Environmental Impact Report

Cooper Basin Petroleum Production Operations

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1 Introduction

1.1 Background

Beach Energy's Cooper Basin production activities currently operate under the *Cooper Basin Petroleum Production Operations Statement of Environmental Objectives* (Beach 2019b). This Statement of Environmental Objectives (SEO) and the associated Environmental Impact Report (EIR) (Beach 2019a) were approved under the *Petroleum and Geothermal Energy Act 2000* in June 2019, following the five-yearly review process under the Act[1].

In March 2021 Beach Energy acquired a number of licence areas across the Cooper Basin previously held and operated by Senex Energy (Senex). Production operations in these licence areas have previously been undertaken under Senex's *Cooper Basin Petroleum Production Operations Statement of Environmental Objectives* (Senex 2017b). During the five-yearly review of the Senex production SEO (2017b) in 2022, Beach decided to integrate the acquired licence areas into the Beach production operations EIR and SEO (Beach 2019a and 2019b), creating a consolidated EIR and SEO that covers all of Beach's operational areas.

This Environmental Impact Report has been updated with relevant information for the acquired licence areas taken from the Senex production EIR (Senex 2017a), to use as the basis for the preparation of the consolidated production SEO.

1.2 Beach Energy Company Profile

Beach Energy is an oil and gas exploration and production company headquartered in Adelaide and is Australia's largest onshore oil producer. Beach has a core focus on the resource-rich Cooper Basin with gross acreage of over 31,330 km^2. During the financial year to 30 June 2021, Beach produced 25.6 million barrels of oil equivalent. At 30 June 2021, Beach held oil and gas reserves (2P) of 339 million barrels of oil equivalent and contingent oil and gas resources (2C) of 191 million barrels of oil equivalent.

In the South Australian section of the Cooper Basin, Beach undertakes oil and gas exploration and production operations under a number of Petroleum Production Licences (PPL), Petroleum Retention Licences (PRL), Associated Activities Licences (AAL) and Petroleum Exploration Licences (PEL). Beach is also a participant in the Santos-operated Cooper Basin

[1] Under Regulation 14 of the *Petroleum and Geothermal Energy Regulations 2013*, an approved Statement of Environmental Objectives (SEO) must be reviewed at least once in every five years. Beach's production SEO was originally approved in 2003, then reviewed and updated in 2008-9, 2014-15 and 2017-19. A revised SEO was approved in 2019, prepared on the basis of the Environmental Impact Report (EIR) (Beach 2019a), which consolidated the coverage of fracture stimulation into Beach's production operations in the Cooper Basin.

Joint Venture. The locations of Beach's petroleum production operations are shown in

