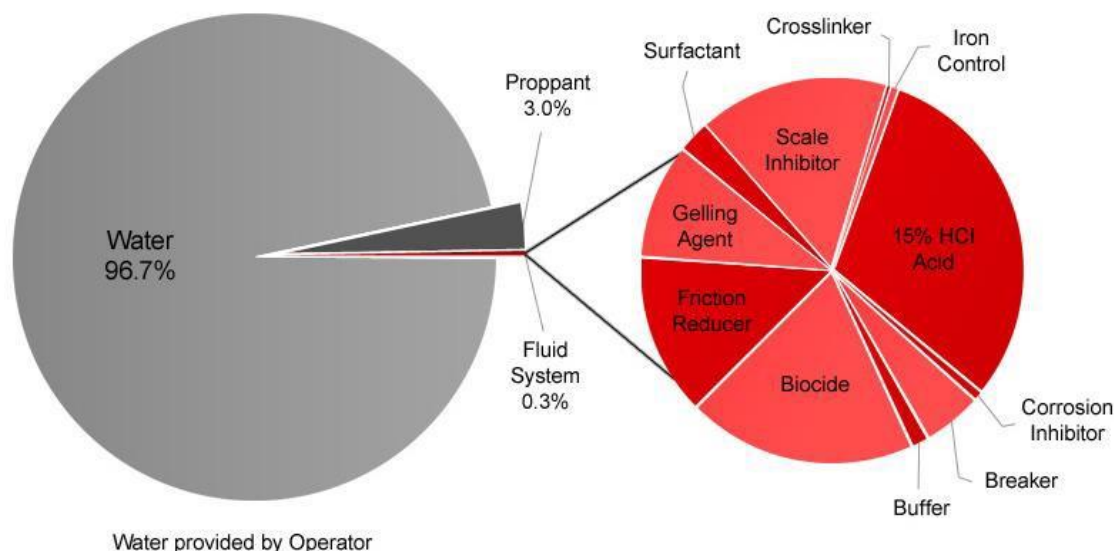


Figure A5-1: Indicative overall percentages of Additives from a fracture operation in the Cooper Basin

1.2 Safety Data Sheets

Safety Data Sheets for the fracturing fluid additives listed above are available at the following website:

Halliburton

<http://www.halliburton.com/en-US/tools-resources/safety/material-safety-data-sheet-search.page>

Schlumberger

<http://www.slb.com/resources/msds-sheets.aspx>

1.3 Further Information

Additional information on fracture stimulation additives is available from the following sources:

Table A5-3: Fracture Stimulation Additives information sources

Government web sites:	
DEM (SA)	http://www.petroleum.statedevelopment.sa.gov.au/
Fracture stimulation providers:	
Halliburton	http://www.halliburton.com/public/projects/pubsdata/Hydraulic_Fracturing/fluids_disclosure.html
Schlumberger	http://www.slb.com/services/completions/stimulation/unconventional_gas_stimulation/openfrac_hydraulic_fracturing_fluids.aspx
Baker Hughes	https://www.bakerhughes.com/products-and-services/pressure-pumping/hydraulic-fracturing/environmental-solutions-and-chemical-disclosure
Industry bodies:	
APPEA	http://www.appea.com.au
API	http://www.api.org
Frac Focus (USA)	https://fracfocus.org/hydraulic-fracturing-process

Appendix 6:

Summary of Government Agency Consultation Submissions and Responses

Note: Where 'EIR' and 'SEO' are used through this Appendix, unless otherwise specified, EIR refers to the *PEL122 & PEL123 Fracture Stimulation Activities Environmental Impact Report*, this document, and SEO refers to the *PEL122 & PEL123 Fracture Stimulation Activities Statement of Environmental Objectives*.

EIR Section / Table	Stakeholder	Issues Raised or Comments Made	SAPEX Comment / Change
Generic	Department for Environment and Water (DEW)	<i>What is the number of vertical exploration wells proposed and if successful, the number of horizontal completions for each vertical well</i>	The EIR identifies risks associated with fracture stimulation activities within PEL122 and PEL123. The SEO documents environmental objectives and assessment criteria based on the risks identified in the EIR. These objectives are common to fracture stimulation activities throughout the area and provide the environmental framework to conduct environmentally responsible activities. The number of wells, and their locations, have not been specified in these documents as the extent and location of exploration and appraisal will be dictated by the drilling and stimulation results.
Section 4.5 & 4.6	South Australia Environmental Protection Agency (EPA)	<u>Hydrogeology (pg. 33) & Groundwater Use (pg. 38)</u> <i>Sapex Pty Ltd should consider and include new information from the Bioregional Assessment Program, particularly with regard to hydrogeological structure, aquifer connectivity, and groundwater chemistry data. Reports are available here: http://www.bioregionalassessments.gov.au/assessments/galilee-subregion/supporting-knowledge-projects</i>	Section 4.5 updated to include a new section titled <u>Arckaringa Basin Aquifer Connectivity</u> focusing on the hydrogeological connectivity of Eromanga and Arckaringa aquifers based on the discussion in DEWNR reports. Section 4.6 left unchanged.
Section 5.4	EPA	<u>Fracturing Fluids (pg52)</u> <i>The EPA supports the proposal to provide full detail of additives proposed for use in fracture stimulation operations to DEM as part of the activity approval process, along with a demonstration that the level of risk posed by these additives is consistent with the EIR.</i> <i>It is noted the level of risk posed by additives containing BTEX is described as relatively low and that it is not proposed to use additives where BTEX is present in significant quantities (but likely at trace levels). The EPA acknowledges the reasoning behind the proposed rating of 'relatively low' risk but encourages the use of best practice technologies. It is understood that there are alternatives to BTEX additives.</i>	Comment noted. Sapex Pty Ltd will provide details of volumes, pump rates, additives, concentrations and Safety Data Sheets to DEM as part of the notification of activity. Consistent with best practice technologies, SAPEX will minimise use of fracture stimulation additives containing trace BTEX and will use alternatives where practical.

EIR Section / Table	Stakeholder	Issues Raised or Comments Made	SAPEX Comment / Change
		<i>Sapex Pty Ltd should investigate and implement alternatives through a process of continuous improvement.</i>	
Section 5.5	EPA	<u>Fracture Height Growth and Fracture Monitoring (Pg54)</u> <i>Fracture modelling is discussed in this section and includes the use of techniques such as micro seismic monitoring, surface tilt meters, proppant tracers, chemical tracers and sonic anisotropy logging. As the EIR does not limit the number of wells to be drilled and fracture stimulated, the EPA recommends that after 1 – 2 wells have been fracture stimulated and modelling has occurred, the results of this (and report of outcomes) is received and reviewed by DEM prior to permitting Sapex Pty Ltd (via the Activity Notification Process) to conduct further fracture stimulation activities.</i> <i>The EPA supports the implementation of diagnostic tools on a case by case basis with a more detailed program included in the submissions to DEM during Activity Notification Process.</i>	Comment noted. Where diagnostic tools are used on a fracture stimulation treatment, DEM will be kept informed of the monitoring program. However, further drilling and stimulation should not be decided on this information, which may or may not be successfully obtained.
Section 5.5	EPA	<u>Proppant Tracers (pg. 56)</u> <i>If Sapex Pty Ltd uses proppant Tracers above the threshold level outlined in the 'Radiation Protection and Control (Ionising Radiation) Regulations 2015', then Sapex Pty Ltd (or the contractor carrying out the work) will require a radiation licence under the Radiation Protection and Control Act 1982 and will need to apply to the EPA for approval to dispose of the proppant tracers.</i>	Comment noted. Section updated to reference the 'Radiation Protection and Control Act 1982' & the 'Radiation Protection and Control (Ionising Radiation) Regulations 2015'.
Section 5.8	EPA	<u>Temporary Holding Ponds (pg. 57)</u> <i>This section outlines the ponds which are to be used to receive water for stimulation and recovered flow back fluids, which are to be lined and fenced. The EPA understands that the timeline for use of these ponds may vary, but all will be in</i>	Comments noted. Wording regarding pond constructions and extended pond use incorporated into Section 5.8.

EIR Section / Table	Stakeholder	Issues Raised or Comments Made	SAPEX Comment / Change
		<i>use for approximately three to six months. This estimated timeframe will assist in the understanding of longer term well performance. Consequently, a water balance approach methodology to leak detection would be considered acceptable.</i> <i>Considering aspects such as the provision for lining, the short-term nature of storage, and the depth to groundwater, the risk of environmental harm is low. However, the following should be carried out to ensure the likelihood of seepage is reduced:</i> <i>a) All ponds are to be lined with suitable UV stabilised polyethylene material. All liners must be constructed to the manufacturers recommend installation method and be welded and checked for joint adherence and leak tested prior to being placed in operation, and</i> <i>b) Regular water balance calculation and visual inspections are made to ensure any loss of significant volumes from the recovered fluid ponds is detected.</i> <i>If the ponds are to be used for a period greater than one year, a more stringent leak detection method should be employed (e.g. monitoring bores).</i> <i>A map of watercourses within the Arckaringa Basin has not been provided, however it is stated that ephemeral watercourses exist and that temporary holding ponds will not be located near significant watercourses. The EPA considers any water course as significant and a contributor to the local (and wider) ecosystem. The location of the temporary holding ponds should be in accordance EPA Guideline 509/14 Wastewater Lagoon Construction. Whilst it is acknowledged that specific locations have not been determined, locations where flooding risk is high should be avoided and the ponds should not be located within 50m of any watercourse. This information should be included in the SEO, particularly under Objective 3.</i>	Reference in regard to the EPA Guideline 509/14 Wastewater Lagoon Construction incorporated into Section 5.8. The following has been incorporated into the SEO under Objective 3: • Locations where flooding risk is high should be avoided • Ponds should not be located within 50m of any watercourse

EIR Section / Table	Stakeholder	Issues Raised or Comments Made	SAPEX Comment / Change
Section 6	EPA	<u>Environmental Impact Assessment (pg. 61)</u> <i>The ability to assess potential environmental impact is dependent on the Bioregional Assessment Program (see EIR comments under 4.5 and 4.6). Robust data/discussion would be useful around:</i> • <i>Hydraulic pressures in surrounding formations;</i> • <i>Potential Impact to existing users; and</i> • <i>Environmental values of different hydrogeological units in accordance with the Environmental Protection (Water Quality) Policy 2015.</i>	Hydraulic pressures within aquifer formations including the Great Artesian Basin and the Boorthanna Formation are dependent on many factors including structure, depth, geology, temperature and topography. For example, within PEL123 where the Cadna-Owie Formation outcrops at surface hydraulic pressures are low due to erosion of the Bulldog Shale aquitard. To the north into PEL122 where the Bulldog Shale thickens, water pressure increases, and the GAB is artesian. These factors will be considered on a case by case basis during the submission of a detailed proposal to DEM during the activity notification phase. Potential impacts to existing water users generally relate to aquifer contamination or depressurisation of the Great Artesian Basin. Stimulation activities will target deeper formations as discussed in Section 6.1 and are not expected to have any impact on the GAB with the described controls in place. Section 6.5.2 has been added to re-iterate this and reference relevant sections in Table 11 Environmental Values of different hydrogeological units in accordance with the Environmental Protection (Water Quality) Policy 2015 table updated into Section 4.6 in Table 2
Section 6	EPA	<u>Additional Comments</u> <i>The remediation of contaminated soils from chemical and hydrocarbon spills is mentioned in a number of areas within the EIR (including in the document summary and Table 11). Sapex Pty Ltd should describe the treatment and/or disposal path for any contaminated soil. The EPA considers that a spill remediation approach should be referenced based on volume, estimated horizontal and vertical impact.</i> <i>The assessment for uncontained spills with a larger scale impact (potentially non-trivial) should be undertaken in accordance with the National Environmental Protection (Assessment of Site Contamination) Measure (1999) amended in 2013 and relevant SA EPA guidelines.</i>	Section 5.10.3 updated to include the following wording: “Minor spills in lined bunded areas are generally treated in situ in accordance with EPA guidelines. The main method of treatment and disposal of hydrocarbon contaminated soil resulting from spills outside of bunded areas is removal for temporary storage in a designated bunded area. The contaminated soil is then transported by a licensed regulated waste contractor to a suitable EPA licensed facility for treatment or disposal”. The following wording is already incorporated into Objective 4 (Minimise disturbance and avoid contamination to soil) of the Statement of Environmental Objectives:

EIR Section / Table	Stakeholder	Issues Raised or Comments Made	SAPEX Comment / Change
			“Assessment and remediation of uncontained spills with larger scale impact (e.g. greater than 200 litres to land, or any volume to water) undertaken in accordance with the National Environmental Protection (Assessment of Site Contamination) Measure (1999) amended in 2013 and relevant SA EPA guidelines”
Generic	DEW	<i>In recent years, there have been a number of projects undertaken in the far north of SA that have improved our knowledge of groundwater in the region. These projects include the GAB western margin study (national water initiative), GAB water resources assessment, and the Pedirka and Arckaringa basins groundwater assessments (Bioregional Assessment). Hydrogeology maps have also been generated for the GAB (SA and NT portion), Arckaringa and Pedirka basins.</i> <i>Relevant information from these reports should inform the EIR and SEO documents.</i>	Comment noted. Section 4.5 updated to include a new section titled <u>Arckaringa Basin Aquifer Connectivity</u> focusing on the hydrogeological connectivity of Eromanga and Arckaringa aquifers based on the discussion in DEWNR reports.
Generic	DEW	<i>What is the maximum zone of influence resulting from fracture stimulation? This is not the extent of the fractures but rather the maximum extent that rock / sediment units may be disrupted as a result of the fracture stimulation. Has any work been undertaken to measure this aspect of fracture stimulation, how is it monitored and what are the results. Supporting information will need to be provided in the EIR document.</i> <i>The reasons for raising this issue is that disruption, of any magnitude, to the flow pathways that provide groundwater to springs could result in a change to the flow regime supporting the spring and impact the health of the spring and its associated environment. A worst-case scenario would be the drying up of a spring. The SEO is to consider stating a minimum distance that fracture stimulation activity can occur within any spring and will need to provide objectives on how this can be achieved.</i>	The information provided in Section 6.1.2 and Figure 27 demonstrates the average height fractures propagates in the American analogy, the Eagle Ford Shale. This dataset is the typical height growth observed from micro seismic monitoring which measures noise using acoustic tools which does not necessarily mean the fracture propagated and is connected to where the noise was measured. The data indicates height growth is typically less than 200 – 300m. (Fisher and Warpinski 2011) demonstrate that shallow hydraulic fractures are not observed to grow vertically because of the changing stress state. At less than 1,500ft (450m), the overburden stress is the least principle stress and this causes fractures to be primarily horizontal at shallow depths. This is amplified by stress barriers due to changes in Young's Modulus and Bulk Density.

EIR Section / Table	Stakeholder	Issues Raised or Comments Made	SAPEX Comment / Change
			Impacts from Fracture Stimulation on the GAB and GAB springs are not expected with the described controls in place. Per Section 1.1, a 5km trigger zone (shown in Figure 2) has been identified around surface Springs. Additional consultation with both State and Federal Government Agencies (and potential impacts to MNES under EPBC) is required during the stage 3 approval process prior to any stimulation activities being approved within these trigger zones.
Generic	DEW	<i>Analysis of groundwater samples collected at a spring in the region of the PELs has shown that the chemistry is much closer to the chemistry found in the Boorthanna Formation / fractured rock – basement aquifer than the GAB groundwater west of the Torrens Hinge Zone. Isotope results from this spring also support this hypothesis. Additional information on this can be found in the report “A hydrogeological characterisation of the Arckaringa Basin” report no: 2015/03 (details are in the reference list document attached). Acknowledgment of this is required in the EIR and SEO documents.</i>	Connectivity of the Boorthanna Formation with the GAB is referenced in Section 4.5, subsection <u>Arckaringa Basin Aquifer Connectivity</u>. It is noted the spring and majority of other data points used in the hydrochemistry data set is located in the South East of the Arckaringa Basin, within the Billa Kalina Sub Basin. Existing drill hole and seismic data indicates significant Permian erosion has occurred within this part of the basin with the removal of the Mount Toondina and Stuart Range Formation (both demonstrated to form aquitards) in part leaving the Boorthanna Formation in direct contact with the overly Great Artesian Basin (see B-B’ and C-C’ cross section in Figure 16). As discussed in Section 4.5, DEWNR (2015/03) describes the Boorthanna Formation as being heterogenous at a local scale with multiple isolated sandstone aquifers. This heterogeneity is reflected in stated lateral hydraulic conductivity figures in the Boorthanna Formation which vary from 0.02 – 5 m/d. It is thought the relatively isolated semi-discontinuous aquifers are related to sporadic turbidity flows within an otherwise quiescent glacio-marine environment and that further discontinuity may arise from syn and post depositional faults.
Generic	DEW	<i>With regards to the GAB springs in the region is an EPBC referral required? If Y, has this been applied for?</i>	An EPBC referral is not required. Stimulation activities will target deeper formations as discussed in Section 6.1 and are not expected to have any impact on the GAB with the described controls in place.

EIR Section / Table	Stakeholder	Issues Raised or Comments Made	SAPEX Comment / Change
			Per Section 1.1, a 5km trigger zone (shown in Figure 2) has been identified around surface Springs. Additional consultation with both State and Federal Government Agencies (and potential impacts to MNES under EPBC) is required during the stage 3 approval process prior to any stimulation activities being approved within these trigger zones.
Generic	DEW	<i>The department DEWNR – Department of Environment, Water and Natural Resources is expressed in various combinations in the report (eg: pg12 Department of Environment and Natural Resources). These need to be corrected.</i>	Comment noted, sections of the report updated where required to DEW.
Section 4.3	DEW	• <i>to consider renaming Surface Water Resources</i> • <i>document to note that PELs fall within the LEB (surface water) and possible implications to activities undertaken in the PELs.</i> • <i>to note that whilst the majority of springs are sourced from the GAB Cadna-owie / Algebuckina aquifer not all springs in the region are GAB springs or the source groundwater possibly comes from a number of aquifers. The text needs to reflect this.</i> • <i>Section 4.3.1 – corrections / additions are required in the text regarding</i> ○ <i>that most of the PEL area overlies the GAB, with artesian conditions occurring on the northern border of PEL 122 and eastern boundary of PEL 123</i> ○ <i>The PELs do not overlie the Lake Eyre geological basin. The western extent of the LEB (geological) is east of the Peake and Denison Ranges.</i> ○ <i>Not all GAB springs are mounds springs, in fact the majority of GAB springs are not mound springs per se.</i>	• Comment noted, section title updated to <i>Surface Water Resources</i>. • Section 4.3.2 Lake Eyre Basin added along with figure showing Lake Eyre Basin overlayed by Permian basins. • Section 4.3.1 updated to recognise some springs may be sourced from deeper aquifers other the GAB. • Comments noted – wording updated as suggested.

EIR Section / Table	Stakeholder	Issues Raised or Comments Made	SAPEX Comment / Change
Section 4.5	DEW	<i>It would be useful for water chemistry values to be displayed on a map for both the Eromanga and Arckaringa Basins</i>	Comment noted and section updated with water chemistry figure displaying values and additional discussion in Section 4.5.
Section 4.6	DEW	• <i>Section is to acknowledge all 3rd party users within the PEL boundaries and surrounding areas. Prominent Hill, Cairn Hill and Peculiar Knob are mining operations that have both production and monitoring wells in the area and monitoring wells associated with Prominent Hill fall within PEL 123. Also, to consider providing a map of existing 3rd party users in the region.</i> • <i>Figure 12 – to consider changing the figure title. Information presented in the figure is of all water wells drilled in the region and GAB springs. The wells are not a network per se and not all of the wells are operational.</i> • <i>Document should also mention the state monitoring network for the Far North PWA. Further information can be found on the DEWNR Groundwater Data web site https://www.waterconnect.sa.gov.au/Systems/GD/Pages/default.aspx#Obswell</i>	All comments noted and section amended with suggested updates.
Section 5.3.2	DEW	<i>The monitoring and reporting of fracture activities is to include the design factors listed in this section along with information on the dimensions of the fractures generated.</i>	Comment noted. The implementation of diagnostic tools to measure the dimensions of fractures generated will be assessed on a case by case basis as discussed in Section 5.5. Where diagnostic tools are used on a fracture stimulation treatment, DEM will be kept informed of the monitoring program.