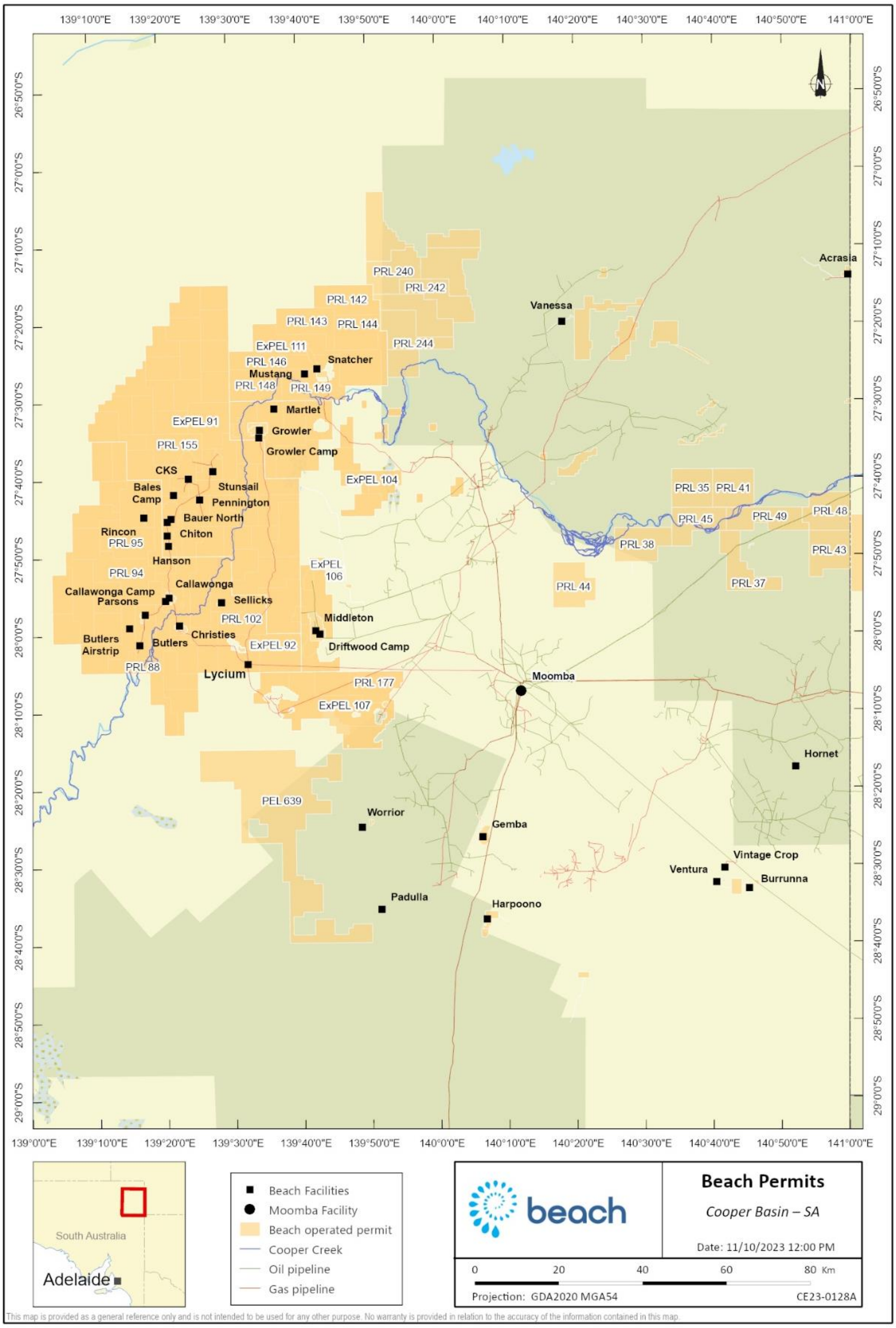

Figure 1 and Figure 2.

1.3 About this Document

This document has been prepared to satisfy the requirements of an Environmental Impact Report (EIR) under the *Petroleum and Geothermal Energy Act 2000* (PGE Act). It has been prepared in accordance with current legislative requirements, in particular with Section 97 of the PGE Act and Regulation 10 of the *Petroleum and Geothermal Energy Regulations 2013* (PGE Regulations).

This document is based on the EIR for Cooper Basin petroleum production operations (Beach 2019a) that was finalised in December 2019. It has been updated to include coverage of production operations in licence areas in the Cooper Basin recently acquired from Senex, using information from Senex (2017a), which is the existing environmental impact report covering these licence areas.

Previously published EIRs for the Cooper Basin were used to provide background information for this EIR, including detailed background information on the environment of the Cooper Basin and the environmental risks and consequences gathered over more than 30 years of operations in the Cooper Basin.

1.3.1 Scope

This EIR addresses potential environmental risks and consequences associated with Beach's production activities in the Cooper Basin (which encompasses both the Cooper and Eromanga geological basins). It has been written to address both current and potential future production activities in all land systems in the Cooper Basin, in order to develop a SEO that will address reasonably foreseeable future activities over the lifetime of the SEO.

Production operations in the future (e.g. production at new sites) will be assessed against this EIR and the revised SEO to demonstrate that the EIR and SEO are applicable, as discussed in Section 2.1.3. This assessment will be submitted to the Department for Energy and Mining (DEM) as a component of the Activity Notification, as required by Regulations 19 and 20 of the PGE Regulations. It may on occasion, be necessary to produce a bridging document or brief EIR to supplement this EIR if it does not adequately address associated risks and consequences.