EIR Section / Table	Stakeholder	Issues Raised or Comments Made	SAPEX Comment / Change
Section 6.1	DEW	• <i>A hazard not identified is the closure / disruption of fractures supporting springs in the region.</i> • <i>If fracture activity is to occur towards the base of the Stuart Range Formation the risk of growth of fractures into the underlying Boorthanna Formation needs to be taken into account. The Boorthanna Formation is used as a water supply for the Prominent Hill mine and by pastoralists. Groundwater required for mining and industrial purposes does not need to be of fresh quality. Groundwater with salinity in the 10,000's mg/L can be used for such purposes.</i> • <i>Comments have been made regarding the Mt Toondina and Boorthanna formations not being identified as aquifers. This is not consistent with the information presented in table 2 – where the Mt Toondina and Boorthanna formations are classified as aquifers.</i>	Section 6.1 and Table 11 updated to include reference to disruption of natural fractures supporting springs. While this is considered a risk, the potential for a fracture to propagate through multiple Formations at depth to surface with relevant controls in place is considered rare. As discussed throughout in Section 6.1.2, height growth is governed by the vertical stress profile with changes in stress, with Young's Modulus and bulk density which typically act as barriers to fracture growth (Stress Barriers). Where sufficient barriers exist this significantly reduces the potential for growth into adjoining formations. The orientation of the fracture (planar vertical fractures, sub-vertical, t-shaped, horizontal fractures) is governed by the stress regime (normal, strike slip or reverse). The risk of fractures propagating into aquifers within the Boorthanna Formation is discussed in Section 6.1.2. SAPEX notes the Boorthanna Formation is used as a water supply for pastoralists and major mining complexes west of PEL123. As discussed in Section 4.5, DEWNR (2015/03) describes the Boorthanna Formation as being heterogenous at a local scale with multiple isolated sandstone aquifers. This heterogeneity is reflected in stated lateral hydraulic conductivity figures in the Boorthanna Formation which vary from 0.02 – 5 m/d. It is thought the relatively isolated semi-discontinuous aquifers are related to sporadic turbidity flows within an otherwise quiescent glacio-marine environment and that further discontinuity may arise from syn and post depositional faults. Comments on groundwater use with high salinity are noted. Comment noted and wording updated to recognise the Upper Mount Toondina and Boorthanna Formation as potential aquifers.
Summary	Department for Energy and Mines (DEM)	Update Arckaringa Basin Drilling Activities EIR 2013 reference to include 'Initial Production Testing'.	Section amended with suggested re-wording

EIR Section / Table	Stakeholder	Issues Raised or Comments Made	SAPEX Comment / Change
Section 2	DEM	<i>Update reference DMITRE to DEM</i>	References updated
Section 2.6	DEM	<i>Update reference to the Petroleum Act to the Petroleum and Geothermal Act 2000</i>	References updated
Section 2.6	DEM	<i>Update reference to Minister for Environment and Conservation to Minister for Sustainability, Environment and Conservation</i> <i>Update reference to Regional Reserves to Conservation Parks.</i>	References updated
Section 4.3.1	DEM	<i>Suggest providing a map of known GAB springs within and near to licence area</i>	Map of GAB springs included in Figure 5 .
Section 4.4.3	DEM	<i>Suggest rewording or even providing a diagram that outlines fractures will 'open' in the direction of the minimum stress, however will still propagate in the maximum horizontal stress direction (i.e. in a strike-slip stress regime, the fractures will be of vertical orientation, but propagate in the maximum stress direction which is expected to be horizontal).</i>	Section amended with suggested re-wording.
Section 5.7	DEM	<i>More Clarity is required regarding Production Testing. Is this IPT or EPT? IPT is allowed under the Sapex Drilling SEO. EPT is out of scope.</i> <i>Remove reference to Santos SEO.</i>	Section updated to reference initial production testing as discussed in the Arkaringa Basin Drilling Activities EIR & SEO. Reference to Santos SEO removed.
Section 6.1.4	DEM	<i>In assessing this impact, worth considering the sandstone units of the Boorthanna may be used as an aquifer where it is shallower (e.g. around nearby mining sites including Prominent Hill).</i>	Comment noted. Section updated with the following text: <i>"The sandstone units of the Permian Boorthanna Formation and Mt Toondina Formation are not generally targeted for aquifer purposes within PEL122 and PEL123. As discussed in Section 4.6, the Boorthanna Formation is used as a water supply for pastoralists and</i>

EIR Section / Table	Stakeholder	Issues Raised or Comments Made	SAPEX Comment / Change
			<i>major mining complexes south of PEL123. DEWNR (2013) demonstrates water extraction is within the Billa Kalina Sub-Basin. The Boorthanna Formation aquifer within the Billa Kalina Sub Basin occurs in isolated semi discontinuous pods, this is discussed in greater detail in Section 4.5.”</i>
Section 6.4	DEM	<i>It is expected that fauna escape mechanisms will also be provided. This is suggested in the guide to how section of the SEO.</i>	Section updated to include reference to escape mechanisms.
Table 11	DEM	<i>Include reference to leak detection and water balance in following control measures:</i> <i>Leak of brackish or saline pre-stimulation water from holding ponds</i> <i>Major leak or spill to ground from surface handling / storage of flowback fluids (e.g. pond wall failure)</i> <i>Major leak or spill of flowback fluids to surface water (e.g. if pond fails and contents reach surface water or flood overtops ponds)</i>	The following wording updated into each control measures section: <i>“Water balance method used for leak detection (incorporating inflow, evaporation, fluid levels and measurement uncertainty)”.</i>
Table 11	DEM	<i>Reference NEPM in Major spill / leak from hazardous material storage and handling (e.g. entire contents of refuelling tanks)</i>	The following wording updated into the control measures section: <i>“Clean-up of large spills will be in accordance with the National Environmental Protection (Assessment of Site Contamination) Measure (1999) amended in 2013 and relevant SA EPA guidelines”.</i>
Generic	Aboriginal Affairs and Reconciliation Division (AARD)	<i>The applicant is advised that sites or objects may exist in the proposed development area, even though the Register does not identify them. All Aboriginal sites and objects are protected under the Aboriginal Heritage Act 1988 (the Act), whether they are listed in the Register or not. Land within</i>	Comment noted.

EIR Section / Table	Stakeholder	Issues Raised or Comments Made	SAPEX Comment / Change
		<i>200m of a watercourse in particular, may contain Aboriginal sites and objects.</i>	
Generic	AARD	<i>Pursuant to the Act, it is an offence to damage, disturb or interfere with any Aboriginal site, object or remains (registered or not) without the authority of the Minister for Aboriginal Affairs and Reconciliation (the Minister). If the planned activity is likely to damage, disturb or interfere with a site, object or remains, authorisation of the activity must be first obtained from the Minister under Section 23 of the Act. Section 20 of the Act requires that any Aboriginal sites, objects or remains, discovered on the land, need to be reported to the Minister. Penalties apply for failure to comply with the Act.</i>	Comment noted
Summary	DEW	<i>A key environmental aspect that should be identified in the 1st set of dot points is the potential for impact on GAB springs, which are an EPBC listed threatened communities.</i>	Summary updated to reference potential impact to GAB springs.
Introduction	DEW	<i>The paragraph discusses the fact that hundreds of fracture stimulation activities have occurred in the Cooper Region. To support the proposed activities in the Arckaringa Basin it would be useful to present statistics on the activities in the Cooper Basin. Information to include number of fracking activities, stratigraphic unit, unit thickness, lithology description of fracking intervals, fracking initiation depth, fracture dimension.</i>	Section 6.1.2 updated to include reference to fracture stimulation data from the Cooper Basin.

EIR Section / Table	Stakeholder	Issues Raised or Comments Made	SAPEX Comment / Change
Section 2.6	DEW	<i>To note that a permit under the NRM Act is not required for conversion of a petroleum well to a water well. Approval is required from DEW, subject to an assessment of the well construction (there is no requirement to meet the minimum construction requirements of a waterwell as outlined in the standard "Minimum Construction Requirements for a Water Bore in Australia 3rd Edition"). The well must be fit for purpose and both parties (tenement holder and the landholder) are in agreement and the transfer is approved by DEM and DEW the tenement holder and the landholder will need to provide a deed of transfer document which outlines that both parties acknowledge and accepts the transfer.</i>	Comment noted, reference to petroleum well conversion removed. Conversion of wells is not proposed as part of this EIR and SEO, the details of the approval process for conversion will be resolved outside this document.
Section 4.2.1	DEW	<i>There have been a number of reports written recently, regarding GAB springs, as part of the Lake Eyre Basin Springs Assessment (LEBSA) Project. One report in particular, DEWNR Technical Report 2016/02, focussed on springs in the western LEB and the Arckaringa Basin Region. These reports should be informing the EIR and SEO documents.</i> <i>The section should also acknowledge that the springs are listed under the EPBC Act as threatened ecological communities.</i>	Noted, Section 4.2.1 refers to landforms. Reference to the EPBC Act is provided in Section 4.3.1 Section 4.3.1 updated to reference DEWNR 2016/02. Figures 4-2 – 4-8 of DEWNR 2016/02 provides conceptual diagrams of spring types and potential impacts due to coal mining and coal seam gas extraction from coal reservoirs in the upper Mount Toondina Formation. These activities are outside the scope of the PEL122 & PEL123 Fracture Stimulation EIR & SEO. Sapex notes water production is not expected from its target formations. In the unlikely event an aquifer is impacted and flowback has a high concentration of water, the well will not be economic and will therefore be decommissioned.
Section 4.2.1	DEW	<i>2nd last paragraph belongs in the significant fauna section rather than flora.</i> <i>The paragraph should also be included or referred to in Section 4.2.2.</i>	Comment noted, sections updated.

EIR Section / Table	Stakeholder	Issues Raised or Comments Made	SAPEX Comment / Change
Figure 5	DEW	<i>Updated maps are available in later reports, which present the latest Arckaringa Basin extent, which should be presented correctly in the EIR.</i> <i>The figure should also display the PEL Boundaries rather than an approximate extent.</i>	Comment noted, suggested changes made
Figure 7	DEW	<i>To note that basin extents have been updated since this map was produced (1995).</i>	Noted. Figure caption updated acknowledging this.
Section 4.4.2	DEW	<i>Editorial: Mesozoic Sediments – the total Eromanga Basin sequence is, in the Arckaringa Basin, is up to 300m thick.</i>	Wording updated.
Section 4.4.2	DEW	<i>Editorial: Mesozoic Sediments – delete the word ‘above’ from sentence.</i>	Wording updated
Section 4.4.2	DEW	<i>A map showing the location of the wells referred to in the text, with the Arckaringa Basin margin, would be useful.</i>	A map with historical petroleum well locations has been included in Figure 10 .
Section 4.4.3	DEW	<i>Editorial: Stress contrasts and fracture containment – green line displays minimum horizontal stress.</i>	Wording updated
Section 4.4.3	DEW	<i>It is stated that stress fractures are not expected to extend beyond the Mount Toondina Formation. Noting that where the upper units of the Mount Toondina Formation are sandier, there could be hydraulic connection with the GAB. Is fracture propagation to extend beyond the Lower Mount Toondina Formation? Clarification is required.</i>	Wording updated to reference the lower Mount Toondina Formation. Sapex notes within PEL123 and part of PEL122 the upper Mount Toondina Formation has been eroded. Where the Upper Mount Toondina Formation exists in PEL122, Permian rock between the Stuart Range Formation and Algebuckina Sandstone is greater than 500m.

EIR Section / Table	Stakeholder	Issues Raised or Comments Made	SAPEX Comment / Change
Section 4.5	DEW	• <i>Can a copy of the Coffey 2007 report be obtained? This report is continually referenced in the documents?</i> • <i>Clarification is required on the context of the paragraph reading ‘the Arckaringa Basin is underlying the GAB yet is separated from it?’</i> • <i>The GAB is not artesian throughout the Arckaringa Basin. Please refer to GAB hydrogeology map (2012)</i> • <i>Is the Bulldog Shale Jurassic or Cretaceous in age?</i> • <i>To note the ‘Western Eromanga Region’ refers to the area of the Eromanga west of the Birdsville Track Ridge.</i> ○ <i>Editorial – The GAB sediments overlie the Arckaringa Basin rather than are within.</i>	• A copy of the Coffey 2007 report will be provided to DEM. • Wording updated to demonstrate Western Eromanga is hydrogeologically partially separated from the main aquifer. • Wording updated to parts of the Arckaringa Basin • Wording updated to Cretaceous Bulldog Shale • Noted, wording updated to reference Birdsville Track Ridge ○ Wording updated to reference GAB sediments overlie the Arckaringa Basin.
Section 4.6	DEW	<i>To note that Cairn Hill operation is located west of PEL123 and its water is sourced from the GAB rather than the Boorthanna Formation.</i>	Comment noted, and suggested changes made
Figure 16	DEW	<i>To note this cross section was replaced in a 2015 report.</i>	Comment noted. DEWNR2015/03: • Cross section provided in Figure 5 – 7 is located in the northern extent of PEL122 and supports greater thickness of Permian sediment in Boorthanna Trough consistent with the current Figure. • Cross section provided in Figure 5 – 10 is located South of PEL123 where the Stuart Range Formation sub-crops into the GAB. This is outside of Sapex’s exploration area. Cross section taken from DEWNR2013 provides a better example of geology in target areas therefore figure remains unchanged.

EIR Section / Table	Stakeholder	Issues Raised or Comments Made	SAPEX Comment / Change
Figure 17	DEW	<i>To note that this figure presents all water wells and springs in the area rather than just water wells. Text and figure title to reflect this.</i>	Comment noted, and suggested changes made
Figure 21	DEW	<i>To consider replacing this diagram with a schematic relevant to the region, which adequately addresses stratigraphic units, aquifer units, and likely depths of fracture stimulation activities.</i>	Diagram updated with requested information.
Section 5.4	DEW	<i>BTEX in Fracturing Additives – clarification is required regarding the statement ‘and are not near water supply aquifers’.</i>	Wording removed.
Section 6	DEW	<i>A key environmental aspect that should be identified up front and discussed further is the potential for impact on GAB springs, which are an EPBC listed threatened community. This could be discussed as a separate section or included in Section 6.1 Aquifers.</i>	Springs are referenced in the second point of Section 6.1, reference to EPBC listed threatened communities updated into section. The stimulation treatment is not expected to propagate into the GAB aquifers, therefore mound springs will not be impacted. Sapex notes water production is not expected from its target formations. In the unlikely event an aquifer is impacted and flowback has a high concentration of water, the well will not be economic and will therefore be decommissioned. Per Section 1.1, a 5km trigger zone (shown in Figure 2) has been identified around surface Springs. Additional consultation with both State and Federal Government Agencies (and potential impacts to MNES under EPBC) is required during the stage 3 approval process prior to any stimulation activities being approved within these trigger zones.
Section 6.1	DEW	<i>Potential hazards associated with fracture stimulation that need to be acknowledged in this section include:</i> <i>Loss of aquifer pressure (from any aquifer)</i>	Comments noted, refer to section 6.1.2 and 6.1.4 for discussion on these points.

EIR Section / Table	Stakeholder	Issues Raised or Comments Made	SAPEX Comment / Change
		- Multiple Permian aquifers have been identified in the region including the Boorthanna and Mount Toondina Formation - Cross flow between aquifers resulting from fracture generation - Fracture propagation into the Upper Mount Toondina Formation which is considered to be in hydraulic connectivity to the GAB (J-K) aquifer. - Fracture propagation into underlying aquifers - Disruption of flow pathways supporting GAB and other springs in the region.	
Section 6.1.4	DEW	<i>The deeper aquifers beneath the PEL boundaries may not have been targeted to date for water supply options, due to the presence of the GAB aquifer at relatively shallow depths, but this does not indicate that they may not be used at some time in the future for alternative supplies.</i> <i>To note that cross section in Figure 16 was updated post the 2013 report and whilst there is still a structure in the region the Boorthanna fault is not as prominent. There is no evidence to suggest that the northern area of the Boorthanna trough is hydraulically separate from the Billa Kalina sub-basin.</i>	Comments noted. Section 6.1.4 updated to remove reference to hydraulic separation at basin level. The cross section illustrated in Figure 16 provides a better example of geology in target areas therefore the figure remains unchanged. As discussed in Section 4.5, DEWNR (2015/03) describes the Boorthanna Formation as being heterogenous at a local scale with multiple isolated sandstone aquifers. This heterogeneity is reflected in stated lateral hydraulic conductivity figures in the Boorthanna Formation which vary from 0.02 – 5 m/d. It is thought the relatively isolated semi-discontinuous aquifers are related to sporadic turbidity flows within an otherwise quiescent glacio-marine environment and that further discontinuity may arise from syn and post depositional faults.
Table 11	DEW	<i>The risk event 'Fracture Propagation into overlying GAB aquifers' does not account for other aquifers in the region or known connectivity between aquifers. The risk event needs to account for fracture propagation into both overlying and underlying aquifers. Further to this, studies have identified groundwater signatures from aquifers other than GAB (J-K) aquifers at springs in the region. Control measures will need to be modified to reflect this change.</i>	Comment noted. New risk event added to Table 11 titled Fracture Propagation into Permian Aquifers. Springs where groundwater signatures have been identified from aquifers other than the GAB are generally located in areas where target formations (Stuart Range & Boorthanna Formations) are too shallow to be an unconventional target.

EIR Section / Table	Stakeholder	Issues Raised or Comments Made	SAPEX Comment / Change
Table 11	DEW	<i>Following on from previous comment a potential environmental impact to address is risk to establishing cross flow between aquifer resulting from fracture network.</i>	Comment noted. New risk event added to Table 11 titled Fracture Propagation into Permian Aquifers.
Table 11	DEW	- Control measures for the fracture propagation – Current conceptualisation of groundwater in the region is that the Upper Mount Toondina Formation is considered to be in hydraulic connectivity to the GAB (J-K) aquifer and as such groundwater generated from the Upper Mount Toondina Formation could have an impact on the GAB (J-K) aquifer. Fracture propagation should not extend into the Upper Mount Toondina Formation. - For consideration as a control measure is a monitoring program to monitor aquifer pressures and water quality at wells and springs prior to and following fracture stimulation activity. The extent and details of the monitoring to be discussed with regulators (DEM, DEW, EPA).	Comment noted, reference to Upper Mount Toondina Formation updated to Lower Mount Toondina Formation. Sapex notes the Upper Mount Toondina Formation is mostly eroded in PEL123 and in parts of PEL122. Reference to water monitoring programs captured in Table 11 of EIR and objective 1 and 2, guide to how objectives can be achieved, of the SEO. The requirement for a water monitoring program is outside the scope of these document and will be reviewed during stage 3 approval based on well location.
Table 11	DEW	<i>General use of the term Permian Aquifer. Multiple aquifers have been identified in stratigraphic units in the Arckaringa Basin – namely the Boorthanna Formation and Upper Mount Toondina Formation. Groundwater, which is saline, is extracted from the Boorthanna Formation for use at the Prominent Hill mine. Therefore, the occurrence of saline water within Permian sediments does not preclude the use of groundwater. Changes are required to the table to reflect this. Also, the depth to the groundwater resource does not necessarily preclude it for productive use. If groundwater quality is not a concern and use of the GAB aquifer is not considered acceptable then use of the deeper aquifers will be considered.</i>	Comments noted, Table 11 updated. Reference to Permian aquifer updated to Permian aquifers. A thorough description of the Permian Aquifers, namely the Boorthanna and Upper Mount Toondina Formation is provided in Section 4.5. Permian aquifer water use is discussed in Section 4.6. Reference to Permian reservoirs not forming suitable aquifers removed.

EIR Section / Table	Stakeholder	Issues Raised or Comments Made	SAPEX Comment / Change
Table 11	DEW	<i>Water supply / use control measures:</i> <i>Last item – consider modifying to ‘Monitor and reporting of water extraction volumes’</i> <i>2nd item – clarification is required in the use of the term ‘adverse’. To consider providing a table in the EIR document outlining scale of impacts on groundwater resources, springs and groundwater users – similar to Table 8 in risk assessment section of the report.</i> <i>2nd last item – impact on aquifer resulting from a ‘once off extraction’. Is the take of groundwater to be a once-off or on an ongoing basis? Clarification is required in item?</i>	- Comment considered, management measure not changed - Water extraction will be completed in compliance with licencing and water allocations where applicable. Where an existing groundwater user (ie pastoralist) is impacted by the use of a particular water point an alternative source will be used. A table outlining impact on groundwater resources has not been included given the early nature of the activities proposed. - Management measure removed to avoid confusion, water extraction will be completed in compliance with licencing and water allocations where applicable.
Table 11	DEW	<i>Risk event – Water supply – additional control measures for consideration:</i> <i>Take of water supply is to be in accordance with principals in Far North PWA Water Allocation Plan (e.g. No take within 5km of a GAB spring)</i> <i>Implementing a monitoring plan to monitor aquifer pressures and water quality at wells and springs prior to water production – it is envisaged that this monitoring plan be merged with that for the fracture stimulation activity.</i>	- Existing control measures already state water extraction will be in compliance with licensing and water allocations where applicable, no changes made. - The requirement for a water supply monitoring plan will be reviewed during stage 3 of the approval process after consultation with relevant stakeholders, no changes made.
Section 8.7	DEW	<i>The groundwater quality monitoring program should also include aquifer water level / aquifer pressure.</i> <i>Where are these monitoring programs located and are they reviewed by regulators? Is there a process for reviewing the monitoring plans?</i> <i>Who determined their adequacy to meet the environmental objectives?</i> <i>How are the monitoring data and results reported to DEM?</i>	Wording updated to ‘<i>Monitoring programs will be implemented where applicable</i>’. Aquifer water level / aquifer pressure added. Location, adequacy and reporting of any monitoring program is outside the scope of this document and will be reviewed during Stage 3 of the approvals process.

EIR Section / Table	Stakeholder	Issues Raised or Comments Made	SAPEX Comment / Change
Section 10	DEW	<i>References need to ensure that hyperlinks are still valid and use correct department abbreviations. E.g. DEH (2012). DEH has not been a SA department for many years and definitely not when web page was accessed.</i>	Comment noted, References have been reviewed updated where appropriate.
Section 12	DEW	<i>Glossary, to consider adding text to the definition for PFW to note that the term is also known as co-produced water (as in the Far North Water Allocation Plan).</i>	Comment noted and Glossary updated.
General	DEW	<i>An EPBC referral has not been sought regarding the fracture stimulation activities within the boundaries of PEL122 and 123. GAB springs (spring groups) occur within the PEL boundaries and not far outside the PEL boundary. Given that fracture stimulation activity could occur anywhere within the PEL boundary why has an EPBC referral not been made? If fracture stimulation activity is not to occur near springs, then the area within which activities are likely to occur should be declared in the report. As an EPBC referral has not been sought, the report should also nominate (and justify) a distance from any spring at which point an EPBC referral will be required before fracture stimulation activities is to occur. It is recommended that SAPEX contact the relevant government agency to confirm that their assessment is valid.</i>	An EPBC referral is not required. Stimulation activities will target deeper formations as discussed in Section 6.1 and are not expected to have any impact on the GAB with the described controls in place. Sapex notes The EIR identifies risks associated with fracture stimulation activities within PEL122 and PEL123. The SEO documents environmental objectives and assessment criteria based on the risks identified in the EIR. These objectives are common to fracture stimulation activities throughout the area and provide the environmental framework to conduct environmentally responsible activities. Per Section 1.1, a 5km trigger zone (shown in Figure 2) has been identified around surface Springs. Additional consultation with both State and Federal Government Agencies (and potential impacts to MNES under EPBC) is required during the stage 3 approval process prior to any stimulation activities being approved within these trigger zones.
General	DEW	<i>To note DEWNR has been renamed and is now the Department for Environment and Water (DEW). Future versions of the document are to reflect this.</i>	Noted, References updated where appropriate.
General	DEW	<i>There have been a number of regional groundwater assessments undertaken in the far north of SA in recent years, which include:</i>	Noted, relevant reports already referenced throughout EIR document. A list of references is provided in Section 10.

EIR Section / Table	Stakeholder	Issues Raised or Comments Made	SAPEX Comment / Change
		• <i>Bioregional Assessment Programme (Pedirka and Arckaringa Basins)</i> • <i>GAB Water Resources Assessment</i> • <i>NWI – Allocating Water and Maintaining Springs in the Great Artesian Basin</i> <i>A summary of reports written for these projects is provided as an attachment to this email. Knowledge from these studies, where relevant need to be incorporated into the EIR document.</i>	
General	DEW	<i>At some stage it would be beneficial for a consistent extent of the Arckaringa Basin be used throughout the report. An alternative is to acknowledge on diagrams where the extent is an older version</i>	Noted, figure captions have been updated to acknowledge where the basin extent is an older version.
General	DEW	<i>It would be beneficial for this EIR, and any other EIR involving fracturing activities, to present statistics on what fracturing activity has occurred. Information to include the number of fracks, frack type (horizontal / vertical), basin, formation, fracture depth, planned fracture dimensions, actual fracture dimensions.</i>	No fracture stimulation activities have occurred in the Arkaringa Basin. Statistics from the Cooper Basin and North America are provided in Section 6.1.2.
General	DEW	<i>Whole document – to consider using the formation name Stuart Range Formation (where applicable) rather than just Stuart Range, which is also the name of a surficial feature in the region</i>	Reference updated where applicable to the Stuart Range Formation.
Summary	DEW	<i>Summary, pg. 7, 3rd para – text edit – Stratigraphically to stratigraphically</i>	Comment noted and suggested change made
Section 1.1	DEW	<i>Section 1.1, pg. 8, 3rd para – text edits</i> • <i>ash to as</i> • <i>Springs to springs</i>	Comment noted and suggested change made

EIR Section / Table	Stakeholder	Issues Raised or Comments Made	SAPEX Comment / Change
Figure 2	DEW	<i>Figure 2, pg. 11 – differing extents of the Arckaringa Basin sediments are presented in the diagram</i>	Noted, map identifies interpreted Permian thickness using subsurface data including drill holes and seismic. Caption updated to acknowledge the figure does not represent the latest published basin extent.
Section 2.3	DEW	<i>Section 2.6, pg. 15, Commonwealth EPBC Act, 2nd para – The text needs to be acknowledged that the requirement for a referral is to be reviewed if fracturing activities are to occur within the 5km ‘trigger zone’.</i>	Comment noted. Text updated to include the following statement: <i>‘If fracturing activities are proposed with the 5km trigger zone shown in Figure 2, additional consultation with both State and Federal Government Agencies (and potential impacts to MNES under EPBC) is required during the stage 3 approval process prior to any stimulation activities being approved within these trigger zones.’</i>
Section 2.4	DEW	<i>Section 2.4, pg. 14, 1st para – test edit – Department for Energy and Mining</i>	Comment noted and suggested change made
Section 4.1	DEW	<i>Section 4.1, pg. 18 – text edit – to consider referring to the Arckaringa Basin as the Arckaringa Basin region</i>	Comment noted and suggested change made
Section 4.3.1	DEW	<i>Section 4.3.1, pg. 28 – text edits</i> • 1st para –Northern to northern • 5th para – ‘South of the Arckaringa Basin’ to • ‘southern region of the Arckaringa Basin’ 6th para – wsa to was	Comment noted and suggested change made
Section 4.2	DEW	<i>Section 4.2, pg. 33, 2nd para – text edit – to consider referring to the Arckaringa Basin as the Arckaringa Basin region</i>	Comment noted and suggested change made
Section 4.2	DEW	<i>Section 4.2, pg. 34, 2nd para – text edit – change Owied to Owie the Arckaringa Basin region</i>	Comment noted and suggested change made
Section 4.4.2	DEW	<i>Section 4.4.2, pg. 35 – text edits</i> • 2nd para – add ‘(figure 10)’ to the end of the paragraph • 4th para – close bracket (Purcell 2012)	Comment noted and suggested change made

EIR Section / Table	Stakeholder	Issues Raised or Comments Made	SAPEX Comment / Change
Section 4.5	DEW	<i>Section 4.5, pg. 40 –to note that the references used in the Coffey 2007 report are dated between 1983 and 1986 and a number of regional groundwater assessments undertaken in the far north of SA in recent years, which include:</i> <i>• Bioregional Assessment Programme (Pedirka and Arckaringa basins)</i> <i>• GAB Water Resources Assessment</i> <i>• NWI - Allocating Water and Maintaining Springs in the Great Artesian Basin</i>	Noted, suggested references already incorporated into document.
Section 4.5	DEW	<i>Section 4.5, pg. 40, 2nd para – text edit – to consider text ‘main aquifer’ to ‘central region’.</i>	Comment noted and suggested change made
Section 4.5	DEW	<i>Section 4.5, pg. 40, 5th para – the second sentence requires some further explanation as it appears to be in contradiction with the 3rd paragraph and information presented in table 3 of the report.</i>	Comment noted, ‘at basin scale’ added for context.
Section 4.5	DEW	<i>Section 4.5, pg. 40, 8th para –text edit – remove the term ‘mound’ as not all GAB springs are mound springs</i>	Comment noted and suggested change made
Section 4.5	DEW	<i>Section 4.6, pg. 46, 5th para – text edit – change east to west (mis-direction previously provided)</i>	Comment noted and suggested change made

Comments on the Statement of Environmental Objectives

SEO Section / Table	Stakeholder	Issues Raised or Comments Made	Sapex Comment / Change
Objective 3	South Australia Environmental Protection Agency (EPA)	<i>A map of watercourses within the Arckaringa Basin has not been provided, however it is stated that ephemeral watercourses existing and that temporary holding ponds will not be located near significant watercourses. The EPA considers any water course as significant and a contributor to the local (and wider) ecosystem. The location of the temporary holding ponds should be in accordance EPA Guideline 509/14 Wastewater Lagoon Construction. Whilst it is acknowledged that specific locations have not been determined, locations where flooding risk is high should be avoided and the ponds should not be located within 50m of any watercourse. This information should be included in the SEO, particularly under Objective 3.</i>	Objective 3 'Guide to how Objectives can be Achieved' updated as suggested.
Objective 11	EPA	<u>Environmental Objective 11: Optimise waste avoidance, reduction, reuse, recycling, treatment and disposal (pg. 12)</u> <i>Assessment Criteria Putrescible wastes from small camp sites should be buried at an appropriate location and depth in order to prevent exposure of waste by fauna or wind/water erosion. Once covered, the site should also be compacted to further minimise the risk of future exposure</i>	Objective 11 assessment criteria updated with suggested wording.
Table 1	DEW	<i>Monitoring plans - There are a number of references to monitoring programs in the 'guide to how objectives can be achieved' section of the table 1 in the SEO. Where are these monitoring plans located? Are the monitoring plans to be prepared prior to the commencement of activities and if so when and how often are they to be reviewed? When and how are the results to be reported? To consider adding a criteria / objective that monitoring plans, for the relevant environmental objectives, are to be developed, discussed with and approved by DEM / DEW prior to the commencement of activities and that the results are to be provided to DEM / DEW in electronic format. Each monitoring plan is to outline the features that are to be monitored, frequency of monitoring, parameters to be</i>	Comment noted - monitoring plans identified in Table 1 of the SEO relate too: • Well integrity • Stimulation treatments and propagation of fractures • Water extraction volumes • Where there is potential for impact to groundwater dependent ecosystems • Fauna incursion and mortality rate in temporary ponds Any monitoring plan will be dependent on the proposed well location, proximity to local receptors, target formation, timeframes to complete valid test etc and will be assessed on a case by case basis during the activity notification process.

SEO Section / Table	Stakeholder	Issues Raised or Comments Made	Sapex Comment / Change
		<i>measured, compliance or trigger levels for each parameter and actions to be undertaken if the compliance / trigger values are exceeded. I have provided a number of templates, as examples, that used by DEW for the loading of various data sets into the state groundwater database.</i>	The EIR identifies risks associated with fracture stimulation activities within PEL122 and PEL123. The SEO documents environmental objectives and assessment criteria based on the risks identified in the EIR. These objectives are common to fracture stimulation activities throughout the area and provide the environmental framework to conduct environmentally responsible activities. The number of wells, and their locations, has not been specified in these documents as the extent and location of exploration and appraisal will be dictated by the drilling and stimulation results.
General	DEW	<i>To consider adding a glossary to the document to explain terminology used and avoid possible mis-interpretations. A glossary is provided in the EIR document, which could be filtered to relevant terminology for the SEO.</i>	Comment noted – the EIR and SEO documents are designed to be read in conjunction with each other, SAPEX believes the glossary in the EIR is sufficient for these purposes.
Section 2.1 Objective 1	DEW	<i>Objective 1 to be changed to 'Minimise loss of aquifer pressure and avoid aquifer contamination'. The 'assessment criteria' and 'guide to how the objectives can be achieved' will need to be modified to reflect this change. Addition of the 'loss of aquifer pressure' phrase relates to the potential for fracking extending into adjoining aquifers (both underlying and overlying).</i>	Comment noted and suggested changes made
Section 2.1 Objective 2	DEW	<i>Due to the significance of springs in the PEL region objective 2 is to be split into 2 separate objectives</i> <i>No impacts on groundwater dependent ecosystems</i> <i>No significant impacts on existing groundwater users</i>	Comment noted and suggested changes made

SEO Section / Table	Stakeholder	Issues Raised or Comments Made	Sapex Comment / Change
Section 2.1 Objective 3	DEW	<i>Objective 3 – to consider removing the shallow groundwater component from this objective as it is also accounted for in objective 1. The ‘assessment criteria’ and ‘guide to how the objectives can be achieved’ will need to be modified to reflect this change.</i>	Comment noted and suggested changes made
Section 2.1	DEW	<i>Section 2.1 (Objectives) – The use of generic terminology in the objectives makes them open to mis-interpretation.</i> <i>• Appropriate details are required in the assessment criteria and guide to sections in Table 1, which will provide understanding of the intent of the objective and in assessing its success.</i> <i>• The objectives also lack specifics which results in several of the objectives sounding like duplications. Making the objectives more specific would assist in both understanding the intent of the objective and in assessing its success.</i>	Objectives listed in Section 2.1 need to be read in conjunction with the ‘Assessment Criteria’ and ‘Guide to How Objective Can Be Achieved’ in Table 1. Sapex has reviewed the Objectives and has not made any further changes than those already listed in this table.
Table 1 Objective 1	DEW	<i>• Assessment criteria to be edited to ‘No contamination of aquifers as a result of fracture stimulation activities’.</i> <i>Fracturing activities are to occur in shale units, therefore the text ‘non-target / non-hydrocarbon bearing’ is not required.</i> <i>• Assessment criteria and guides need to be added relating to the objective addition ‘loss of aquifer pressure’.</i> <i>• The 2nd statement under ‘well integrity’ – is well pressure tested prior to all fracture stimulation or each stimulation? Clarification is required.</i>	Comment noted and suggested changes made SAPEX is of the opinion the ‘Guide to How’ is adequate to cover loss of aquifer pressure. The following wording was added to the Assessment Criteria <i>‘Compliance with assessment criteria relating to well integrity in the Drilling Activities SEO’</i> The well will be pressure tested prior to the stimulation program.

SEO Section / Table	Stakeholder	Issues Raised or Comments Made	Sapex Comment / Change
Table 1 Objective 2	DEW	<i>See comment above regarding the splitting of Objective 2 into 2 separate objectives.</i>	Comment noted and suggested changes made
Table 1 Objective 3	DEW	<i>See comments above regarding the removal of the shallow groundwater component from Objective 3</i>	Comment noted and suggested changes made
Section 3	DEW	<i>It is not clear in this section, including Table 2, what environmental damage is considered 'serious' or is reportable</i>	A number of serious environmental damage examples are provided in Table 2 including: • Damage, disturbance or interference to Aboriginal or non-indigenous sites of cultural and / or heritage significance without appropriate permits and approvals³. • An escape of petroleum, process substance, fracturing fluid, a chemical or a fuel to a water body, or to land in a place where it is reasonably likely to enter a water body by seepage or infiltration, or onto land that affects the health of native flora and fauna species. • Identification of cross flows in aquifers in natural hydraulic isolation, or uncontrolled flows to the surface. • Any well incident or failure that threatens or poses an imminent risk to safety or a risk of serious damage to environmental values. • Detection of a declared weed, animal / plant pathogen or plant pest species that has been introduced or spread as a direct result of activities. • Any removal of rare, vulnerable or endangered flora and fauna without appropriate permits and approvals SAPEX considers these appropriate for the purposes of the EIR.

SEO Section / Table	Stakeholder	Issues Raised or Comments Made	Sapex Comment / Change
Section 1.2	DEM	<i>Update Arckaringa Basin Drilling Activities EIR 2013 reference to include 'Initial Production Testing'.</i>	Section amended with suggested re-wording
Table 1 Objective 1	DEM	<i>Remove reference to Santos SEO.</i>	Reference to Santos SEO removed.
Table 1 Objective 2	DEM	<i>Update wording in 'Guide to' to monitoring of water extraction volumes and pressures</i>	Guide to amended with suggested re-wording
Table 1 Objective 4	DEM	<i>Suggest adding to the guide to how flowback ponds will be remediated following evaporation of fluids.</i>	No updates made, reference to remediation and rehabilitation in Objective 12.
General	DEW	<i>The SEO relates to any fracture simulation activities within the boundary of PEL's 122 and 123. There are numerous GAB springs within and near this boundary and recent studies have shown that there is potential for groundwater from aquifers, in addition to the GAB, to be supporting springs. These springs are also located within or near the extent of the Arckaringa Basin. No indication has been provided in either of the EIR/SEO documents as to likely locations of fracture stimulation activities and therefore are considered to be undertaken anywhere within the extent of PEL's 122 and 123. Fracking simulation activities within the Arckaringa Basin must account for potential impacts to the springs in the area. Has an EPBC referral been sought for fracture stimulation activities?</i>	An EPBC referral is not required. Stimulation activities will target deeper formations as discussed in Section 6.1 of the EIR and are not expected to have any impact on the GAB with the described controls in place. Sapex notes The EIR identifies risks associated with fracture stimulation activities within PEL122 and PEL123. The SEO documents environmental objectives and assessment criteria based on the risks identified in the EIR. These objectives are common to fracture stimulation activities throughout the area and provide the environmental framework to conduct environmentally responsible activities. Per Section 1.2 of the SEO, a 5km trigger zone (shown in Figure 2 of the SEO) has been identified around surface springs. Additional consultation with both State and Federal Government Agencies (and potential impacts to MNES under EPBC) is required during the stage 3 approval process prior to any stimulation activities being approved within these trigger zones.

SEO Section / Table	Stakeholder	Issues Raised or Comments Made	Sapex Comment / Change
General	DEW	<i>If fracking simulation activities are likely to only occur within a sub-region of the PEL boundary, which can be defined, and is distant to any of the GAB springs then consideration should be to defining this boundary in both the EIR and SEO documents. Should fracking stimulation activities be planned external to this boundary a subsequent review of the SEO and proposed activities would be required.</i>	Per Section 1.2 of the SEO, a 5km trigger zone (shown in Figure 2 of the SEO) has been identified around surface springs. Additional consultation with both State and Federal Government Agencies (and potential impacts to MNES under EPBC) is required during the stage 3 approval process prior to any stimulation activities being approved within these trigger zones. The number of wells, and their locations, have not been specified in these documents as the extent and location of exploration and appraisal will be dictated by the drilling and stimulation results.
General	DEW	<i>There are a number of references to monitoring programs in the 'guide to how objectives can be achieved' section of the table. Where are these monitoring plans located? Are the monitoring plans to be prepared prior to the commencement of activities and if so when and how often are they to be reviewed? When and how are the results to be reported?</i>	Reference to water monitoring programs captured in objectives 1 and 2, guide to how objectives can be achieved, of the SEO. The requirement for a site-specific water monitoring program is outside the scope of this document and will be reviewed during stage 3 approval based on well location relative to receptors.
General	DEW	<i>This is a new area of SA in which fracture stimulation is to occur. And it is recommended that monitoring of aquifer pressures and water chemistry be undertaken at both private wells and springs both prior to (as baseline) and after fracture stimulation activities to provide confidence that activities have not affected GAB springs. The monitoring program is to be designed in consultation with DEM and DEW.</i>	Reference to water monitoring programs captured in Table 11 of EIR, Control Measures and objectives 1 and 2, guide to how objectives can be achieved, of the SEO. The requirement for a water monitoring program is outside the scope of these document and will be reviewed during stage 3 approval based on well location. Any monitoring plan will be contingent on the proposed well location, proximity to local receptors, target formation, timeframes to complete valid test etc and will be assessed on a case by case basis during the activity notification process.
General	DEW	<i>The collection of all groundwater related data is to be provided to DEM in electronic format using data templates provided be DEW (attached to email).</i>	Noted.
General	DEW	<i>To note that DEWNR has been renamed and is now the Department for Environment and Water (DEW). Future versions of the documents are to reflect this.</i>	Comment noted and department reference updated

SEO Section / Table	Stakeholder	Issues Raised or Comments Made	Sapex Comment / Change
Section 1.1	DEW	<i>Section 1.1, pg. 2, editorial – when citing or referring to legislation it is preferable for the documents name to be in italics. P&GE act not completely italicised.</i>	Comment noted and legislation reference updated
Section 1.2	DEW	<i>Section 1.2, 1st paragraph, pg. 2 – editorial - reference to 'south eastern portion of the basin' to include the full basin name to avoid mis-interpretation as the GAB also extends across the area. ('south eastern portion of the Arckaringa Basin')</i>	Comment noted and basin reference updated to Arckaringa Basin
Table 1 Objective 1	DEW	<i>Table 1 – environmental objective 1:</i> <i>To consider adding the following items to the assessment criteria</i> <i>Appropriate controls exist to protect separate aquifer systems and / or hydrocarbon reservoirs that are typically in natural hydraulic isolation from each other</i> <i>There is no uncontrolled flow to surface (e.g. blow out)</i> <i>To consider adding the following items to the 'Guide to...' section.</i> <i>SAPEX to undertake baseline monitoring of aquifer pressure and water quality in areas where fracking activities are to occur both prior to and after fracking activities to show compliance.</i> <i>Seismic measurement monitoring equipment to be installed near spring groups</i> <i>'Guide to...' section – 2nd item under Fracture stimulation - fracture design needs to ensure that fracture growth does not extend into either the overlying or underlying aquifers</i>	Assessment Criteria: - Assessment criteria updated with suggested wording - Suggested inclusion not necessary, well integrity issues are subject to the requirements of the Exploration Drilling Activities SEO (SAPEX 2013) Guide to: - The following text updated into Guide to section 'Monitoring of aquifer pressure and water quality to be implemented where there is potential for impacts to groundwater dependant ecosystems and/or groundwater users.'. Sapex notes any monitoring plan will be dependent on the proposed well location, proximity to local receptors, target formation, timeframes to complete valid test etc and will be assessed on a case by case basis during the activity notification process. - Suggested inclusion not necessary, reference to diagnostic tools already included in the Guide to section. Use of diagnostic tools will be contingent on the proposed well location, proximity to local receptors, target formation, timeframes to complete valid test etc and will be assessed on a case by case basis during the activity notification process. - Guide to section amended with suggested wording
Table 1 Objective 2	DEW	<i>Table 1 – environmental objective 2:</i> <i>2nd assessment criteria to be modified:</i>	- Assessment criteria amended with suggested wording - Reference to 5km trigger zone included in Guide to, remaining suggestions have not been included for the following reasons:

SEO Section / Table	Stakeholder	Issues Raised or Comments Made	Sapex Comment / Change
		○ No impact on groundwater dependent ecosystems resulting from extraction of groundwater or fracture stimulation activities. • The 'Guide to...' section will need to be modified to reflect this change. Possible items include: ○ Seismic measurement monitoring equipment to be installed near spring groups ○ No fracture stimulation activities within X kilometres of a spring or fracture zone. ○ Proposed water supply wells reviewed to ensure that their use does not impact adversely on existing users of groundwater	○ Use of diagnostic tools contingent on the proposed well location, proximity to local receptors, target formation, timeframes to complete valid test etc and will be assessed on a case by case basis during the activity notification process. ○ Water extraction and minimising third party impacts already incorporated in Guide to.
Table 1 Objective 3	DEW	Table 1, environmental objective 3: • 2nd last item in 'Guide to' section – to correctly refer to the relevant NRM plan – SA Arid Lands Regional NRM Plan • Items in the 'Guide to' section regarding pond location, construction and leak detection also relate to environmental objective #1. Reference to these items is to be made in environmental objective #1.	• Comment noted and NRM plan reference updated • Comment noted, reference to objective 3 included in Objective 1 guide to.
Section 4	DEW	Section 4, pg. 17 –To consider extending the list of abbreviations by adding a glossary to the document to explain terminology used and avoid mis-interpretation. A glossary is provided in the EIR document, which could be filtered to relevant terminology for the SEO.	Comment noted – the EIR and SEO documents are designed to be read in conjunction with each other, SAPEX believes the glossary in the EIR is sufficient for these purposes.