The sites addressed specifically in this EIR are located on pastoral leases and the Innamincka and Strzelecki Regional Reserves. While risks and consequences of production operations are not different inside Regional Reserves, any future production operations inside Regional Reserves will require additional approval of the PPL from the Minister responsible for the *National Parks and Wildlife Act 1972*.

Beach activities that are specifically covered by this EIR include:

- well operations (after drilling has finished) including completions and workovers, well integrity management, artificial lift and wellhead production equipment, gas well deliquification and downhole abandonment following production.
- fracture stimulation
- oil and gas production facility construction, operation, maintenance and abandonment (including extended production test facilities, camps and operational areas such as laydowns)
- produced formation water disposal operations
- waterflood activities (for enhanced oil recovery) and produced water reinjection
- pipeline, trunkline and flowline construction, operation and abandonment

- road construction, maintenance and restoration
- aircraft landing area construction, maintenance and restoration
- oil transport
- waste management, landfill and land treatment unit operations
- restoration of production well sites and access tracks
- decommissioning / rehabilitation activities.

This EIR and the accompanying SEO do not apply to:

- well site and access track construction
- drilling activities
- down hole abandonment following drilling
- restoration of well sites and access tracks following drilling
- seismic operations.

These activities are covered by other EIRs and SEOs. The relevant SEOs in place at the time of preparation of this document are:

- *South Australia Cooper Basin Statement of Environmental Objectives: Drilling, Completions and Well Operations* (Santos 2021b).
- *South Australia Cooper / Eromanga Basin Environmental Impact Report: Geophysical Operations* (Santos 2018).

2 Legislative Framework

This chapter briefly describes the legislative framework that applies to petroleum activities in South Australia.

2.1 Petroleum and Geothermal Energy Act 2000

Onshore petroleum production activities are governed by the PGE Act and the PGE Regulations. This legislation is administered by DEM.

Key objectives of the legislation include:

- to create an effective, efficient and flexible regulatory system for exploration and recovery or commercial utilisation of petroleum and other regulated resources
- to minimise environmental damage from the activities involved in exploration and recovery or commercial utilisation of petroleum and other regulated resources
- to establish appropriate consultative processes involving people directly affected by regulated activities and the public generally
- to protect the public from risks inherent in regulated activities.

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.

Statement of Environmental Objectives

As a requirement of Part 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.

Under Regulation 14 of the PGE Regulations, an approved SEO must be reviewed at least once in every five years. Beach originally developed the SEO for Beach production operations in the Cooper Basin in 2003 (Beach 2003b). It was reviewed and updated in 2008/9 (Beach 2009b), 2015/16 (Beach 2016b) and in 2019 (Beach 2019b). As noted in Section 1.3, the production SEO has been revised in parallel with this EIR to include coverage of production operations in newly acquired licence areas.

2.1.1 Environmental Impact Report

In accordance with Section 97 of the PGE Act, an 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 PGE Regulations, 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 events during the construction, operational and abandonment stages, atypical events, estimated frequency of events and the basis of predictions)
- an assessment of the potential consequences of these events on the environment (including size and scope, duration, cumulative effects (if any), the extent to which these consequences can be managed or addressed and proposed management actions)
- an explanation of the basis on which these consequences have been predicted
- a list of all owners of the relevant land
- information on consultation undertaken during preparation of the EIR.

2.1.2 Environmental Significance Assessment and SEO Consultation Requirements

The EIR is submitted to DEM and an Environmental Significance Assessment is undertaken to determine whether the activities described in the EIR are to be classified as 'low', 'medium' or 'high' impact[2]. A corresponding SEO is prepared, reflecting the impacts and measures identified in the EIR or other assessments that may be required as determined by the classification.