Appendix 7:

Summary of Public Consultation Submissions and Responses

Comment Reference Number	Issues Raised or Summary of Comments Made by the public	SAPEX Comment / Change
1	<i>Coober Pedy Council raised concerns regarding fracture stimulation underneath the Great Artesian Basin. The GAB is the main water source for the township.</i>	The Coober Pedy district is located approximately 32km from the south-western corner of PEL 122 and approximately 90km away from the Boorthanna Trough (See Figure 2, unconventional targets are generally located within the areas shaded green to red – the Boorthanna Trough). Mitigation methods to minimise risks associated with the Great Artesian Basin are discussed extensively in Sections 5 and Section 6 of the document. Section 4.6 updated to reference Coober Pedy town supply bores. Figure 17 updated to show the town water supply bore location in relation to PEL122 & PEL123.
2	<i>The Coober Pedy community raised concerns regarding a potential contamination event reaching Coober Pedy's water supply.</i>	Sections 6.1.1 and 6.1.3 updated to incorporate work completed by Jacobs (2016) and presented by Malavazos (2016) that simulates contaminate migration caused (in the unlikely event) by fracture stimulation in the South East of South Australia. Key scenarios discussed: • Potential impact to aquifers as a result of fracture stimulation • Potential impact to aquifers due to leakage of fluid into a fault zone • Potential impact to aquifers as a result of a high-pressure fluid (contaminant) release In the unlikely event a contamination event occurs, distance of contaminant migration for all scenarios listed above ranges between 2 – 350m within 12 months after the event. All cases have been risk assessed by Jacobs (2016) using the matrix defined in the report and found to be very low to moderate, these risks will be further reduced once mitigation measures discussed in Section 5 of this report are applied.
3	<i>The Coober Pedy community raised concerns regarding seismicity caused by fracture stimulation impacting underground housing.</i>	Section 6.5.6 updated to include reference to Drummond (2016) report titled “Review of Hydrofracturing and Induce Seismicity”. Drummond (2016) concludes seismicity induced by hydrofracturing usually has zero or negative magnitudes and will not be felt or damaging. In the extremely unlikely event a seismic event occurs, it is generally only felt up to 100's m away from the source and is not a credible risk.

Comment Reference Number	Issues Raised or Summary of Comments Made by the public	SAPEX Comment / Change
4	<i>The potential impact upon the potentiometric levels (static ground water levels) at the councils Oodnadatta Track Drinking Water Supply. There is no detail on how this will be assessed.</i>	Under Objective 2 of the SEO, Sapex will avoid extracting groundwater where there is potential for impacts to groundwater dependant ecosystems and other groundwater users. Within PEL122, the Oodnadatta Track runs adjacent to the sub-crop of the Arkaringa Basin. Further South, the mapped extent of the Arkaringa Basin is approximately 25km west of the Oodnadatta track. (See Figure 5) therefore target formations are unlikely to be present underneath Council bore locations and there is no credible risk. Further, the proposed fracture stimulation activities will be designed to stay in zone of the target formation. Potential impacts and risk mitigation measures are discussed extensively in Section 6.1.
5	<i>The potential impact on the seismic activity in the area posing a threat generally to the current fault line under the mound springs. Almost all fracking has had an effect upon the seismic activity where it has been performed. How will it be assessed in this case prior to drilling and what modelling is proposed.</i>	Section 6.1 and Table 11 include reference to disruption of natural fractures supporting springs. The potential for a fracture to propagate through multiple formations at depth to surface with relevant controls in place is considered rare. As discussed in Section 6.1.2, height growth is governed by the vertical stress profile with changes in stress, with Youngs's Modulus and bulk density which typically act as barriers to fracture growth (Stress Barriers). Where sufficient barriers exist this significantly reduces the potential for growth into adjoining formations. The orientation of the fracture (planar vertical fractures, sub-vertical, t-shaped, horizontal fractures) is governed by the stress regime (normal, strike slip or reverse). Sapex disputes the comment “<i>Almost all fracking has had an effect upon the seismic activity where it has been performed</i>”. As discussed in Section 6.5.6, Drummond (2016) concludes seismicity induced by hydrofracturing usually has zero or negative magnitudes and will not be felt or damaging. In the extremely unlikely event a seismic event occurs, it is generally only felt up to 100's m away from the source (not at surface).

Comment Reference Number	Issues Raised or Summary of Comments Made by the public	SAPEX Comment / Change
		The majority of earthquakes reported in case studies from the United States of America are associated with long-term re-injection of waste water into disposal wells, Sapex are not proposing to use disposal wells for the purposes of this EIR. Section 5.3.2 discusses the fracture stimulation design process. Each design is treated on a case by case process and assessed by DEM during stage 3 approvals.
6	<i>The potential impact upon the seismic stability of the basin hence the stability of underground housing and accommodation at Coober Pedy.</i>	Drummond (2016) concludes seismicity induced by hydrofracturing usually has zero or negative magnitudes and will not be felt or damaging. In the extremely unlikely event a seismic event occurs, it is generally only felt up to 100's m away from the source (not at surface). Such an event would be very rare with negligible consequences at the wellsite. The Coober Pedy District is located approximately 32km from the south-western corner of PEL 122 and approximately 90km away from the Boorthanna Trough (See Figure 2, unconventional targets are generally located within the areas shaded green to red – the Boorthanna Trough). therefore, seismic events are not a credible risk to underground housing or accommodation in Coober Pedy. It is noted drill and blast operations have been carried out at Cairn Hill (48km SE Coober Pedy), Peculiar Knob (86km SE of Coober Pedy) and Prominent Hill (110km SE of Coober Pedy) since mining commenced with no effect to the Coober Pedy infrastructure. Explosives have also been used in and around Coober Pedy for opal mining and dugout excavations historically. It is also noted the Woomera Prohibited Area (WPA) is within 10km of Coober Pedy. The WPA is a defence premise used for testing of war material under the control of the Royal Australian Airforce.
7	<i>How is it proposed that the building rules assessors adapt to a changed seismic profile? What before and after information will be captured to assist council in building rules assessments?</i>	As discussed above and in Section 6.5.6, there is no credible risk to infrastructure as a result of fracture stimulation treatments in the Arkaringa Basin. Relevant information will be submitted to DEM per relevant legislation and approvals. It is noted drill and blast operations have been carried out at Cairn Hill (48km SE Coober Pedy), Peculiar Knob (86km SE of Coober Pedy) and Prominent Hill

Comment Reference Number	Issues Raised or Summary of Comments Made by the public	SAPEX Comment / Change
		(110km SE of Coober Pedy) since mining commenced with no effect to the Coober Pedy infrastructure. Explosives have also been used in and around Coober Pedy for opal mining and dugout excavations historically. It is also noted the Woomera Prohibited Area (WPA) is within 10km of Coober Pedy. The WPA is a defence premise used for testing of war material under the control of the Royal Australian Airforce.
8	<i>How will the effect upon the cross strata natural fracture planes which will open up the Stuart Range formation through the fracking process as part of the shale zone fracking be monitored? This issue has not been articulated in the proposal. What conditions are going to apply to avoid fracture of the confining layers and the entry of the Boorthanna aquifer into the fracture zone?</i>	It's important to note fractures are not necessarily faults and generally result from both localised and regional stresses placed on the rock. Such fracture planes can be mapped and modelled utilising wireline logging data to better understand stress regimes and ensure the horizontal well path and stimulation program are orientated to give the best chance of success (as discussed in Section 4.4.3). It's unlikely fractures within the Permian Stuart Range Formation extend to the Triassic Algebuckina Sandstone, this is evident by pressure differentials between the GAB and Permian formations. As discussed in Section 6.1.3, once the fracture stimulation treatment is performed the well is then flow tested creating a pressure sink at the wellbore. The pressure differential between fluids in the rock pore space and the wellbore is the drive mechanism that results in gas and fluid production to the well. Once flow commences the pressure gradient underground will result in fluids moving towards the well rather than migrating either upwards or away from the fracture stimulation.
9	<i>How is the effect of the perception by tourist's, investors and interpretation of the rules surrounding underground buildings relating to safety of the accommodation to be assessed and compensated?</i>	As discussed above and in Section 6.5.6, there is no credible risk to infrastructure as a result of fracture stimulation treatments in the Arkaringa Basin. Sapex does not believe fracture stimulation will affect tourist perception of below ground accommodation at Coober Pedy. It is noted drill and blast operations have been carried out at Cairn Hill (48km SE Coober Pedy), Peculiar Knob (86km SE of Coober Pedy) and Prominent Hill (110km SE of Coober Pedy) since mining commenced with no effect to the Coober Pedy community. Explosives have also been used in and around Coober Pedy for opal mining and dugout excavations historically.

Comment Reference Number	Issues Raised or Summary of Comments Made by the public	SAPEX Comment / Change
		It is also noted the Woomera Prohibited Area (WPA) is within 10km of Coober Pedy. The WPA is a defence premise used for testing of war material under the control of the Royal Australian Airforce.
10	<i>How is the industry brand effect on the state of tourism in particular to be addressed with the perception of unsafe underground housing?</i>	As discussed above and in Section 6.5.6, there is no credible risk to infrastructure as a result of fracture stimulation treatments being pumped in the Boorthanna Trough. Tourism is discussed in Section 4.8.4 including current vehicle traffic on existing roads. Sapex does not believe fracture stimulation will affect tourist perception of below ground accommodation at Coober Pedy. It is noted drill and blast operations have been carried out at Cairn Hill (48km SE Coober Pedy), Peculiar Knob (86km SE of Coober Pedy) and Prominent Hill (110km SE of Coober Pedy) since mining commenced with no effect to the Coober Pedy community. Explosives have also been used in and around Coober Pedy for opal mining and dugout excavations historically. It is also noted the Woomera Prohibited Area (WPA) is within 10km of Coober Pedy. The WPA is a defence premise used for testing of war material under the control of the Royal Australian Airforce.
11	<i>How is the lending institutions attitudes to lending for purchase of dugouts in the zone to be addressed? Two institutions have already refused loan for dugouts in Coober Pedy another is now contemplating it?</i>	Sapex assumes reference to the 'zone' is within PEL122 & PEL123 – there are not any dugouts or freehold land within the tenures. As discussed above and in Section 6.5.6, there is no credible risk to infrastructure as a result of fracture stimulation treatments in the Arckaringa Basin. It is noted drill and blast operations have been carried out at Cairn Hill (48km SE Coober Pedy), Peculiar Knob (86km SE of Coober Pedy) and Prominent Hill (110km SE of Coober Pedy) since mining commenced with no effect to the Coober Pedy community. Explosives have also been used in and around Coober Pedy for opal mining and dugout excavations historically.

Comment Reference Number	Issues Raised or Summary of Comments Made by the public	SAPEX Comment / Change
		It is also noted the Woomera Prohibited Area (WPA) is within 10km of Coober Pedy. The WPA is a defence premise used for testing of war material under the control of the Royal Australian Airforce.
12	<i>How the interpretation of the building rules in a higher risk seismic zone are to be addressed?</i>	As discussed above and in Section 6.5.6, there is no credible risk to infrastructure as a result of fracture stimulation treatments being pumped in the Arkaringa Basin. Any interpretation of building rules should be referred to the relevant local government. It is noted drill and blast operations have been carried out at Cairn Hill (48km SE Coober Pedy), Peculiar Knob (86km SE of Coober Pedy) and Prominent Hill (110km SE of Coober Pedy) since mining commenced with no effect to the Coober Pedy community. Explosives have also been used in and around Coober Pedy for opal mining and dugout excavations historically. It is also noted the Woomera Prohibited Area (WPA) is within 10km of Coober Pedy. The WPA is a defence premise used for testing of war material under the control of the Royal Australian Airforce.
13	<i>How are DEWNR concerns about aquifer interconnection effects and salinity mixing in the existing fault lines under a fracking regime close by to be addressed?</i>	The areas hydrogeology is discussed extensively in Section 4.5 including reference to the follow reports: ○ CSIRO 2012 ○ DEWNR 2013 ○ DEWNR 2015/03 ○ DEWNR 2015/14 ○ DEWNR 2016/02 As stated in Section 4.5, the work completed by DEWNR suggests inter-aquifer connectivity is not a factor within deeper areas of the basin such as the Boorthanna Trough. This is due to the development of fine siltstones and shales within the middle to lower Mount Toondina Fm and the Stuart Range Formation with both forming regional aquitards. Evidence of such lithologies are present in all offset wells within the trough including Boorthanna 1 and William Creek 1 (William Creek 1 leak off test 21.1ppg at 203m).

Comment Reference Number	Issues Raised or Summary of Comments Made by the public	SAPEX Comment / Change
		Section 4.5 discusses the Stuart Range Formation acting as an aquitard to the deeper aquifers within the Boorthanna Formation DEWNR 2015/14 concludes flow through the Stuart Range Formation is in the order of mm/1000 years indicating the GAB is not connected to the Stuart Range Formation. This test was completed at a location where all formations were thin (Bulldog Shale 18m thick, GAB 29m thick and Stuart Range Formation 57.5m thick), and the Mount Toondina Fm absent. Where the Stuart Range Formation is thicker and Mt Toondina Fm is better developed, flow is expected to be significantly lower. Seismic interpretation to date indicates the Eromanga Basin sediment deposition did not re-activate Permian faults, the Eromanga basin generally drapes such features. Evidence supporting this includes pressure differentials between the GAB and Permian formations (ie the formation pressure of the GAB is different to the formation pressure of target formations indicating faults are not currently acting as conduits).
14	<i>How is the potential for other tenements to be opened up in the Basin resulting in additional stress on the existing fault system and how that will compound effects mentioned later in this letter?</i>	Sapex holds a number of petroleum licences throughout South Australia that provides the opportunity to explore for oil & gas. Depending on the potential of the licences, fracture stimulation maybe proposed to test tight plays. In such an event Sapex will be required to undergo further consultation per relevant legislation.
15	<i>The fear for the physical health of the community and tourist?</i>	Sapex is not aware of anything that will affect the physical health of the community and tourists in Coober Pedy. The proposed operations are not located within the district council of Coober Pedy.

Comment Reference Number	Issues Raised or Summary of Comments Made by the public	SAPEX Comment / Change
16	<i>The acceleration of the declining population creating an increased burden on the remaining community and how that will be compensated.</i>	The proposed operations are not located within the district of Coober Pedy.
17	<i>How the unknown effects upon the aquifer below and above the fracking zone and it's connectedness to the GAB within fracture zones. Ref DEWNR report. The current fault lines adjacent to the simulation zone transgress through the Great Artesian and Boorthanna Basins.</i>	The areas hydrogeology is discussed extensively in Section 4.5 including reference to the follow reports: ○ CSIRO 2012 ○ DEWNR 2013 ○ DEWNR 2015/03 ○ DEWNR 2015/14 ○ DEWNR 2016/02 As stated in Section 4.5, the work completed by DEWNR suggests inter-aquifer connectivity is not a factor within deeper areas of the basin such as the Boorthanna Trough. This is due to the development of fine siltstones and shales within the middle to lower Mount Toondina Fm and the Stuart Range Formation with both forming regional aquitards. Evidence of such lithologies are present in all offset wells within the trough including Boorthanna 1 and William Creek 1 (William Creek 1 leak off test 21.1ppg at 203m). Section 4.5 discusses the Stuart Range Formation acting as an aquitard to the deeper aquifers within the Boorthanna Formation DEWNR 2015/14 concludes flow through the Stuart Range Formation is in the order of mm/1000 years indicating the GAB is not connected to the Stuart Range Formation. This test was completed at a location where all formations were thin (Bulldog Shale 18m thick, GAB 29m thick and Stuart Range Formation 57.5m thick), and the Mount Toondina Fm absent. Where the Stuart Range Formation is thicker and Mt Toondina Fm is better developed, flow is expected to be significantly lower. Seismic interpretation to date indicates the Eromanga Basin sediment deposition did not re-activate Permian faults, the Eromanga basin generally drapes such features. Evidence supporting this includes pressure differentials between the GAB and Permian formations (ie the formation pressure of the GAB is different to the

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		formation pressure of target formations indicating faults are not currently acting as conduits).
18	<i>How the lack of knowledge of the aquifer integration as detailed in the DEWNR report leaves any scientific assessment of the effects of seismic activity and the aquifers unresolved</i>	Sapex does not agree with this statement, DEWNR completed an extensive assessment including drilling as part of the Bioregional Assessment of the Arckaringa region with some key results discussed above and in Section 4.5. It is noted DEWNR 2013 referred to knowledge gaps and may be what the comment may be referring too. The scope of the DEWNR reports did not include seismicity therefore councils' reference is irrelevant. Refer to Section 6.5.6 and other comments above.
19	<i>How the GAB and the Boorthanna zones shear stress and any movement in shear stress levels may affect the springs and how it is assessed and how an increase in seismic activity is to be monitored.</i>	Stress contrasts within both the Eromanga and Arckaringa formations will act as stress barriers between the target zones and overlying aquifers (which feed the springs) as discussed in Section 4.4.3. Fracture stimulation will not impact on basin stress regimes. Seismic activity is discussed in Section 6.5.6.
20	<i>How the potential negative pore pressure during the suction phase on the spring mound potentiometric levels and how the Government will address the serious environmental consequences if the springs dry up</i>	The stimulation treatment is not expected to impact on the GAB aquifers, therefore there will not be any pressure effect on the GAB or mound springs. Council is referred to DEM regarding Government related questions.
21	<i>How can approval be granted when there is no indication in the application as to the proximity of the fracking to the springs and the technical impact cannot be modelled or assessed</i>	Well locations and proximity to local receptors will be reviewed as part of DEM's stage 3 approvals. Fracture propagation can be modelled as discussed in Section 5.3. Where necessary, modelling will be completed to determine appropriate stimulation parameters to ensure fractures stay in zone.

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		The stimulation treatment is not expected to propagate into the GAB aquifers, therefore mound springs will not be impacted. Per Section 1.1, a 5km trigger zone (shown in Figure 2) has been identified around surface Springs. Additional consultation with both State and Federal Government Agencies (and potential impacts to MNES under EPBC) is required during the stage 3 approval process prior to any stimulation activities being approved within these trigger zones.
22	<i>How are the concerns of the AMYAC indigenous community to be addressed?</i>	The area Fracture Stimulation applies to within PEL122 & PEL123 is shown in Figure 1 and discussed in section 4.8.6 of the EIR and section 1.2 of the SEO. The figure was updated in both reports to include the AMYAC Native Title area for clarity. Section 4.8.6 confirms the following: <i>“All planned fracture stimulation activities will be completed within the Arabana Native Title area. While a small portion of the Antakirinja Matu-Yankunyjtajara area falls within PEL122, this section is not included in the EIR”.</i> A meeting was held with the AMYAC board on the 17th April 2018 (as per Table 13) to discuss Sapex’s proposed operations.
23	<i>To what extent are the observation wells proposed to enable the modelling of the static ground water level before and after the fracking trial? This is information that appears to have been omitted from the proposal. This an essential piece of information that is necessary before the proposal is considered appropriate.</i>	The stimulation treatment is not expected to propagate into the GAB aquifers therefore there is no credible risk. Given this EIR only applies to exploration and appraisal fracture stimulation, monitoring bores will not be considered unless the proposed wells are located in close proximity to local receptors. The requirement for water monitoring at any particular location will be assessed on a case by case basis during stage 3 of the approvals process. In these cases, existing water bores will be used where possible. Baseline monitoring of waterbores in the Arckaringa has been completed in the past, this is discussed in section 4.5.

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24	<i>The EIR suggests that the risk of the cross connection between aquifers is covered by the “proper fracture stimulation design”. Can the proponents give an adequate explanation of how human error will be addressed for a range of potential scenarios in the drilling process? A description of the instrumentation that will be used to detect a failure and the success of rectification is not provided for in the documents.</i>	The PEL122 & PEL123 Fracture Stimulation EIR & SEO does not cover the drilling process. Please refer to Sapex’s Exploration Drilling Activities EIR & SEO for the Arckaringa Basin gazetted September 2013. Given Sapex is a high supervision operator within South Australia, all relevant operational documents will be submitted to the Minister during the activity approval process as required under the Petroleum and Geothermal Act (2000) and Regulations (2013). Within these submissions, Sapex will demonstrate the experience and competencies of third-party operators on site and the fitness for purpose of all equipment. The fracture stimulation process is discussed in Section 5. Relevant diagnostic tools are discussed in detail in Section 5.5.
25	<i>The Sapex EIR conveniently omits many more GAB springs within the project area, including the spring complex around Lake Cadibarrawirracanna and several springs from the Peake Creek West complex within PEL 122, and the Lethbridge and Billa Kalina spring complexes in PEL 123.</i>	Sapex acknowledges there are numerous springs located around the edges of PEL122 and PEL123 as demonstrated in Figure 1 of the submission. A similar map is provided in Figure 5 of the EIR taken from DEWNR (2015/03). Well locations and proximity to local receptors (including springs) will be reviewed in the Environmental Assessment Report (EAR) in compliance with the SEO for Exploration Drilling Activities in the Arckaringa Basin and submitted to DEM’s as part of the stage 3 approvals. Per Section 1.1, a 5km trigger zone (shown in Figure 2) has been identified around surface Springs. Additional consultation with both State and Federal Government Agencies (and potential impacts to MNES under EPBC) is required during the stage 3 approval process prior to any stimulation activities being approved within these trigger zones.
26	<i>The suspected interconnectivity of the different aquifers in the Arckaringa Basin (J-K aquifers/GAB, Mount Toondina Formation aquifers, and Boorthanna Formation aquifers) has been recently verified within PEL 123 (Priestley et al., 2017). This contradicts the EIR which states that connectivity between the Boorthanna Formation and overlying aquifers only exists in areas where the Mount Toondina and Stuart Range Formation are absent.</i>	Sapex disputes the conclusion that Priestly et al. (2017) report verifies interconnectivity between the Mt Toondina Formation and the Boorthanna Formation within the Boorthanna Trough. The report clearly states that interconnectivity is possible as demonstrated within the Billa Kallina Sub Basin where Permian Formations sub crop however there is no evidence for enhanced inter-aquifer leakage in the ground water system where the aquitard (the Stuart Range Formation) is present (in the Boorthanna Trough).

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	<i>Beside diffuse leakage through the pore space within the aquitard (Stuart Range Formation), Priestley et al. (2017) have highlighted the existence of preferential pathways enhancing inter-aquifer leakage. Such preferential pathways can be faults, intercalations of higher permeability sediments, or thinner aquitard sections (Cherry and Parker, 2004). Zones of enhanced inter-aquifer leakage can have a disproportional contribution to the water balance relative to their size.</i>	As discussed in Section 4.5, DEWNR (2015/03) describes the Boorthanna Formation as being heterogenous at a local scale with multiple isolated sandstone aquifers. This heterogeneity is reflected in stated lateral hydraulic conductivity figures in the Boorthanna Formation which vary from 0.02 – 5 m/d. It is thought the relatively isolated semi-discontinuous aquifers are related to sporadic turbidity flows within an otherwise quiescent glacio-marine environment and that further discontinuity may arise from syn and post depositional faults. As discussed in Section 4.5, DEWNR (2015/03) concludes the complexity of the Arckaringa Basin geology stems from fluvioglacial activity during the Permo-Carboniferous time rather than faulting. This complexity may have resulted in sub-basinal hydrogeological systems being isolated from regional flow regimes. Numerous reports referenced in Section 4.5 suggest the Billa Kalina Sub-Basin is one of these areas. As stated in Section 4.5, the work completed by DEWNR suggests inter-aquifer connectivity is not a factor within deeper areas of the basin such as the Boorthanna Trough. This is due to the development of fine siltstones and shales within the middle to lower Mount Toondina Fm and the Stuart Range Formation with both forming regional aquitards. Evidence of such lithologies are present in all offset wells within the trough including Boorthanna 1 and William Creek 1 (William Creek 1 leak off test 21.1ppg at 203m). DEWNR 2015/14 concludes flow through the Stuart Range Formation is in the order of mm/1000 years indicating the GAB is not connected to the Stuart Range Formation. This test was completed at a location where all formations were thin (Bulldog Shale 18m thick, GAB 29m thick and Stuart Range Formation 57.5m thick), and the Mount Toondina Fm absent. Where the Stuart Range Formation is thicker and Mt Toondina Fm is better developed, flow is expected to be significantly lower. Table 1 in Priestly et al., 2017 shows the location of interpreted faults were not useful to identify enhanced inter-aquifer leakage, and clearly states not all identified faults are hydraulically active. Seismic interpretation to date indicates the Eromanga Basin sediment deposition did not re-activate Permian faults, the Eromanga basin generally drapes such features. Evidence supporting this includes pressure differentials between the GAB

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		and Permian formations (ie the formation pressure of the GAB is different to the formation pressure of target formations indicating faults are not currently acting as conduits).
27	<i>Priestley et al. (2017) also mention upward inter-aquifer leakage in the spring discharge area (in this case the Billa Kalina spring complex, within PEL 123), where the hydraulic gradient brings water from the Boorthanna Formation to the surface (Figure 2). The study confirms previous work realised by DEWNR (2015b) indicating the “connectivity” between the Boorthanna Formation and the J-K aquifer does occur due to secondary permeability in the Stuart Range Formation.</i>	Sapex disputes the Priestly et al. (2017) report confirms connectivity between the Boorthanna Formation and the J-K aquifer within the Boorthanna Trough where Permian sediment are thickest. Evidence supporting this includes pressure differentials between the GAB and Permian formations (ie the formation pressure of the GAB is different to the formation pressure of target formations indicating faults are not currently acting as conduits). Priestly et al. (2017) study area is located south of PEL123 in the Billa Killina Sub-Basin where the Permian sediments sub-crop. As discussed in Section 4.5, DEWNR (2015/03) describes the Boorthanna Formation as being heterogenous at a local scale with multiple isolated sandstone aquifers. This heterogeneity is reflected in stated lateral hydraulic conductivity figures in the Boorthanna Formation which vary from 0.02 – 5 m/d. It is thought the relatively isolated semi-discontinuous aquifers are related to sporadic turbidity flows within an otherwise quiescent glacio-marine environment and that further discontinuity may arise from syn and post depositional faults. Objective 3 of DEWNR (2015/14) concludes: <i>“There was a <u>lack</u> of connectivity between the Boorthanna Formation and the J-K aquifer at the majority of the well nest locations. One location, well nest 9, provided evidence for inter-aquifer connectivity between the Boorthanna Formation and the J-K aquifer. Evidence from the hydraulics and hydrochemistry, particularly the Sr isotopes and noble gases, suggests <u>localised</u> connectivity between the Boorthanna Formation and J-K aquifer most likely due to secondary permeability in the Stuart Range Formation.”</i> Well nest 9 is located approximately 25km south west of the Prominent Hill mine where Permian sediments are thinning or outcrop (approximately 50km south of the south western corner of PEL123).

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28	<i>DEWNR (2015a) also states that “conditions similar to those described for the south-east corner of the Arckaringa Basin occur to the west of the Peake and Denison Inlier, i.e. in PEL122. Aquaterra REM (2005) and SKM (2009) also indicate that upward leakage from the Boorthanna Formation aquifer into the overlying J-K aquifer, salt pan and saline environments near the eastern edge of the Arckaringa Basin is possible on the basis of hydraulic gradient data.</i>	The reference provided refers to a table which summarises the current information prior to the study being completed. The full text within DEWNR (2015/14) states: <i>“Upwards leakage from the Boorthanna Formation aquifer into the overlying J-K aquifer, salt pan and saline environments near the eastern margin of the Arckaringa Basin is possible on the basis of hydraulic gradient data. <u>However, the Stuart Range Formation may limit this capacity.</u> Beyond this, discharge from the Arckaringa Basin is poorly understood, although conditions similar to those described for the south-east corner of the Arkcaringa Basin occur to the west of the Peak & Denison Inlier”.</i> The areas DEWNR 2015/14 is referring to is on the basin edge where the Boorhanna Formation and the GAB are in direct contact based on surface mapping. In these areas the Stuart Range Formation is either poorly formed or pinches out. The results of the investigation are further discussed in DEWNR (2015/14). As stated in Section 4.5, inter-aquifer connectivity is not a factor within deeper areas of the basin such as the Boorthanna Trough. DEWNR 2015/14 concludes flow through the Stuart Range Formation is in the order of mm/1000 years indicating the GAB is not connected to the Stuart Range Formation. This test was completed at a location within the Billa Kalina Sub-Basin where all formations were thin (Bulldog Shale 18m thick, GAB 29m thick and Stuart Range Formation 57.5m thick), and the Mount Toondina Fm absent. Where the Stuart Range Formation is thicker and Mt Toondina Formation is better developed, flow is expected to be significantly lower. Both Aquaterra REM (2005) and SKM (2009) refer to conceptual hydrogeological models prepared for the Prominent Hill Mine. As shown in Figure 17, Prominent Hill is located 18.5km south west of PEL123 and is located on a basement high. As discussed in Section 4.6, Prominent Hill extracts water from the Boorthanna Formation in the Billa Kallina Sub-Basin for mining purposes.

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29	<i>The Arckaringa Basin is significantly cross-cut by faults with sufficient vertical displacement to place in direct contact different lithologies (Howe et al., 2008). In a similar way, the different lithological units present major lateral thickness variations, with lithologies such as the Stuart Range absent in places. This come as a direct consequence of alternate episodes of erosion and deposition during the geological history of the basin (Drexel and Priess,, 1995).</i>	Seismic interpretation to date indicates the Eromanga Basin sediment deposition did not re-activate Permian faults, the Eromanga basin generally drapes such features. Evidence supporting this includes pressure differentials between the GAB and Permian formations (ie the formation pressure of the GAB is different to the formation pressure of target formations indicating faults are not currently acting as conduits). Drexel and Priess., (1995) is misrepresented within the submission as it relates to The Phanerozoic geology of South Australia. Reference to the Stuart Range Formation refers to the 170km escarpment as shown in Figure 11.1 of the report. The Stuart Range Formation is a major quaternary alluvial fan and piedmont slope unit consisting of the Callabonna Clay, the Benitos Clay, the Oolgelima Gravel, the Giddinna Formation and the Russo Beds. This does not relate to the Permian Stuart Range Formation.
30	<i>In the EIR, SAPEX states that silt units within the Lower Mount Toondina Formation constitute an additional aquitard separating the aquifers around the Stuart Range Formation and the GAB . The Lower Mount Toondina Formation comprises fluvio-lacustrine units (Figure 3). It is thus expected to present important cross bedding and lateral lithological variations. This implies that silt units in neighbouring drill holes are not necessarily continuous. Furthermore, the continuity of thin silt units would be significantly disrupted by even minor faults with little vertical play, and faults and features within the unit will constitute preferential pathways for fluid circulation. It is thus important to note silt lenses within the Lower Mount Toondina Formation do not constitute an aquitard. In any case, as stated in the Bio-Regional Assessment website, “given these uncertainties regarding the disruption and lithological composition of the Lower Mount Toondina Formation, little can be implied regarding the hydrogeological characteristics”. (Bioregional Assessments, 2017). Stating that silt units within the Lower Mount Toondina Formation would prevent pollution</i>	Arkeeta 1 is located in the Philipson Trough over 100km west of PEL123. The Philipson Trough is not covered by PEL122 or PEL123. The basin stratigraphy is misrepresented in this section of the report. The submission indicates the lower Mount Toondina Formation comprises fluvio-lacustrine depositional facies, as per Figure 3 in the submission which is not correct. The Upper Mount Toondina Formation comprises Fluvio-lacustrine depositional facies with coal swamps. The mid Mount Toondina Formation comprises deltaic – lacustrine depositional facies and the Lower Mount Toondina Formation comprises Deltaic, lacustrine – brackish – marginal marine facies. This is discussed in more detail in Section 4.4.2. Evidence of siltstone packages within the Lower Mount Toondina Formation are present in all offset wells within the trough including Boorthanna 1 and William Creek 1. Section 4.4.3 discusses how the Mount Toondina Formation provides geological separation between the Stuart Range Formation and the GAB. As discussed in Section 6.1.2, height growth is governed by the vertical stress profile with changes in stress, with Youngs’s Modulus and bulk density which typically act as barriers to fracture growth (Stress Barriers). Where sufficient barriers exist this significantly reduces the potential for growth into adjoining formations. The orientation of the

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	<i>related to the fracturing activities from reaching the GAB is thus misleading.</i>	fracture (planar vertical fractures, sub-vertical, t-shaped, horizontal fractures) is governed by the stress regime (normal, strike slip or reverse). The Bio-Regional Assessment Website states the Arckaringa assessment concluded: <i>“The assessment also found that the Arckaringa Basin is structurally complex and that most of this complexity stems from past glacial activity rather than from faulting structures. Further, the deep hydrogeological systems are isolated from the regional flow system and not affected by modern recharge.”</i>
31	<i>Pre-existing fractures require a lesser pressure to be opened and as thus constitute preferential pathways for fluid movements, so that hydraulic fracture fluid can move greater distances in pre-existing fracture systems (Lacazette and Geiser, 2013).</i>	Fracture planes can be mapped and modelled utilising wireline logging data to better understand stress regimes and ensure the horizontal well path and stimulation program are orientated to give the best chance of success (as discussed in Section 4.4.3). This interpretation assumes the fractures intersect the GAB sediments and is propped which is unlikely. Migration of any significant quantities of injected fluids away from the fracture treatment zone is considered highly unlikely, as once the fracture stimulation treatment has been completed, the well is flowed back, creating a pressure differential and a flow path from the end of the fracture treatment to the well. This pressure differential increases into the production phase of the well as production of reservoir fluids continues. Consequently, injected fluids would flow back to the well. A pressure gradient to drive vertical migration would likely not exist. As discussed in Section 6.1.3, In the unlikely event a fault was impacted, Jacobs (2016) modelled fluid travel within a fault/single fracture resulting from unintended fluid escape during fracture stimulation and concluded the risks to be low (by definition of the reports risk matrix). A 5,000psi release was assumed in a 45° fault with aperture of 0.01mm. The distance of contaminant migration after one day of escape was simulated to be approximately 350m from the well bore. Jacobs (2016) concludes that it's most unlikely that high pressure release into a fracture could migrate into shallow economic aquifers before a leak is detected and stopped.

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32	SAPEX presented data from Eagleford Shale as an analogy to the Stuart Range formation. Data in the Eagleford shale show that fractures of up to 556m have been measured using microseismicity (Davies et al., 2012). This study also determines that roughly 1% of fractures will extend more than 350m. In light of the high number of fractures created by a single fracture stimulation event, this implies that fractures of that size will be created with every stimulation episode. Fracture Stimulation in the Stuart Range (up to 250m thick in the project area) would thus create significant amount of fractures cutting it from top to bottom, necessarily connect Boorthanna aquifers and Mount Toondina aquifers.	Fracture heights of 556m in the Eagleford shale have only been observed at depths around 3300m. Fracture heights of approximately 100m are evident at 1000m depth, which is closer to the depth of the Stuart Range Formation. As discussed in Section 4.4.3, deeper fracture stimulation in general is in rock where the vertical stress (overburden) is the principal or intermediate stress (i.e. normal or strike-slip regime), leading to vertical orientation of fractures. At shallower depths the vertical stress is more likely to be the minimal principal stress (i.e. reverse regime), leading to horizontal orientation of fractures which limit height growth. Fisher and Warpinski, 2011 concludes: <i>“As wells get shallower, and the overburden stress lessens, mapped fractures are typically observed exhibiting increasingly larger horizontal components.”</i> 1% of fractures extending more than 350m refers to 1% of fracture stimulation stages, not 1% of individual cracks created by a single fracture stimulation stage. Sapex considers Davies et al. (2012) demonstrates maximum estimates where acoustic tools picked up noise. This does not necessarily mean that the fracture propagated and is connected to where the noise was measured. The paper also suggests the majority of fractures reported were less than 100m in length.
33	Using microseismicity to monitor fracture propagation is however limited and does not accurately identify pre-existing fractures that might be opened or reactivated by the fracture stimulation process, due to the very weak seismicity associated with this phenomenon. More recent studies using newer methods indicate that fracturing fluids can move at	Warpinski, 2009 has demonstrated that microseismicity accurately monitors fracture stimulation extent, including when a fault is intersected by a fracture (larger movement magnitudes are evident). Warpinski, 1998 discusses microseismic validation tests have taken place, the most extensive of which being the M-Site test in Colorado, funded by the Department of

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	<i>much greater distances in pre-existing fractures (Lacazette and Geiser, 2013), with documented distances of the order of 1000m. Pre-existing fluid paths zones such as faults will inherently facilitate the movement of fracturing fluids or freed hydrocarbons.</i>	Energy. Several approaches were taken to verify the microseismic data at this test site, including tiltmeter installation and intersection wells drilled both before and after the fracture treatment. All parameters – length, height, and azimuth – exhibited close agreement between the microseismic results and the verification technologies. Newer techniques such as Tomographic Fracture Imaging (TFI) can detect more subtle activation of natural fractures and has the potential to give a more accurate representation of the fracture network. Maximum induced fracture heights up to 1 km have been published for both microseismic monitoring and TMI (including the microseismic monitoring of geothermal fracture stimulation in the SA Cooper Basin). However, the reservoir objectives, stimulation parameters and depth these fractures occur at must be considered. Lacazette and Geiser, 2013 state that the earth's stress field and rock mechanical properties create what is effectively a seal for vertical cracks at about 700 meters below the surface. Thus, upward propagating fractures are stopped well before the approximately 300-meter maximum depth of potable ground water aquifers. Migration of any significant quantities of injected fluids away from the fracture treatment zone is considered highly unlikely, as once the fracture stimulation treatment has been completed, the well is flowed back, creating a pressure differential and a flow path from the end of the fracture treatment to the well. This pressure differential increases into the production phase of the well as production of reservoir fluids continues. Consequently, injected fluids would flow back to the well. A pressure gradient to drive vertical migration would likely not exist.
34	<i>In a situation like that of the Arckaringa Basin, where water from various aquifers supports all human presence and activities as well as fragile endemic ecosystems, this would have catastrophic consequences.</i>	There is no credible risk to the Great Artesian Basin and associated mound springs. Sapex notes formations within the Great Artesian Basin have been targeted for oil exploration and production for many years in the Cooper Basin. Over 120 wells completed in GAB sediments have been fracture stimulated to date with no adverse impacts to aquifers. Numerous hydrocarbon shows have been recorded in the GAB sediments within the Arckaringa Basin since the 60's including oil shows at Oodnadatta 1, gas shows at Cootanoorina 1 and numerous gas shows in water bores.

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		Per Section 1.1, a 5km trigger zone (shown in Figure 2) has been identified around surface Springs. Additional consultation with both State and Federal Government Agencies (and potential impacts to MNES under EPBC) is required during the stage 3 approval process prior to any stimulation activities being approved within these trigger zones.
35	<i>SAPEX offers to realise numerical simulations before actual fracturing episodes, in order to assess the potential impact of fracture stimulation. It is extremely important to keep in mind that fracture propagation in anisotropic geological units, especially containing pre-existing discontinuities, is very poorly understood. To date, numerical models fail to correctly predict fracture propagation (Hattori et al., 2017). As was explained in an earlier study: “We cannot yet accurately predict fracture propagation behaviour in detail, so to date much of what we know of how fractures will behave in situ conditions comes from operational experience” (King et al., 2008).</i>	Operational experience in the South Australia’s Cooper Basin includes over 900 fracture stimulated wells (including 120 wells fracture stimulated in the oil zones of the Great Artesian Basin), without any evidence of groundwater contamination due to fracture propagation. Numerous operators in the Cooper Basin have successfully simulated and executed fracture stimulation treatments within the GAB sediments with no adverse impacts to aquifers. Lacazette and Geiser, 2013 state that the earth’s stress field and rock mechanical properties create what is effectively a seal for vertical cracks at about 700 meters below the surface. Thus, upward propagating fractures are stopped well before the approximately 300-meter maximum depth of potable ground water aquifers. Section 4.4.3 discusses how the Mount Tonie Formation provides geological separation between the Stuart Range Formation and the GAB. As discussed in Section 6.1.2, height growth is governed by the vertical stress profile with changes in stress, with Youngs’s Modulus and bulk density which typically act as barriers to fracture growth (Stress Barriers). Where sufficient barriers exist this significantly reduces the potential for growth into adjoining formations. The orientation of the fracture (planar vertical fractures, sub-vertical, t-shaped, horizontal fractures) is governed by the stress regime (normal, strike slip or reverse).
36	<i>As stated above, fracturing fluids or freed hydrocarbons can find their way along newly created fractures or pre-existing discontinuities. Due to the interconnectivity of the various aquifers in the Arckaringa Basin, those pollutants will find their way to the GAB. This can have dramatic consequences on GAB spring ecosystems, wiping out entire species. This could also have dramatic consequences on the cattle industry, other mining activities, tourism or the water supply for human</i>	There is no credible risk to the Great Artesian Basin and associated mound springs. Per Section 1.1, a 5km trigger zone (shown in Figure 2) has been identified around surface Springs. Additional consultation with both State and Federal Government Agencies (and potential impacts to MNES under EPBC) is required during the stage 3 approval process prior to any stimulation activities being approved within these trigger zones

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	<i>consumption. (note: the risk assessment table in the EIR states that contamination of the GAB or drawdown of the GAB would have “minor” consequences).</i>	As discussed in Section 6.1.3, once the fracture stimulation treatment is performed the well is then flow tested creating a pressure sink at the wellbore. The pressure differential between fluids in the rock pore space and the wellbore is the drive mechanism that results in gas and fluid production to the well. Once flow commences the pressure gradient underground will result in fluids moving towards the well rather than migrating either upwards or away from the fracture stimulation. If flowback has a high concentration of water, the well will not be economic and will therefore be shut in or decommissioned. Sections 6.1.1 and 6.1.3 includes reference to work completed by Jacobs (2016) and presented by Malavazos (2016) that simulates contaminate migration caused (in the unlikely event) by fracture stimulation in the South East of South Australia. Key scenarios discussed: ○ Potential impact to aquifers as a result of fracture stimulation ○ Potential impact to aquifers due to leakage of fluid into a fault zone ○ Potential impact to aquifers as a result of a high-pressure fluid (contaminant) release In the unlikely event a contamination event occurs, distance of contaminant migration for all scenarios listed above ranges between 2 – 350m within 12 months after the event. All cases have been risk assessed by Jacobs (2016) using the matrix defined in the report and found to be very low to moderate, these risks will be further reduced once mitigation measures discussed in Section 5 of this report are applied. Oil and gas has been produced from the Great Artesian Basin for many years in the Cooper Basin. Further, numerous hydrocarbon shows have been recorded in the GAB sediments within the Arckaringa Basin since the 60's including oil shows at Oodnadatta 1, gas shows at Cootanoorina 1 and numerous gas shows in water bores with no adverse impacts to aquifers, pastoralists or tourism.
37	<i>It is also important to note that fracture stimulation uses proppant to keep the fractures open. This means that once a fracture has been created, it will stay open and enable the flow of any fluid, water, hydrocarbon or chemical additives used in the fracture stimulation process.</i> <i>The fluid flow in the various aquifers can be fairly slow. In the GAB it is estimated to be about 5mm/y. This also implies that pollutants could appear in an artesian spring or water bore well</i>	As discussed in Section 6.1.3, once the fracture stimulation treatment is performed the well is then flow tested creating a pressure sink at the wellbore. The pressure differential between fluids in the rock pore space and the wellbore is the drive mechanism that results in gas and fluid production to the well. Once flow commences the pressure gradient underground will result in fluids moving towards the well rather than migrating either upwards or away from the fracture stimulation. As discussed in Section 5.4, Stimulation fluid makes up is typically 99.51% water and sand. The water used for exploration and fracture stimulation will be sourced

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	<i>after the end of the hydrocarbon production, and a significant distance away from the production area.</i>	from the Great Artesian Basin and will form the bulk of the fluid. A very small percentage of chemicals will be mixed to reduce friction, remove bacteria, dissolve minerals and improve transportation of sand. The chemicals are not unique to the oil and gas industry and are found in many household products including tooth paste, baked goods, ice cream, food additives, detergents and soap. As discussed in Section 5.6 Chemical returning from a well after fracturing treatment are usually a fraction (e.g. 20% or less for chemicals and about 40% for polymers) of what was pumped down the well (King 2012, Friedman 1986, Howard 2009) and fluid disposal plans are tailored accordingly. Polymers decompose quickly at reservoir temperature, biocides are spent on organic demand and degrade, and surfactants are absorbed on rock surfaces (King 2012).
38	<i>Poorly cased water holes or de-commissioned bore holes that have not properly been sealed are also a known conduit for fracking related pollutants. There are numerous used or abandoned bore holes in the area (Figure 4). Those bore holes present a serious risk if fracture stimulation were to be conducted in the Arckaringa Basin.</i>	There is no credible risk to the Great Artesian Basin or existing and/or abandoned waterbores (poorly cased or not). The operational or abandoned water bores in the PEL122 and PEL123 area are predominately shallow (less than 50m – 100m depth pending the location) and represent no credible risk to conduct an induced fracture. As with all petroleum operations in the state, drilling sites are selected to ensure there will be no adverse interference with surface or subsurface features.
39	<i>It is also known that unconventional wells are six times more likely to have problems affecting cement and/or casing than conventional wells (Ingraffed et al., 2014). Those integrity problems can induce aquifer contamination around the well at any given level (Figure 5). This itself should constitute a high enough risk for the sustainability of the Arckaringa Basin environment to justify a ban on fracture stimulation in this area.</i>	It is known throughout the history of well construction and operations that there have been documented failures of casing and cement behind casing. However, in all documented cases the failures have mainly been attributed to historic well construction practices that have led to poor coverage of cement (preventable mishaps) within the annulus or annuli between various casing strings. According to Davies et al., 2014, where industry best practice is applied, worldwide industry experience in both conventional and unconventional petroleum resources suggests that well integrity failures are low for both active and abandoned wells. Well design and construction is discussed in Section 5.2. Mitigation measures to prevent well integrity issues identified in the conceptual illustration submitted are also discussed in detail.