[2] DEM's assessment is undertaken in accordance with the guideline *Criteria for classifying the level of environmental impact of regulated activities: Petroleum and Geothermal Regulatory Guidelines 004* (DEM 2019)

The classification also determines the level of consultation DEM will be required to undertake prior to final approval of the SEO as follows:

- **Low impact activities** do not require public consultation and are subjected to a process of internal government consultation and comment 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 *Planning, Development and Infrastructure Act 2016*.

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.

2.1.3 Activity Notification / Approval Process

Prior to commencing a regulated activity, Section 74(3) of the PGE Act provides that:

- The Minister's prior written approval is required for activities requiring high level supervision (as per Regulation 19), and
- Notice of activities requiring low level supervision is to be given at least 21 days in advance (as per Regulation 18).

In order to obtain written approval for activities requiring high level supervision, an application and notification of activities (in accordance with Regulation 20) must be submitted to the Minister at least 35 days prior to the commencement of activities.

The notification of activities 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 an SEO that applies to a broad geographical area, as it provides site-specific detail that is not usually contained in the generic documents.

2.1.4 Environmental Liability Management

Licensees under the PGE Act are required to account for the status of all regulated activities, and plan for management of environmental liabilities arising from undertaking regulated activities.

Liability and financial assurance for environmental is guided by DEM's Environmental Liability Management Policy (ELMP) (DEM, 2020). The ELMP encompasses all regulated activities including wells, seismic lines and infrastructure such as pipelines, flowlines, facilities and access roads. The policy takes a risk-based approach to managing liabilities set out in the policy and aims to reduce the proportion of expired wells and ensure an adequate level of financial security.

There are four elements to the ELMP:

- **Financial security**: consistent with sections 66(2) and 76 of the PGE Act the Minister may require a licensee to give security of a kind and amount acceptable to the Minister for the satisfaction of obligations under the Act. Under the ELMP this includes provision of a Rehabilitation Liability Estimate (RLE) to meet legal obligations to decommission wells, facilities, flowlines, transmission lines, access roads and seismic lines and rehabilitate land disturbed by regulated activities

- **Well activity status**: Each licensee is required to prepare an activity status report detailing all regulated activities and declaring the status of wells as active, inactive or expired. The activity status of a well as at 31 December of the preceding year will be based on monthly production reports.

- **Inactive well management**: Licensees are required to demonstrate a bona fide future use of a well that has not been in production for over 24 months, as at 31 December of the reporting year, by satisfactorily proving a future use in applying for it to be declared 'inactive'. An annual inactive well fee will apply based on the age of the well.

- **Expired well management** Licensees are required to prepare an expired well rehabilitation plan and to decommission a minimum proportion of expired wells each year to progressively reduce the number of expired wells that have no bona fide future use.

2.2 Other Legislation

A number of additional environmental approvals may be required under Commonwealth and South Australian legislation. These are outlined in Table 1. (Note that this is not a comprehensive list of all applicable legislation).

It must be noted that not all subsequent approvals are mandatory at the development (or construction) stage, as approvals may be required as circumstances arise (for example cultural artefact finds during construction or operation).