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40	<i>Another likely consequence of fracture stimulation in the Arckaringa Basin would be the lowering of the water table in areas where the hydraulic gradient would drain GAB waters into deeper aquifers. Once again, the creation of propped fractures would make this phenomenon irreversible once started. This could lead to the drying out of GAB springs and water bores.</i>	There is no credible risk to the Great Artesian Basin or the water table. Per Section 1.1, a 5km trigger zone (shown in Figure 2) has been identified around surface Springs. Additional consultation with both State and Federal Government Agencies (and potential impacts to MNES under EPBC) is required during the stage 3 approval process prior to any stimulation activities being approved within these trigger zones.
41	<i>I also believe fracture stimulation activity in the Arckaringa Basin should require an approval under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999, due to the high sensitivity of endemic ecosystems in the area</i>	An EPBC referral is not required. Stimulation activities will target deeper formations as discussed in Section 6.1 and are not expected to have any impact on the GAB with the described controls in place. Per Section 1.1, a 5km trigger zone (shown in Figure 2) has been identified around surface Springs. Additional consultation with both State and Federal Government Agencies (and potential impacts to MNES under EPBC) is required during the stage 3 approval process prior to any stimulation activities being approved within these trigger zones.
42	<i>First of all, “the GAB springs of SA are complex and relatively unique ecosystems “(DEWNR 2015), and all springs in SA are protected under the EPBC Act 1999. The DEWNR Technical Report (2015 p26) identifies the many current knowledge gaps associated with the connectivity between the aquifers and springs, spring sensitivity to drawdown, limited species distribution information, mobilisation and accumulation of sulphides, heavy metals and metalloids not to mention the degree to which spring ecosystems have already been degraded post- European influences. The report further identifies human activities as the most significant risk of aquifer drawdown.</i> <i>The effects of aquifer drawdown on springs associated with the GAB include habitat fragmentation and reduction, biodiversity loss, increased risk of endemic extinctions, increased salinity and acid sulfate hazard, damage to spring structure, changes in community ecology. (DEWNR 2015)</i>	Comment noted. Per Section 1.1, a 5km trigger zone (shown in Figure 2) has been identified around surface Springs. Additional consultation with both State and Federal Government Agencies (and potential impacts to MNES under EPBC) is required during the stage 3 approval process prior to any stimulation activities being approved within these trigger zones. As discussed throughout in Section 6.1.2, height growth is governed by the vertical stress profile with changes in stress, with Youngs’s Modulus and bulk density which typically act as barriers to fracture growth (Stress Barriers). Where sufficient barriers exist this significantly reduces the potential for growth into adjoining formations. The orientation of the fracture (planar vertical fractures, sub-vertical, t-shaped, horizontal fractures) is governed by the stress regime (normal, strike slip or reverse). The risk of fractures propagating into aquifers is discussed in Section 6.1.2. Where there is potential for impacts to groundwater dependent ecosystems and/or groundwater users a water monitoring program will be implemented. This may also include diagnostic tools (discussed in Section 5.5) to monitor fracture propagation.

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	<i>Whilst the EIR identifies that “not all springs are mound springs and some springs maybe sourced from deeper aquifers other than the GAB,” it is significant here to acknowledge that we just don’t have the objective science to confirm that there is absolutely no risk to these unique, endangered and fragile wetland ecosystems (National Water Commission 2013 p1). These wetland ecosystems have survived more than one million years in the landscape (NWC 2013 p1) and as custodians of the landscape we cannot afford any additional risk no matter how small for selfish short term limited financial gain. We must manage our natural resources sustainably to ensure their healthy existence for at least another million years.</i>	As discussed in Section 6.1.3, once the fracture stimulation treatment is performed the well is then flow tested creating a pressure sink at the wellbore. The pressure differential between fluids in the rock pore space and the wellbore is the drive mechanism that results in gas and fluid production to the well. Once flow commences the pressure gradient underground will result in fluids moving towards the well rather than migrating either upwards or away from the fracture stimulation. If flowback has a high concentration of water, the well will not be economic and will therefore be decommissioned.
43	<i>The EIR fails to list all springs located within close proximity and within the PEL areas in question. The EIR only refers to the major tourist mound springs outside the PEL’s and the Francis Swamp Complex. Who will be monitoring the additional springs not listed in the EIR for example the Lake Cadibarrawirracanna Complex and The Peake Creek Group including Weedina Springs and Warrangarrana Spring, Billa kalina or Lethbridge Springs? Are these springs deemed not important enough even though they have EPBC Act protection? A line on map delineating an exploration lease area above ground does not ecologically delineate all connected processes below the soil surface. Water sourced from local aquifers are already sustaining the regional communities of Coober Pedy and William Creek and more extensively the pastoral industry; unnecessary additional ecological pressures from drilling activities maybe enough to cause the further extinction of Springs. In the EIR (pages 44 and 47) it is stated that “the majority of bores in the target area have been abandoned” due to the geological formation of the</i>	Sapex acknowledges there are numerous springs located around the edges of PEL122 and PEL123 as demonstrated in Figure 1 of the submission. A similar map is provided in Figure 5 of the EIR taken from DEWNR (2015/03). Per Section 1.1, a 5km trigger zone (shown in Figure 2) has been identified around surface Springs. Additional consultation with both State and Federal Government Agencies (and potential impacts to MNES under EPBC) is required during the stage 3 approval process prior to any stimulation activities being approved within these trigger zones. Further, well locations and proximity to local receptors (including all springs mentioned plus other) will be reviewed in the Environmental Assessment Report (EAR) and submitted to DEM as part of the stage 3 approvals. Section 4.5 discusses the hydrogeology of the region and mentions: <i>“The southern portion of PEL122 & PEL123, the Algebuckina Sandstone pinches out with only the Cadna-Owie Formation remaining. Here the GAB sub-crops at surface notable by the surface topography changing from stony plains to sand dune country. Existing drill hole data indicates the GAB formation can be weathered in part/full with common clayey bands formed</i>

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	<i>cretaceous sediments and possibly historical pastoral activities. Therefore, I advise that nonessential, opportunistic activities would merely be wasting the most precious resource we have in central arid Australia, that is our water.</i>	<i>causing isolated aquifer lenses. Water is generally sub artesian and saline (up to 12,000mg/L TDS)."</i> Most bores drilled in the area were never completed due to high salinity, not because they dried up.
44	<i>To reiterate and highlight the importance of interconnectedness of vital water in an arid landscape I refer to Allan Savory's (p 68. 1988) explanation of effective and non-effective water cycles.</i> <i>Simplistically in an effective water cycle, after one inch of rain the surface water infiltrates the soil. If during the next month there is no rainfall, then half an inch of that rain is utilised by plants and there is little run-off. Half an inch of that water remains in the subsoil. With the second fall of rain a month later, water molecules are easily absorbed into the already moist soil penetrating deeper than the first inch of rain. After the third fall of rain, water molecules finally reach and replenish the underground aquifers.</i> <i>Whereas in a non-effective water cycle water is continually lost from the environment through evaporation, surface run-off and very little infiltration. Let me explain, after one inch of rain poorly plants utilise some water and hard, compacted exposed surface soil expels water across the landscape leaving only a minimal amount to infiltrate the soil. Any infiltration is used by the poorly plants before the next rainfall event. One month later after another inch of rainfall the same scenario occurs only there is no soil moisture to enhance infiltration and the majority of water is lost from the immediate area.</i> <i>This scenario is obviously focussing on surface water and aquifer recharge, however with water being sourced from local aquifers this surely must have a longer-term effect on the localised vegetation given perennial vegetation has significant deep roots to access underground water to survive prolonged</i>	Comment noted. Any water extraction from the Great Artesian Basin will be done in accordance with relevant legislation, in particular the NRM Act and the Far North Prescribed Well Area Water Allocation Plan.

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	<i>periods of drought. For the protection of native vegetation in the longer term, localised aquifer extraction activities should be triggering additional native vegetation clearance requirements. In addition, if extremely valuable ground water is being extracted for short term mining exploration and drilling activities it is highly likely these non-essential activities are having a detrimental impact on already stressed and fragile arid vegetation and potentially the springs mentioned earlier.</i>	
45	<i>Working in the rangelands for 15 years and residing in Coober Pedy for the last 10 years I have travelled the world multiple times undertaking volunteer activities and am currently working in the environmental and tourism industries. During this time, I have met many thousands of people through my work and travel and every time I meet a new person the second question they ask is “Do you live underground?” My point being is Coober Pedy is internationally renowned for its underground living. Much of the Coober Pedy business industry focusses on the underground component with underground accommodation and tourism ventures.</i> <i>My concern being that I am not convinced Tri Star has given due consideration to the wider implications of the perceived impact fracking in the Arckaringa basin may have on Coober Pedy’s significant industries and wider community. I appreciate the drill site/s are not in the immediate vicinity of the town, whether they directly physically impact the town or not is irrelevant if tourists perceive they may not be safe staying underground. This is something which needs serious consideration given how easily hysteria drives a mob mentality just remember 9/11 and how the airlines were impacted. More closely the affect the movie Wolf creek had on outback travellers and tourism. This may seem a frivolous analogy but when people’s livelihoods, investment opportunities and communities may so easily be damaged this is a genuine concern which requires further investigation and most certainly</i>	Comment noted. The land area within the proposed PEL122 & PEL123 Fracture Stimulation EIR & SEO does not overlap the Coober Pedy township. There is no credible risk to infrastructure in Coober Pedy as a result of fracture stimulation treatments being pumped in the Boorthanna Trough (refer to Figure 2). It is noted drill and blast operations have been carried out at Cairn Hill (48km SE Coober Pedy), Peculiar Knob (86km SE of Coober Pedy) and Prominent Hill (110km SE of Coober Pedy) since mining commenced with no effect to the Coober Pedy community. Explosives have also been used in and around Coober Pedy for opal mining and dugout excavations historically. It is also noted the Woomera Prohibited Area (WPA) is within 10km of Coober Pedy. The WPA is a defence premise used for testing of war material under the control of the Royal Australian Airforce.

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	<i>does not deserve to be ignored for one company's short-term gain.</i> <i>In summing up we know we don't know enough about aquifer connectedness to be 100 percent sure drilling and fracking in one area will not detrimentally affect another area over time or initiate geological fractures beyond the scope of the models.</i> <i>As a concerned environmental citizen, underground dweller, owner of an underground dwelling and developing underground business in Coober Pedy I have significant reservations regarding the Fracture Stimulation Activities proposed for PEL 122 1nd 123.</i>	
46	<i>Finally, I draw your attention to the following comment on page 44 of the EIR which states, "weather conditions are too hot for cropping as discussed in section 4", is this just a generic cut and paste comment or does it show complete disrespect for the people, industries and legislation applicable to the area? For your information the area in question is pastoral country, largely sustained by accessing underground water, under the Pastoral Land Management and Conservation Act 1989, cropping in this region is prohibited. I suggest the company need to undertake some more homework with respect to the environment and the people who live out here 24/7.</i>	Section 4.8.1 acknowledges the relevant pastoral leases within the area covered by the EIR & SEO. Table 13 captures consultation with relevant stakeholders associated with the drafting of these documents. Sapex is unaware of any cropping within the Tenure area.
47	<i>The submission refers a number of times to impacts fracture stimulation may have on the Great Artesian Basin and associated mound springs.</i>	The stimulation treatment is not expected to impact on the GAB aquifers, therefore there is no credible risk to the GAB or associated mound springs. As discussed throughout in Section 6.1.2, height growth is governed by the vertical stress profile with changes in stress, with Youngs's Modulus and bulk density which typically act as barriers to fracture growth (Stress Barriers). Where sufficient barriers exist this significantly reduces the potential for growth into adjoining formations. The orientation of the fracture (planar vertical fractures, sub-vertical, t-

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		shaped, horizontal fractures) is governed by the stress regime (normal, strike slip or reverse). As discussed in Section 6.1.3, once the fracture stimulation treatment is performed the well is then flow tested creating a pressure sink at the wellbore. The pressure differential between fluids in the rock pore space and the wellbore is the drive mechanism that results in gas and fluid production to the well. Once flow commences the pressure gradient underground will result in fluids moving towards the well rather than migrating either upwards or away from the fracture stimulation. If flowback has a high concentration of water, the well will not be economic and will therefore be shut in or decommissioned. Sapex notes formations within the Great Artesian Basin have been targeted for oil exploration and production for many years in the Cooper Basin. Over 120 wells completed in GAB sediments have been fracture stimulated to date with no adverse impacts to aquifers. Numerous hydrocarbon shows have been recorded in the GAB sediments within the Arckaringa Basin since the 60's including oil shows at Oodnadatta 1, gas shows at Cootanoorina 1 and numerous gas shows in water bores.
48	<i>Sapex have only provided general environmental impacts. There is no mention of interconnectivity of the aquifers.</i> <i>There are only 3 springs identified.</i>	Specific environmental impacts will be reviewed in the Environmental Assessment Report (EAR) and submitted to DEM as part of the stage 3 approvals. Aquifer connectivity is discussed in Section 4.5 under the heading <u>Arckaringa Basin Aquifer Connectivity</u> Sapex acknowledges there are numerous springs located in PEL122 and PEL123 as demonstrated in Figure 5 of the EIR taken from DEWNR (2015).
49	<i>It is in fact, only recently that within our own country, the State of Queensland has been forced, in the aftermath of disastrous destruction to the country, to ban fracking throughout the state.</i>	This Statement is not correct. There is no Fracking ban in Queensland. APPEAs website indicates of 6,830 production wells drilled in Queensland, 6% (or 410) have been fracture stimulated. This percentage is increasing due to coal seam gas development.

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50	<i>The fracking has occurred in the north-east part of your state is traditional fracking. It uses perhaps a few hundred thousand litres of fracking fluid. To get gas out of shale you will need 20 million litres of fracking fluid per well. You will also need pressures three or four times higher than are currently being used for fracking jobs in your state.</i>	Estimated water usage for fracture stimulation in PEL122 and PEL123 is discussed in Section 5.9. Each fracture stimulation will require approximately 0.4 – 1.2 megalitres per stage. Fracture Stimulations completed in the Cooper Basin use between 0.35 – 1.6 megalitres per stage depending on the target formation. Exploration in the Cooper Basin targeting unconventional reservoirs were large in volume and pressure (up to 14,000 psi). Injection pressure for a shale at 1,000m is expected to be between 3,500 – 4,000 psi.
51	<i>What is the accuracy of an estimate put forward by Sapex of the amount of contaminated fluid which will result from the process?</i>	Estimated water usage for fracture stimulation in PEL122 and PEL123 is discussed in Section 5.9. Percentage of additives used in stimulation fluids is discussed in Section 5.4. Stimulation fluid flowback is discussed 5.7.
52	<i>What will be done with the large amounts of contaminated fluid from each well?</i>	Handling of flowback fluid is discussed in Section 5.8. As discussed in Section 5.4, Stimulation fluid make up is typically 99.51% water and sand. The water used for exploration and fracture stimulation will be sourced from the Great Artesian Basin and will form the bulk of the fluid. A very small percentage of chemicals will be mixed to reduce friction, remove bacteria, dissolve minerals and improve transportation of sand. The chemicals are not unique to the oil and gas industry and are found in many household products including tooth paste, baked goods, ice cream, food additives, detergents and soap.
53	<i>What will be done with the large amounts of methane?</i>	Initial production testing is discussed in Section 5.7.

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54	<i>How will the fragile ecosystems be affected by the large and constant amount of heavy vehicular traffic?</i>	All vehicular access will be completed in accordance with relevant legislation. Existing road networks and station tracks will be utilised where possible.
55	<i>Much of the report contains rather general information, without providing useful information.</i>	Specific environmental impacts relevant to target locations will be reviewed in the Environmental Assessment Report (EAR) in accordance with the approved Statement of Environmental Objectives and submitted to DEM as part of the stage 3 approvals. The EAR will provide an assessment of site-specific environmental factors relevant to the fracture stimulation proposal and identify any site-specific management measures required in addition to standard management practices. Site specific information may include well location, access, soils, landscapes, drainage, vegetation, rare or threatened species etc.
56	<i>Fracking targets are predominantly in the Stuart Range Formation and Boorthanna Formation (Arckaringa Basin Units) at 700 – 1800m depth. If separations of at least 500m (of low permeable or impermeable rocks) between the Upper Stuart Range and Lower Mount Toondina Formation and the Great Artesian Basin aquifers (Eromanga Basin) can be maintained, and no fluid flow paths by the way of geological faults or other interconnectivity can be shown to be present, then the Great Artesian Basin aquifers might possible be safeguarded from effects of fracking in deeper lithological units in the Arckaringa Basin sequence.</i>	Comment noted
57	<i>The determination of faults would require air photos or satellite imagery interpretation, and/or geophysical surveys (seismic) and the determination of the origin of groundwater. The determination of possible connection(s) between groundwater originating from specific aquifers with any artesian spring(s) requires more detailed potentiometric data and hydrochemical data and possibly isotope hydrology data.</i>	Seismic interpretation to date indicates the Eromanga Basin sediment deposition did not re-activate Permian faults, the Eromanga basin generally drapes such features. Evidence supporting this includes pressure differentials between the GAB and Permian formations (ie the formation pressure of the GAB is different to the formation pressure of target formations indicating faults are not currently acting as conduits). The Bio-Regional Assessment Website states the Arckaringa assessment concluded:

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		<i>“The assessment also found that the Arckaringa Basin is structurally complex and that most of this complexity stems from past glacial activity rather than from faulting structures. Further, the deep hydrogeological systems are isolated from the regional flow system and not affected by modern recharge.”</i>
58	<i>Although a separation of at least 500m would provide a guarantee according to the EIR, and it suggests that fracture propagation into the overlying GAB aquifers is considered improbable, recent studies indicate that groundwater present in the Stuart Range Formation and the Boorthanna Formation, and that groundwater movement occurs and interconnectivity between various geological units exist (DEWNR, 2013, 2015-03, Priestly et al., 2017).</i> <i>Direct contact exists between the Eromanga Basin (GAB) sedimentary sequence and the Mount Toondina Formation and Stuart Range Formation in some areas, in particular where paleochannels are present at the unconformity between the Eromanga Basin and the Arckaringa Basin. Although the Stuart Range acts as a regional aquitard in some areas, it is also a leaky aquitard in some areas, with possible interconnectivity and cross formational flow, however, detailed is lacking.</i>	Connectivity of the Boorthanna Formation with the GAB is referenced in Section 4.5, subsection <u>Arckaringa Basin Aquifer Connectivity</u>. It is noted the spring and majority of other data points used in the hydrochemistry data set is located in the South East of the Arckaringa Basin, within the Billa Kalina Sub Basin. Existing drill hole and seismic data indicates significant Permian erosion has occurred within this part of the basin with the removal of the Mount Toondina and Stuart Range Formation (both demonstrated to form aquitards) in part leaving the Boorthanna Formation in direct contact with the overly Great Artesian Basin (see B-B' and C-C' cross section in Figure 16). As discussed in Section 4.5, DEWNR (2015/03) concludes the complexity of the Arckaringa Basin geology stems from fluvio-glacial activity during the Permo-Carboniferous time rather than faulting. This complexity may have resulted in sub-basinal hydrogeological systems being isolated from regional flow regimes. Numerous reports referenced in Section 4.5 suggest the Billa Kalina Sub-Basin is one of these areas. As stated in Section 4.5, the work completed by DEWNR suggests inter-aquifer connectivity is not a factor within deeper areas of the basin such as the Boorthanna Trough. This is due to the development of fine siltstones and shales within the middle to lower Mount Toondina Fm and the Stuart Range Formation with both forming regional aquitards. Evidence of such lithologies are present in all offset wells within the trough including Boorthanna 1 and William Creek 1 (William Creek 1 leak off test 21.1ppg at 203m). The Bio-Regional Assessment Website states the Arckaringa assessment concluded: <i>“The assessment also found that the Arckaringa Basin is structurally complex and that most of this complexity stems from past glacial activity rather than</i>

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		<i>from faulting structures. Further, the deep hydrogeological systems are isolated from the regional flow system and not affected by modern recharge.”</i>
59	<i>That no information has been given to council on whether a security bond (and if so what amount) has been requested by the government</i>	All petroleum activities completed within the licence area are legally governed by the Petroleum & Geothermal Act (2000) and Regulations (2013). Sapex is committed to developing the project within this legislative framework. Under Section 66 of the Act – as a condition of granting or renewing a licence, the Minister may require the applicant to give security, of a kind and amount acceptable to the Minister, for the satisfaction of obligations arising under the Act or the licence.
60	<i>It has not been noted that an independent assessment under s .100(3)(a) has been committed to</i>	All petroleum activities completed within the licence area are legally governed by the Petroleum & Geothermal Act (2000) and Regulations (2013). Sapex is committed to developing the project within this legislative framework. Under Section 98 of the PGE Act the Minister for Energy and Mining or his delegate classifies the activities as either low, medium or high impact on the basis of the criteria for classifying the levels of environmental impact of regulated activities.
61	<i>That this has been rated Medium Impact activity, please state who classified this</i>	All petroleum activities completed within the licence area are legally governed by the Petroleum & Geothermal Act (2000) and Regulations (2013). Sapex is committed to developing the project within this legislative framework. Further questions relating to how Sapex is regulated should be referred to the Department of Energy and Mines.

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62	<i>That the community's plebiscite gave evidence that the majority of the town is against fracking</i>	Comment noted.
63	<i>That no information has been provided regarding the frequency and procedures of reviews and studies after each stage and if the community is consulted</i>	All petroleum activities completed within the licence area are legally governed by the Petroleum & Geothermal Act (2000) and Regulations (2013). Sapex is committed to developing the project within this legislative framework. Under Section 33 of the Petroleum and Geothermal Energy Act 2000, Licensees are required to submit Annual Reports detailing activities undertaken within each licence area during the respective licence year, as well as the activities proposed for the ensuing licence year. An important part of this reporting is to ensure that each Licensee regularly reviews, assesses and reports on their performance and compliance with the Act and relevant environmental objectives. Per Regulation 14, the SEO is required to be reviewed at least once in every 5 years.
64	<i>That no information has been provided to the community on how the government has assessed Tri-Star and SAPEX Limited</i>	All petroleum activities completed within the licence area are legally governed by the Petroleum & Geothermal Act (2000) and Regulations (2013). Sapex is committed to developing the project within this legislative framework. Questions relating to how Sapex is regulated should be referred to the Department of Energy and Mines.
65	<i>That we have not been advised if the community will be informed on any incidents, ie: will the community be advised of any contamination or aquifer impact (is this classified as a serious incident). Will these incidents be made public immediately?</i>	Serious and reportable incidents are discussed in Section 3 of SEO. Section 3.2 states: • Serious Incidents must be reported to the Minister as soon as practicable after the occurrence, as per Section 85 of the Petroleum and Geothermal Energy Act 2000 and Regulation 32. • Reportable Incidents must be reported to DPC DEM on a quarterly basis within 1 month of the end of the quarter, as per Regulation 32.

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		In the unlikely event of a contamination event, potentially impacted groundwater users will be notified.
66	<i>That no emergency response plan has been provided in case of cross-contamination of aquifers/loss of containment</i>	Under Regulation 16(2)(f), Sapex must have established a comprehensive and effective emergency response plan (ERP). The ERP and other relevant operational documents will be submitted to the Minister during the activity approval process as required under the Petroleum and Geothermal Act (2000) and Regulations (2013).
67	<i>That no information was given on the reviewer of the document (EIR) and their level of competency</i>	A full list of relevant stakeholders engaged prior to finalising the documents is provided in Section 9. Different revisions of the documents have been reviewed both internally and externally by third party consultancies. These revisions are captured in the document control table on page 2.
68	<i>That no information has been given as to how they are going to manage the risk human error in design and operation of a stimulation event</i>	Relevant operational documents will be submitted to the Minister during the activity approval process as required under the Petroleum and Geothermal Act (2000) and Regulations (2013). Within these submissions, Sapex will demonstrate the experience and competencies of third-party operators on site and the fitness for purpose of all equipment.
69	<i>That no information has been given as to how the will manage the risk of equipment/instrumentation miscalibration and failure</i>	Relevant operational documents will be submitted to the Minister during the activity approval process as required under the Petroleum and Geothermal Act (2000) and Regulations (2013). To demonstrate fitness for purpose of equipment, Sapex may submit third party inspections, maintenance schedules, operating procedures etc.

Comment Reference Number	Issues Raised or Summary of Comments Made by the public	SAPEX Comment / Change
70	<i>That no independent study has been prepared on the effects of fracking on the tourism of our town</i>	As discussed above and in Section 6.5.6, there is no credible risk to infrastructure as a result of fracture stimulation treatments in the Arckaringa Basin. Sapex does not believe fracture stimulation will affect tourist perception of below ground accommodation at Coober Pedy.
71	<i>That no independent study on the effects of our population. It is very low at this current time and nothing should be allowed to impede its increase to past numbers.</i>	The proposed operations are not located within the district council of Coober Pedy.
72	<i>That no independent study on the loss of income, ie: many Mining companies have gone bankrupt and have left owing great sums of money to local businesses</i>	The proposed operations are not located within the district council of Coober Pedy.
73	<i>That no independent study has been done on the science of this particular activity</i>	Refer to Section 5
74	<i>That it is unclear if the Arabana People were aware of the potential fracking when they signed, since it was signed back in 2006</i>	Presentations were held with the Arabana Board in Port Augusta on the 3 rd of November as listed in Table 13 to discuss Sapex's proposed operations. Sapex is committed to conducting its operations in accordance with the requirements of the Aboriginal Act 1988 and will continue to engage with both Arabana to build a co-operative and mutually beneficial relationship with the Traditional Owners of the region.

Comment Reference Number	Issues Raised or Summary of Comments Made by the public	SAPEX Comment / Change
75	<i>That the PEL should be modified if the AMYAC Native Title is not being classified as a Key Stakeholder</i>	Presentations were held with the AMYAC Board in Adelaide on the 17th April 2018 as listed in Table 13 to discuss Sapex's proposed operations. Sapex is committed to conducting its operations in accordance with the requirements of the Aboriginal Act 1988 and will continue to engage with AMYAC to build a co-operative and mutually beneficial relationship with the Traditional Owners of the region.
76	<i>That no long-term study has been provided into fracking</i>	Refer to Section 5
77	<i>That the EIR was poorly presented, as in the following cases:</i> <i>Figure 1 - Did not provide the name of the other Native Title Determination, ie: AMYAC. It also does not indicate what the red outline means in the key.</i> <i>Figure 4 - Blue outline not identified in key.</i> <i>Figure 6 – Does not state who modified the Figure and where the information came from</i> <i>Figure 8 – Where has this figure been sourced from and the Figure is too confusing too understand given that there is labels in the Figure not explained.</i> <i>Table 2 – Unclear who filled in table</i> <i>Figure 15 – No Legend</i> <i>Figure 16 – No scale given, and map did not include Coober Pedy</i> <i>Section 4.9.1 - Does not state how far Coober Pedy is from PEL areas.</i> <i>Section 6.5.6 - Not enough data has been provided to adequately state that this is not a credible risk</i> <i>Table 11 – Incorrectly evaluated – biased</i>	- Map updated to include Antakirinja Matu-Yankunytjatjara. The red polygon has been included in the key. - Figure updated with PEL boundaries - Regional structural maps modified to include PEL boundaries. Information taken from MESA Journal – (95-1007) - Per the description, the figure provides a schematic cross section of the Arkaringa Basin - Table populated by Sapex using available water quality information with reference to the Environmental Protection (Water Quality) Policy 2015 - Map described in the figure text - Map demonstrates operating mines within the region - Section 4.9.1 updated to include distance of PEL122 and PEL123 from Coober Pedy. A map is provided in Figure 1. - Section 6.5.6 updated to include reference to Drummond (2016) report titled “Review of Hydrofracturing and Induce Seismicity”. Drummond (2016) concludes seismicity induced by hydrofracturing usually has zero or negative magnitudes and will not be felt or damaging. In the extremely unlikely event a seismic event occurs, it is generally only felt up to 100's m away from the source and is not a credible risk.

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	<i>In Appendix 6 -DEWNER has mentioned the word EPBC, but this abbreviation is not listed in the Glossary</i> <i>None of the Figures showed the watercourses underneath the ground</i>	- Method used in the Environmental Risk Assessment discussed in Section 7. - EPBC refers to the Environmental Protection and Biodiversity Conservation Act 1999 and is captured in Section 11 (Abbreviations) - Hydrogeology is discussed in Section 4.5
78	CLEANING UP LARGE CONTAMINATION IN AQUIFERS MAY BE IMPOSSIBLE – EPA AT PENOLA MEETING <i>The question of cleaning up aquifers was raised at a public meeting in Penola in April 2014. As recalled, the EPA representative admitted that small contaminations can be cleaned up, but not large contaminated areas. What was perplexing was the explanation of how contamination of aquifers was dealt with. According to the EPA representative, as recalled by attendees, the water and contamination is pumped out of the aquifer. The question is, what is then done to dispose of the contaminated water once at the surface? Even with the water being treated, there is always a second lot of residue water in a concentrated form that will always remain.</i>	This EIR address's risks specific to Fracture Stimulation in PEL122 and PEL123 and concludes the likelihood of a large contamination event is unlikely (per the definition in Table 9) with the proposed mitigation measures in place. Sections 6.1.1 and 6.1.3 updated to incorporate work completed by Jacobs (2016) and presented by Malavazos (2016) that simulates contaminate migration caused (in the unlikely event) by fracture stimulation in the South East of South Australia. Key scenarios discussed: - Potential impact to aquifers as a result of fracture stimulation - Potential impact to aquifers due to leakage of fluid into a fault zone - Potential impact to aquifers as a result of a high-pressure fluid (contaminant) release In the unlikely event a contamination event occurs, distance of contaminant migration for all scenarios listed above ranges between 2 – 350m within 12 months after the event. All cases have been risk assessed by Jacobs (2016) using the matrix defined in the report and found to be very low to moderate, these risks will be further reduced once mitigation measures discussed in Section 5 of this report are applied.
79	HEALTH IMPACTS <i>In Sept. 2014, a study by Yale University found that people living near gas wells had a higher prevalence of skin conditions and upper respiratory conditions that lived closer to the wells. In Jan. 2014, a study published in the Environmental Health Perspectives showing an association between congenital heart defects and possible neural tube defects of newborn babies increasing with density and proximity of gas wells of the mother's home. At the same time, preliminary data from Princeton University, Columbia University and MIT showed low birth weight in the same</i>	This EIR address's risks specific to Fracture Stimulation in PEL122 and PEL123, Public safety and risk is discussed in Section 6.5.1. The proposed operations are not located within the district council of Coober Pedy, Sapex does not believe fracture stimulation will cause any additional health risks to people living in Coober Pedy.

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	circumstances. October 2013 Cornell University also found decreased birth weight and premature birth.	
80	<i>FOUR HUNDRED PEER-REVIEWED PAPERS SHOWING FRACKING ISSUES ARE OF THE MOST SERIOUS NATURE</i> <i>There are now around 400 peer-reviewed papers that have been evaluated in USA regarding unconventional gas and fracking issues that are of the most serious nature. These can be found at the following link.</i> <i>http://www.ernstversusencana.ca/state-of-science-on-harms-by-fracking-to-public-health-and-water-health-professionals-scientists-release-analysis-of-400-peer-reviewed-studies-on-fracking-along-with-major-scientific-compendium</i> <i>73% of all available scientific peer-reviewed papers have been published in the past 24 months. The credible scientific report is available now to prove that hydraulic fracture stimulation is having massive detrimental effects.</i>	This EIR address's risks specific to Fracture Stimulation in PEL122 and PEL123 with the results presented in Table 9. All petroleum activities completed within the licence area are legally governed by the Petroleum & Geothermal Act (2000) and Regulations (2013). Sapex is committed to developing the project within this legislative framework.
81	<i>FRACTURES CAN EXTEND 600 - 900 METRES</i> <i>In the report "SUPPORT TO THE IDENTIFICATION OF POTENTIAL RISKS FOR THE ENVIRONMENT AND HUMAN HEALTH ARISING FROM HYDROCARBON OPERATIONS INVOLVING HYDRAULIC FRACTURING IN EUROPE" done for the European Commission DG Environment, 2012, on Page 6 states that the "toe" of the horizontal leg can be up to 3 km from the vertical leg (Zoback et al., 2010 NPR). This suggests that a typical horizontal section can be expected to be 1200 to 3000 metres in length. This document also states that in a report by Fisher and Warpinski, 2012, a vertical fracture extended around 600 metres.</i>	Page 6 of the Bloomfield 2013 report discusses use of horizontal wells and typical horizontal section length, this is not referring to fracture height. An example of a typical well is demonstrated in Figure 21. In the Arckaringa Basin, the results of the vertical well will dictate the proposed length of any horizontal section. Maximum induced fracture heights up to 1 km have been published for both microseismic monitoring and TMI (including the microseismic monitoring of geothermal fracture stimulation in the SA Cooper Basin). However, the reservoir objectives, stimulation parameters and depth these fractures occur at must be considered. Bloomfield 2013 indicates analysis completed by Fisher and Warpinski 2012 suggests fracturing carried out close to the surface tended towards the formation of horizontal fracturing.

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	http://ec.europa.eu/environment/integration/energy/pdf/fracking_study.pdf <i>RJ Davies prepared a document "MARINE AND PETROLEUM GEOLOGY". Page 3 –Unintentional hydraulic stimulated fractures can occur, such as an underground blowout (e.g. Tingay 2003), or through injection of waste - water at high enough rates to generate pore pressures which exceed pressure required for hydraulic fracturing (e.g. Loseth et al., 2011). Page 5 – A petroleum company in the Tordis field offshore from Norway injected produced wastewater from oil production 900 metres below the surface. This caused hydraulic fractures to extend 900 metres to the seabed. This caused fracturing of the overburden. As the result the injection only lasted 5 ½ months and leakage to the seabed may have occurred for up to 77 days. One of the concerns is that if hydraulic fracture stimulation is allowed</i>	The Tingay et al.2005 paper referenced by Davies et al 2012 on page 3 discusses numerous underground blowouts offshore Brunei caused by a rapid increase in pore pressure due to fluid movement in a conventional setting. In these cases, the reservoirs were not artificially stimulated as proposed by Sapex, rather naturally over-pressured hydrocarbons migrated into a shallow normally pressurised reservoir where formation break over occurred. Other references refer to waste water re-injection which is a common way to dispose of produced water. Sapex are not proposing to inject wastewater as part of the Fracture Stimulation EIR and SEO.
82	<i>Numerous references from North America, Canada, Russia and the United Kingdom were provided where water injection in production water disposal wells caused seismic events</i>	Sapex are not proposing to inject wastewater as part of the PEL122 and PEL123 Fracture Stimulation EIR and SEO. Waste water disposal is discussed in Section 5.7 and 5.8. A reference paper by Adushken et al. 2000 discusses seismic activity caused directly by human involvement including water filling large surface reservoirs (dams), development of mineral, geothermal and hydrocarbon resources, waste injection, Underground explosions and large-scale construction projects. It is important to consider the conditions under which seismicity may be induced when comparing the discussed examples to what is presented in this EIR. Both the Gazli field in Uzbekistan and the Romashkino Field in Russia are located in areas of high tectonic stress. Hydrocarbon extraction in these fields is believed to have caused production induced seismic events due to significant stress changes in the reservoir and surrounding rocks. These examples are high pressured conventional fields and are not related to fracture stimulation in unconventional reservoirs. Sapex notes the only recorded human induced earthquake in Australia presented in the paper is associated with a dam, there are no examples (in Australia) where a seismic event was induced by oil and gas recovery.

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83	<i>A submission was made identifying concern is relating to rare and unique wildlife and bird species that will be adversely affected by toxic gas emitted.</i>	The environmental impact assessment for Stock, Wildlife and Vegetation is discussed in Section 6.4 Rare and threatened species are discussed in Appendix 2 and 3.
84	<i>Our concerns as an underground business, is work place safety for our staff, and customers. We are concerned about earth movement, and fracking induced earth quakes. We provide guided daily Tours through our old and modern dugouts, and our mine, which we are concerned about the danger and risk to these people, if there was to be a collapse in one of these locations. We also have bunkhouse accommodation for school groups, and large Tour groups, which would also be affected by ground movement, or structural damage.</i>	The proposed operations are not located within the district council of Coober Pedy. As discussed above and in Section 6.5.6, there is no credible risk to infrastructure as a result of fracture stimulation treatments being pumped in the Arkaringa Basin. It is noted drill and blast operations have been carried out at Cairn Hill (48km SE Coober Pedy), Peculiar Knob (86km SE of Coober Pedy) and Prominent Hill (110km SE of Coober Pedy) since mining commenced with no effect to the Coober Pedy community. Explosives have also been used in and around Coober Pedy for opal mining and dugout excavations historically. It is also noted the Woomera Prohibited Area (WPA) is within 10km of Coober Pedy. The WPA is a defence premise used for testing of war material under the control of the Royal Australian Airforce.
85	<i>If there comes a time that there is structural damage caused by ground movement, will tri star financially compensate these business/ Dugout/ Home owners?</i>	The proposed operations are not located within the district council of Coober Pedy As discussed above and in Section 6.5.6, there is no credible risk to infrastructure as a result of fracture stimulation treatments being pumped in the Arkaringa Basin.

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86	<i>We are also concerned we may lose business, if people are afraid to enter or stay underground, for fear of the danger and the risks of being underground, if there are tremors, or earth movements, or the potential of collapsing underground infrastructure.</i>	The proposed operations are not located within the district council of Coober Pedy As discussed above and in Section 6.5.6, there is no credible risk to infrastructure as a result of fracture stimulation treatments being pumped in the Arckaringa Basin. Sapex does not believe fracture stimulation will affect tourist perception of below ground accommodation at Coober Pedy. It is noted drill and blast operations have been carried out at Cairn Hill (48km SE Coober Pedy), Peculiar Knob (86km SE of Coober Pedy) and Prominent Hill (110km SE of Coober Pedy) since mining commenced with no effect to the Coober Pedy community. Explosives have also been used in and around Coober Pedy for opal mining and dugout excavations historically. It is also noted the Woomera Prohibited Area (WPA) is within 10km of Coober Pedy. The WPA is a defence premise used for testing of war material under the control of the Royal Australian Airforce.
87	<i>We are concerned that there has not been testing near underground homes before, and the risks to the structure of the underground businesses and homes, and if they are covered by insurance if they are damaged by fracking induced earth quakes. We would like to know what calculation of risk there is. This leaves us with financial uncertainty, especially as we are locked into a commercial lease for 20 years.</i>	The proposed operations are not located within the district council of Coober Pedy As discussed above and in Section 6.5.6, there is no credible risk to infrastructure as a result of fracture stimulation treatments being pumped in the Arckaringa Basin. It is noted drill and blast operations have been carried out at Cairn Hill (48km SE Coober Pedy), Peculiar Knob (86km SE of Coober Pedy) and Prominent Hill (110km SE of Coober Pedy) since mining commenced with no effect to the Coober Pedy community. Explosives have also been used in and around Coober Pedy for opal mining and dugout excavations historically. It is also noted the Woomera Prohibited Area (WPA) is within 10km of Coober Pedy. The WPA is a defence premise used for testing of war material under the control of the Royal Australian Airforce.

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88	<i>Will this devalue our businesses and residential dwellings, and if we do have structural damage to our properties, we are concerned we will be left with unsellable dwellings.</i>	The proposed operations are not located within the district council of Coober Pedy As discussed above and in Section 6.5.6, there is no credible risk to infrastructure as a result of fracture stimulation treatments being pumped in the Arckaringa Basin. It is noted drill and blast operations have been carried out at Cairn Hill (48km SE Coober Pedy), Peculiar Knob (86km SE of Coober Pedy) and Prominent Hill (110km SE of Coober Pedy) since mining commenced with no effect to the Coober Pedy community. Explosives have also been used in and around Coober Pedy for opal mining and dugout excavations historically. It is also noted the Woomera Prohibited Area (WPA) is within 10km of Coober Pedy. The WPA is a defence premise used for testing of war material under the control of the Royal Australian Airforce.
89	<i>Has there been a risk assessment done with fracking near underground living?</i>	The proposed operations are not located within the district council of Coober Pedy
90	<i>Is it true that new research has linked minor tremors to faults, that have been weakened by human activities?</i>	There are numerous examples worldwide of seismic activity caused directly by human involvement including water filling large surface reservoirs (dams), development of mineral, geothermal and hydrocarbon resources, waste injection, Underground explosions and large-scale construction projects. As discussed in Section 6.5.6, Drummond (2016) concludes seismicity induced by hydrofracturing usually has zero or negative magnitudes and will not be felt or damaging. In the extremely unlikely event a seismic event occurs, it is generally only felt up to 100's m away from the source (not at surface). Such an event would be very rare with negligible consequences at the wellsite.

Comment Reference Number	Issues Raised or Summary of Comments Made by the public	SAPEX Comment / Change
91	<i>Is it made know to the public what chemicals are in the fracking liquid in Coober Pedy, and if so, what chemicals are they, and are they safe?</i>	As discussed in Section 5.4, Stimulation fluid make up is typically 99.51% water and sand. The water used for exploration and fracture stimulation will be sourced from the Great Artesian Basin and will form the bulk of the fluid. A very small percentage of chemicals will be mixed to reduce friction, remove bacteria, dissolve minerals and improve transportation of sand. The chemicals are not unique to the oil and gas industry and are found in many household products including tooth paste, baked goods, ice cream, food additives, detergents and soap. Further, Section 5.4 states 'Where appropriate, detailed additives proposed for use in fracture stimulation operations would be provided to DEM as part of the activity approval process (see Section 2.5), along with a demonstration that the level of risk posed by these additives is consistent with this EIR'.
92	<i>Is it true that scientists have claimed to have found evidence, that even if earthquakes do not occur directly after water is injected underground, the damage they do to fault lines, can lead to tremors triggered by shockwaves from large earthquakes?</i>	There are examples in North America of seismic events caused by long term produced waste water re-injection into deep reservoirs. Sapex are not proposing to inject wastewater as part of the Fracture Stimulation EIR and SEO.
93	<i>If there is a chemical, or fuel leak, what is the time frame for this to be addressed and cleaned up, and will the public be informed?</i>	Serious and reportable incidents are discussed in Section 3 of SEO. Section 3.2 states: • Serious Incidents must be reported to the Minister as soon as practicable after the occurrence, as per Section 85 of the Petroleum and Geothermal Energy Act 2000 and Regulation 32. • Reportable Incidents must be reported to DPC DEM on a quarterly basis within 1 month of the end of the quarter, as per Regulation 32. As discussed in Section 5.10.3, all spills will be cleaned up immediately. Any potentially impacted stakeholders will be notified.