Table 1: Additional environmental legislation and approvals

Agency	Legislation	Issue
Commonwealth		
Department of Climate Change, Energy, the Environment and Water (DCCEEW)	*Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)*	Assessment and approval required if activities will significantly impact matters of national environmental significance, including: • National Heritage Places • wetlands of international importance (Ramsar wetlands) • listed threatened species and communities • listed migratory species (for example JAMBA and CAMBA) • a water resource in relation to coal seam gas and large coal mining developments.
Attorney-General's Department	*Native Title Act 1993 (Cth)*	Intersection of registered Native Title claims.
South Australia		
Department for Environment and Water (DEW)	*Heritage Places Act 1993*	Permission required if listed heritage places or related objects are to be destroyed / disturbed.
DEW	*National Parks and Wildlife Act 1972*	'Taking' of protected plant and animal species. Undertaking regulated activities in Regional Reserves.
DEW	*Native Vegetation Act 1991*	Removal of native vegetation and achievement of significant environmental benefit (SEB).
DEW	*Crown Land Management Act 2009*	Provision for the disposal, management and conservation of Crown Land in South Australia.
DEW	*Pastoral Land Management and Conservation Act 1989*	Provides for the management and conservation of pastoral land to ensure that all pastoral land in SA is well managed and utilised to maintain renewable resources and yields sustained.
DEW SAAL Landscape Board	*Landscape South Australia Act 2019* (including associated Water Allocation Plans and Water Affecting Activities Control Policy)	Management of pest plants and animals. Water sourcing (e.g. from new bores) and licensing of water extraction. Water affecting activities.
Attorney-General's Department - Aboriginal Affairs and Reconciliation	*Aboriginal Heritage Act 1988 (SA)* *Coroners Act 2003 (SA)*	Authorisation required if Aboriginal sites, objects or remains are to be damaged, disturbed or interfered with. Provides for the discovery of human skeletal remains

Agency	Legislation	Issue
Environment Protection Authority (EPA)	*Environment Protection Act 1993* (including all Environment Protection Policies (EPP) e.g. *Environment Protection (Water Quality) Policy 2015*)	General environmental duty to avoid causing environmental harm Protection of water quality Licensing of scheduled / prescribed activities e.g. • establishment of landfill site for waste disposal • transport of prescribed wastes or substances • producing listed wastes • storage or production of large volumes of petroleum (2,000 m^3 storage or 20 tonnes per hour production) • fuel burning at a rate of heat release exceeding 5 megawatts • injection of fluid containing antibiotic or chemical water treatments at a rate of more than 50 kL / day.
EPA	*Radiation Protection and Control Act 2021*	Control of activities related to radioactive substances and radiation apparatus, and for protecting the environment and the health and safety of people against the harmful effects of radiation.
Attorney General's Department	*Native Title (South Australia) Act 1994*	Matters relating to traditional land rights in South Australia. The Act provides for the registration of native title rights, investigations on native title rights, claims and determinations of native title rights and compensation for acts affecting native title rights.
Safework SA	*Explosives Act (South Australia) 1936*	Regulates the manufacture, carriage, storage, import and purchase or explosives.
Safework SA	*Work Health and Safety Act 2012*	Identifies control measures to be applied to specific work activities and hazards.

Other legislation of particular relevance to the proposed activities includes:

- *Fire and Emergency Services Regulations 2005* – in relation to fire bans and hot work permits.
- *South Australian Public Health (Wastewater) Regulations 2013* – in relation to wastewater (sewage) disposal and the operation of septic tank systems with respect to the Department of Health's requirements / approval.

<u>EPBC Act</u>

Approval under the Commonwealth EPBC Act is required for activities that have a significant impact on matters of national environmental significance including World Heritage properties, National Heritage places, Ramsar wetlands of international importance, nationally threatened species and ecological communities, migratory species and water resources in relation to coal seam gas and large coal mining developments.

In regard to petroleum activities in the Cooper 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).

Beach will continue to review proposed activities against the EPBC Act triggers and will submit a referral under the Act for specific activities if necessary. Any future projects involving coal seam gas would need to be referred if they are likely to have a significant impact on a water resource[3].

Native Vegetation Act and Regulations

The South Australian *Native Vegetation Act 1991* and the *Native Vegetation Regulations 2017* apply to vegetation clearance for petroleum operations. Under Regulation 14 of the Native Vegetation Regulations:

1. Clearance of native vegetation incidental to operations authorised under the PGE Act is permitted if it is undertaken in accordance with—
   a. a management plan, approved by the Native Vegetation Council for implementation, that results in a significant environmental benefit; and
   b. in the case of operations authorised under a Mining Act—a management plan under that Act; and
   c. in the case of operations authorised under the PGE Act—a statement of environmental objectives under that Act.
2. Subregulation (1)(a) does not apply if the person undertaking the activities or operations (or a person acting on the person's behalf) has made a payment into the Native Vegetation Fund of an amount considered by the Council to be sufficient to achieve a significant environmental benefit in the manner contemplated by Section 21(6) or (6a) of the Act.