Comment Reference Number	Issues Raised or Summary of Comments Made by the public	SAPEX Comment / Change
94	<i>In the Texan Desert, the landscape is like Coober Pedy, it is believed that years of fracking has caused sinkholes in the Permian Basin, and significant ground movement, in some places up to a meter in 2.5 years, is there a risk that the Arkcaringa Basin will also develop this hazard.</i>	Sink holes in West Texas are generally associated with the dissolution of evaporites (salt) or carbonates creating voids in the subsurface. Similar geology is not present in the Arkcaringa Basin as discussed in Section 4.4.
95	<i>What is the potential pollution of ground water above wells, and the effect of flooding due to excessive rain fall?</i>	See Table 11 Surface ponds will be constructed in accordance with EPA wastewater lagoon guidelines. This allows for adequate freeboard to accommodate weather events.
96	<i>What are the hazards and risks of air pollution to the people living in Coober Pedy?</i>	Section 6.5.4 discusses environmental impacts associated with noise and air emissions at the wellsite. Sapex does not believe there is any risk of air pollution (associated with its activities) to people living in Coober Pedy.
97	<i>In 2012 researchers from the Colorado School of Public Health, released a study showing that air pollution caused by fracking, could contribute to immediate, and long-term health problems, for people living near fracking sites. If this occurs, will Tri-Star be responsible for the medical bills that are to follow, for the rest of their lives?</i>	This EIR address's risks specific to Fracture Stimulation in PEL122 and PEL123, Public safety and risk is discussed in Section 6.5.1. The proposed operations are not located within the district council of Coober Pedy, Sapex does not believe fracture stimulation will cause any additional health risks to people living in Coober Pedy.
98	<i>Research by over 150 studies suggests that chemicals released during natural gas extraction, may harm human reproduction and development, and cause birth defects.</i>	This EIR address's risks specific to Fracture Stimulation in PEL122 and PEL123, Public safety and risk is discussed in Section 6.5.1. The proposed operations are not located within the district council of Coober Pedy, Sapex does not believe fracture stimulation will cause any additional health risks to people living in Coober Pedy.

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99	<i>Has there been any studies carried out on the effects of fracking, in areas prone to seismic activity, that could result in underground homes/businesses collapsing?</i>	As discussed in Section 6.5.6, Drummond (2016) concludes seismicity induced by hydrofracturing usually has zero or negative magnitudes and will not be felt or damaging. In the extremely unlikely event a seismic event occurs, it is generally only felt up to 100's m away from the source (not at surface). Such an event would be very rare with negligible consequences at the wellsite. The Arckaringa Basin is not an area prone to seismic activity.
100	<i>Coober Pedy's only water supply is from the Great Artesian Basin, if this is compromised, and the water is polluted, what are the plans involved, to get safe drinking water to the people living in Coober Pedy, and who is responsible for paying for it?</i>	The Coober Pedy district is located approximately 32km from the most south-western corner of PEL 122 and approximately 90km away from the target zones (See Figure 2 , unconventional targets are generally located within the areas shaded green to red – the Boorthanna Trough). The stimulation treatment is not expected to impact on the GAB aquifers, therefore there is no credible risk to Coober Pedy's water supply.
101	<i>There have been 17 reported earthquakes within Australia in the last 7 days. Is this linked to the hundreds of Drill holes actioned in the Arckaringa basin.?</i>	No. As discussed in Section 6.5.6, Drummond (2016) concludes seismicity induced by hydrofracturing usually has zero or negative magnitudes and will not be felt or damaging. In the extremely unlikely event a seismic event occurs, it is generally only felt up to 100's m away from the source (not at surface). Such an event would be very rare with negligible consequences at the wellsite.
102	<i>Will ground movement increase the cost of Opal Mining, if costs go up to safely extract Opal out of mines?</i>	No. As discussed in Section 6.5.6, Drummond (2016) concludes seismicity induced by hydrofracturing usually has zero or negative magnitudes and will not be felt or damaging. In the extremely unlikely event a seismic event occurs, it is generally only felt up to 100's m away from the source (not at surface). Such an event would be very rare with negligible consequences at the wellsite. It is noted drill and blast operations have been carried out at Cairn Hill (48km SE Coober Pedy), Peculiar Knob (86km SE of Coober Pedy) and Prominent Hill (110km SE of Coober Pedy) since mining commenced with no effect to the Coober Pedy community. Explosives have also been used in and around Coober Pedy for opal mining and dugout excavations historically. It is also noted the Woomera Prohibited Area (WPA) is within 10km of Coober Pedy. The WPA is a defence premise used for testing of war material under the control of the Royal Australian Airforce.

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103	<i>The shallow depth of the target formations in relation to the GAB aquifers is very concerning. Not nearly enough information is known about the interconnectivity of these formations and the fault lines that will act as conduits for pollution. Fracking represents an unacceptable risk the Great Artesian Basin aquifers through and around which this proposed activity would drill and frack. These aquifers are unique and important and support a number of fragile and unique ecosystems such as mound springs which deserve and require protection from threatening processes including fracking.</i>	The areas hydrogeology is discussed extensively in Section 4.5 including reference to the follow reports: ○ CSIRO 2012 ○ DEWNR 2013 ○ DEWNR 2015/03 ○ DEWNR 2015/14 ○ DEWNR 2016/02 As stated in Section 4.5, the work completed by DEWNR suggests inter-aquifer connectivity is not a factor within deeper areas of the basin such as the Boorthanna Trough. This is due to the development of fine siltstones and shales within the middle to lower Mount Toondina Fm and the Stuart Range Formation with both forming regional aquitards. Evidence of such lithologies are present in all offset wells within the trough including Boorthanna 1 and William Creek 1 (William Creek 1 leak off test 21.1ppg at 203m). Section 4.5 discusses the Stuart Range Formation acting as an aquitard to the deeper aquifers within the Boorthanna Formation DEWNR 2015/14 concludes flow through the Stuart Range Formation is in the order of mm/1000 years indicating the GAB is not connected to the Stuart Range Formation. This test was completed at a location where all formations were thin (Bulldog Shale 18m thick, GAB 29m thick and Stuart Range Formation 57.5m thick), and the Mount Toondina Fm absent. Where the Stuart Range Formation is thicker and Mt Toondina Fm is better developed, flow is expected to be significantly lower.

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104	<i>Fracking poses the risk of cross contamination and the release of hydrocarbons and chemicals into these aquifers threatens not only the natural environment but also the community and industry in the region which rely on this water source for drinking and other water uses.</i> <i>The draw-down of water associated with this activity is not an appropriate use of this limited, crucial and irreplaceable water source of the Great Artesian Basin.</i>	As discussed in Section 1, Sapex plans to target the Permian aged Stuart Range and Boorthanna Formations only. The stimulation treatment is not expected to impact on the GAB aquifers, therefore there is no credible risk to the GAB or associated mound springs. Per Section 1.1, a 5km trigger zone (shown in Figure 2) has been identified around surface Springs. Additional consultation with both State and Federal Government Agencies (and potential impacts to MNES under EPBC) is required during the stage 3 approval process prior to any stimulation activities being approved within these trigger zones. While formations within the GAB are not targets for fracture stimulation under this EIR, Sapex notes formations within the GAB have been targeted for oil exploration and production for many years in the Cooper Basin. Over 120 wells completed in GAB sediments have been fracture stimulated to date with no adverse impacts to aquifers. Any water extraction from the Great Artesian Basin will be done in accordance with relevant legislation, in particular the NRM Act and the Far North Prescribed Well Area Water Allocation Plan.
105	<i>The submissions by the proponent also do not give sufficient recognition to the extremely high pressure required to frack open the target formation and the risks of high pressure, high heat environments for polluting aquifers.</i>	Injection pressure for a shale at 1,000m is expected to be between 3,500 – 4,000 psi, these pressures are much lower than deeper shale targets.
106	<i>Numerous references were made in a submission to unconventional gas extraction in Coal Seam Gas developments in Queensland.</i>	This EIR and SEO is not for a coal seam gas development

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107	<i>Fracking for unconventional oil and gas is dangerous, and this proposal does not alleviate the risk.</i>	This EIR address's risks specific to Fracture Stimulation in PEL122 and PEL123. A risk assessment is provided in Table 11 .
108	<i>The difference between conventional and unconventional gas developments.</i>	Conventional and unconventional applications are discussed in Section 3.1.1 and Section 3.1.2.
109	<i>Chemicals used in hydraulic fracturing</i>	As discussed in Section 5.4, Stimulation fluid make up is typically 99.51% water and sand. The water used for exploration and fracture stimulation will be sourced from the Great Artesian Basin and will form the bulk of the fluid. A very small percentage of chemicals will be mixed to reduce friction, remove bacteria, dissolve minerals and improve transportation of sand. The chemicals are not unique to the oil and gas industry and are found in many household products including tooth paste, baked goods, ice cream, food additives, detergents and soap. Further, Section 5.4 states 'Where appropriate, detailed additives proposed for use in fracture stimulation operations would be provided to DEM as part of the activity approval process (see Section 2.5), along with a demonstration that the level of risk posed by these additives is consistent with this EIR'.
110	<i>The possible risks or issues associated with hydraulic fracturing</i>	This EIR address's risks specific to Fracture Stimulation in PEL122 and PEL123. A risk assessment is provided in Table 11. These are discussed in greater detail in Section 5 and Section 6

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111	<i>Additional water risk: Fluid treatments and waste disposal are ineffective and/or cause additional problems</i>	Handling of flowback fluid is discussed in Section 5.6 and 5.7. Waste handling is discussed in Section 5.10.1
112	<i>Spills – a risk to surface and groundwater</i>	Spills and clean-up are discussed in Section 5.10.3 and 5.10.3, refer to Table 11 for risk assessment.
113	<i>Well integrity failure risks</i>	Well design and construction is discussed in Section 5.2, refer to Table 11 for risk assessment.
114	<i>Risk of Biogenic Hydrogen Sulphide Gas</i>	The risk of encountering hydrogen sulphide gas in a formation will be managed in accordance with recognised industry standards for appropriate containment, monitoring and emergency response procedures. Furthermore, the production of oil or gas with high sulphur content (known as “sour” oil or gas), although not occurring in South Australia, takes place around the world using recognised industry standards for containment in appropriate production equipment (such as stainless steel) and separation of sulphides from the production stream using a sulphide scavenger.
115	<i>Rehabilitation</i>	Site clean-up, rehabilitation and well abandonment (when required) would be carried out under the parameters established in the Exploration Drilling Activities EIR and SEO (SAPEX 2007 and 2013). This is referred to in Section 5.10.4

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116	<i>Fragmentation and Biosecurity</i>	The submission refers to fragmentation in forest cover in North America. Per Section 4.1, the Arckaringa Basin region is classified as arid and has a typical desert climate. Weeds are addressed in Table 11 , for more details please refer to the Exploration Drilling Activities EIR and SEO (SAPEX 2007 and 2013).
117	<i>Seismic Activity</i>	References refer to waste water re-injection which is a common way to dispose of produced water. Sapex are not proposing to inject wastewater as part of the Fracture Stimulation EIR and SEO.
118	<i>Air</i>	Refer to Section 6.5.4
119	<i>Impacts on traditional owners</i>	Sapex is committed to conducting its operations in accordance with the requirements of the Aboriginal Act 1988 and will continue to engage with both Arabana and AMYAC to build a co-operative and mutually beneficial relationship with the Traditional Owners of the region
120	<i>Social Impacts</i>	This EIR address's risks specific to Fracture Stimulation in PEL122 and PEL123. Extensive consultation has been completed with relevant stakeholder as discussed in Section 9.

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121	<i>A number of submissions were received stating general opposition to the proposed project without providing a specific reason or question, such as “I write to submit my view against fracture stimulation in the Arckaringa Basin”.</i>	Sapex acknowledges these submissions and notes petroleum activities are regulated by the Petroleum and Geothermal Act (2000) and Regulations (2013). All operations undertaken within the licence area will be completed within this legislative framework.
122	<i>A number of submissions suggest Sapex have only provided general environmental impacts without any detail on specific locations.</i>	Sapex provided a detailed discussion in the EIR (Section 5) of the components of the environment that are potentially impacted by the proposed activities. Specific environmental impacts related to proposed operational areas will be reviewed in the Environmental Assessment Report (EAR) and submitted to DEM's as part of the stage 3 approvals. All petroleum activities completed within the licence area are legally governed by the Petroleum & Geothermal Act (2000) and Regulations (2013). Sapex is committed to developing the project within this legislative framework.
123	<i>A number of submissions raised concerns associated with potential impacts to the Coober Pedy township.</i>	The Coober Pedy district is located approximately 32km from the most south-western corner of PEL 122 and approximately 90km away from the target zones (See Figure 2, unconventional targets are generally located within the areas shaded green to red – the Boorthanna Trough). There is no credible risk to Coober Pedy as a result of fracture stimulation treatments in the Boorthanna Trough. It is noted drill and blast operations have been carried out at Cairn Hill (48km SE Coober Pedy), Peculiar Knob (86km SE of Coober Pedy) and Prominent Hill (110km SE of Coober Pedy) since mining commenced with no effect to the Coober Pedy community. Explosives have also been used in and around Coober Pedy for opal mining and dugout excavations historically. It is also noted the Woomera Prohibited Area (WPA) is within 10km of Coober Pedy. The WPA is a defence premise used for testing of war material under the control of the Royal Australian Airforce.

Comment Reference Number	Issues Raised or Summary of Comments Made by the public	SAPEX Comment / Change
124	<i>A significant number of submissions were received stating their opposition to the project due to potential impacts to the Great Artesian Basin and Associated Mound Springs.</i>	As discussed in Section 1, Sapex plans to target the Permian aged Stuart Range and Boorthanna Formations only. The stimulation treatment is not expected to impact on the GAB aquifers, therefore there is no credible risk to the GAB or associated mound springs. Per Section 1.1, a 5km trigger zone (shown in Figure 2) has been identified around surface Springs. Additional consultation with both State and Federal Government Agencies (and potential impacts to MNES under EPBC) is required during the stage 3 approval process prior to any stimulation activities being approved within these trigger zones. While formations within the GAB are not targets for fracture stimulation under this EIR, Sapex notes formations within the GAB have been targeted for oil exploration and production for many years in the Cooper Basin. Over 120 wells completed in GAB sediments have been fracture stimulated to date with no adverse impacts to aquifers. Numerous hydrocarbon shows have been recorded in the GAB sediments within the Arckaringa Basin since the 60's including oil shows at Oodnadatta 1, gas shows at Cootanoorina 1 and numerous gas shows in water bores. As discussed throughout in Section 6.1.2, height growth is governed by the vertical stress profile with changes in stress, with Youngs's Modulus and bulk density which typically act as barriers to fracture growth (Stress Barriers). Where sufficient barriers exist this significantly reduces the potential for growth into adjoining formations. The orientation of the fracture (planar vertical fractures, sub-vertical, t-shaped, horizontal fractures) is governed by the stress regime (normal, strike slip or reverse). The risk of fractures propagating into aquifers is discussed in Section 6.1.2. Where there is potential for impacts to groundwater dependent ecosystems and/or groundwater users a water monitoring program will be implemented. This may also include diagnostic tools (discussed in Section 5.5) to monitor fracture propagation.

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125	<i>A number of submissions were received questioning the use of water sourced from the Great Artesian Basin for regulated petroleum activities.</i>	As discussed in Section 5.9, the drilling of water wells and the extraction of groundwater in the region (which is within the Far North Prescribed Wells Area) is regulated under the Natural Resources Management Act. Sapex is committed to undertaking its operations within this legislative framework.
126	<i>A number of submissions were received expressing environmental impact concerns associated with the volume of chemicals used in fracture stimulation fluids and how they are disposed of.</i>	As discussed in Section 5.4, Stimulation fluid makes up is typically 99.51% water and sand. The water used for exploration and fracture stimulation will be sourced from the Great Artesian Basin and will form the bulk of the fluid. A very small percentage of chemicals will be mixed to reduce friction, remove bacteria, dissolve minerals and improve transportation of sand. The chemicals are not unique to the oil and gas industry and are found in many household products including tooth paste, baked goods, ice cream, food additives, detergents and soap. A list of potential chemicals that may be used in stimulation injection fluids are provided in Appendix 5. As discussed in Section 6.1.3, once the fracture stimulation treatment is performed the well is then flow tested creating a pressure sink at the wellbore. The pressure differential between fluids in the rock pore space and the wellbore is the drive mechanism that results in gas and fluid production to the well. Once flow commences the pressure gradient underground will result in fluids moving towards the well rather than migrating either upwards or away from the fracture stimulation. The flow back of injection fluids and storage at surface is discussed in Sections 5.6, 5.7 and 5.8. At completion of production testing the ponds will be rehabilitated in accordance with relevant guidelines and legislation.
127	<i>A number of submissions were received expressing concerns associated with natural faults acting as conduits to transport stimulation fluids or hydrocarbons into aquifers.</i>	Seismic interpretation to date indicates the Eromanga Basin sediment deposition did not re-activate Permian faults, the Eromanga basin generally drapes such features. Evidence supporting this includes pressure differentials between the GAB and Permian formations (ie the formation pressure of the GAB is different to the formation pressure of target formations indicating faults are not currently acting as conduits).

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128	A number of submissions were received expressing concerns associated with the fracture stimulation process reactivating faults triggering seismic events.	As per the statement above (refer Section 6.5.6), Drummond (2016) concludes seismicity induced by fracture stimulation usually has zero or negative magnitudes and will not be felt or damaging. In the extremely unlikely event a seismic event occurs, it is generally only felt up to 100's m away from the source (not at surface). Such an event would be very rare with negligible consequences at the wellsite. It is noted the edge of PEL122 is 31km away from Coober Pedy, the edge of PEL123 is 73km away from Coober Pedy, the edge of the Boorthanna trough is 105km, therefore seismic events are not a credible risk to infrastructure in Coober Pedy. A number of submissions provided references that discuss seismic events caused by long term waste water injection in to disposal wells. Sapex notes this process is not fracture stimulation and are not proposing to use disposal wells for the purposes of this EIR.
129	A number of submissions identified concerns associated with Native Title stakeholders including the Arabana and Antakirinja Matu-Yankunytjatjara People.	The area fracture stimulation applies to within PEL122 & PEL123 is shown in Figure 1 and discussed in section 4.8.6 of the EIR and section 1.2 of the SEO. Figure 1 has been updated to include AMYAC. Section 4.8.6 confirms the following: <i>“All planned fracture stimulation activities will be completed within the Arabana Native Title area. While a small portion of the Antakirinja Matu-Yankunytjatjara area falls within PEL122, this section is not included in the EIR”.</i> Presentations were held with both Arabana (in Port Augusta) and AMYAC (in Adelaide) as listed in Table 13 to discuss Sapex's proposed operations. Sapex is committed to conducting its operations in accordance with the requirements of the Aboriginal Act 1988 and will continue to engage with both Arabana and AMYAC to build a co-operative and mutually beneficial relationship with the Traditional Owners of the region.

Comment Reference Number	Issues Raised or Summary of Comments Made by the public	SAPEX Comment / Change
130	<i>In their submission, Arabana states opposition to fracture stimulation in the Great Artesian Basin and the Lake Eyre Basin due to potential risks associated with Lake Eyre and the Wabma Kadarbu Mound Springs Conservation Park.</i>	As discussed in Section 1, Sapex plans to target the Permian aged Stuart Range and Boorthanna Formations only. Sapex are not proposing to stimulate any formations within the GAB or the Lake Eyre Basin (in fact, PEL122 and PEL123 do not cover the geological boundary of the Lake Eyre Basin). The stimulation treatment is not expected to impact on the GAB aquifers, therefore there is no credible risk to the GAB or associated mound springs. Sapex notes Lake Eyre and Wabma Kadarbu Mound Springs Conservation Park is located outside of the Licence Area (See section 4.8.3). Lake Eyre is approximately 45km to the North East of PEL123, Wabma Kadarbu Mound Springs Conservation Park is 16km to the East of PEL123. Figure 18 has been updated to include Lake Eyre and Wabma Kadarbu Mound Springs. Per Section 1.1, a 5km trigger zone (shown in Figure 2) has been identified around surface Springs. Additional consultation with both State and Federal Government Agencies (and potential impacts to MNES under EPBC) is required during the stage 3 approval process prior to any stimulation activities being approved within these trigger zones.
131	<i>In their submission, Arabana suggests fracture stimulation may be a risk to Cultural Heritage and cause destruction of site and culture.</i>	As discussed in Section 6.5.3, a Work Area Clearance will be carried out prior to undertaking any exploration or production activities in the Arckaringa Basin. Fracture stimulation operations will be undertaken on a prepared well lease, within the area cleared by the Work Area Clearance party. Signage and fencing (where required) are installed to delineate approved areas and any restricted areas. If sites of cultural heritage significance are present in the vicinity they may be flagged and/or fenced off where necessary to prevent disturbance. In addition, procedures are in place to deal with the incidental discovery of cultural heritage material. Sapex notes the proposed well locations have already been cleared by the Arabana for the proposed activities in the WAC report dated June 2018.