Guidelines[4] have been developed to provide a framework for determining the SEB requirement or the amount for payment into the Native Vegetation Fund. These guidelines are administered by DEM, who have delegated authority to approve SEBs.

A requirement to achieve a SEB will be included in the accompanying SEO.

Environment Protection Act

The *Environment Protection Act 1993* (EP Act) imposes a general environmental duty 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. The general environmental duty also requires that all steps reasonable and practicable are undertaken to minimise impacts to groundwater including the application of the waste hierarchy and best available technology economically achievable (BATEA).

Environmental authorisations are required to undertake activities prescribed under the Act. Beach holds the following licences:

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[3] South Australia is also a signatory to the National Partnership Agreement on Coal Seam Gas and Large Coal Mining Development. As a consequence, any coal seam gas projects must also be referred by DSD to the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC) for advice under the South Australian protocol for the referral of project applications to the IESC.

[4] *MG16 Guide for a significant environmental benefit for the clearance of native vegetation associated with the Minerals and Petroleum Industry* (NVC 2017).

- EPA 51383) for the *Callawonga Oil Field and other Places within the Cooper Basin Region SA*
- EPA 31222 for other *premises in the Eromanga and Cooper Basins*.

These licences currently cover the following prescribed activities:

- 1(5)(a) Hydrocarbon storage
- 1(5)(b) Hydrocarbon production, storage or processing works or facilities 3(5)(a) Activity producing listed waste
- 8(2)(a) Fuel burning not coal or wood
- 8(7) Discharges to marine or inland waters.

The EP Act also imposes an obligation to report incidents causing or threatening serious or material harm to the EPA, where applicable, in accordance with Sections 83 and 83A of the Act.

The EP Act does not apply to petroleum exploration activity undertaken under the PGE Act or to wastes produced in the course of an activity (not being a prescribed activity of environmental significance) authorised by a licence under the PGE Act when produced and disposed of to land and contained within the area of the licence.

Landscape South Australia Act

The Landscape South Australia Act (LSA Act) (which replaced the *Natural Resources Management Act 2004* in July 2020) applies to a range of aspects of natural resource management. Of particular relevance to production and processing operations are provisions in the Act addressing activities which affect surface water and groundwater resources. The Act also provides for the prevention or control of impacts caused by pest species of animals and plants that may have an adverse effect on the environment, primary production or the community.

Drilling of new water sourcing bores, conversion of petroleum wells to water supply wells or abandonment of water wells requires a permit under the LSA Act. The Cooper Basin is located within the Far North Prescribed Wells Area which is covered by a Water Allocation Plan under the LSA Act. Extraction of groundwater within the Far North Prescribed Wells Area generally requires a licence/allocation under this Act. Beach has a regulatory authorisation for groundwater extraction associated with production and processing activities.

The LSA Act and the regional Water Affecting Activities Control Policy (SAAL Landscape Board 2021a) also set out a number of water affecting activities that must not be undertaken without a permit.

3 Production Operations

This section provides a description of production operations that are currently being or likely to be carried out by Beach in the Cooper Basin.

Production operations have been grouped into the following categories:

- well operations (including completions and workovers, well integrity management, artificial lift and wellhead production equipment, gas well deliquification and downhole abandonment following production)
- fracture stimulation
- production facilities (including oil and gas production facilities and support infrastructure)
- produced formation water disposal
- waterflood and reinjection activities
- pipelines / flowlines
- road construction and maintenance
- aircraft landing area
- oil transport
- waste management, landfill and land treatment operations
- decommissioning / rehabilitation.

Production operations can be undertaken under a number of different types of licence under the PGE Act, including a PPL, PRL, PEL (e.g. extended production tests), AAL and Pipeline Licence (PL) (e.g. for roads or pipelines outside Beach's PELs or PPLs). Figure 1 and Figure 2 provide an overview of Beach's licence areas and production sites in the Cooper Basin.

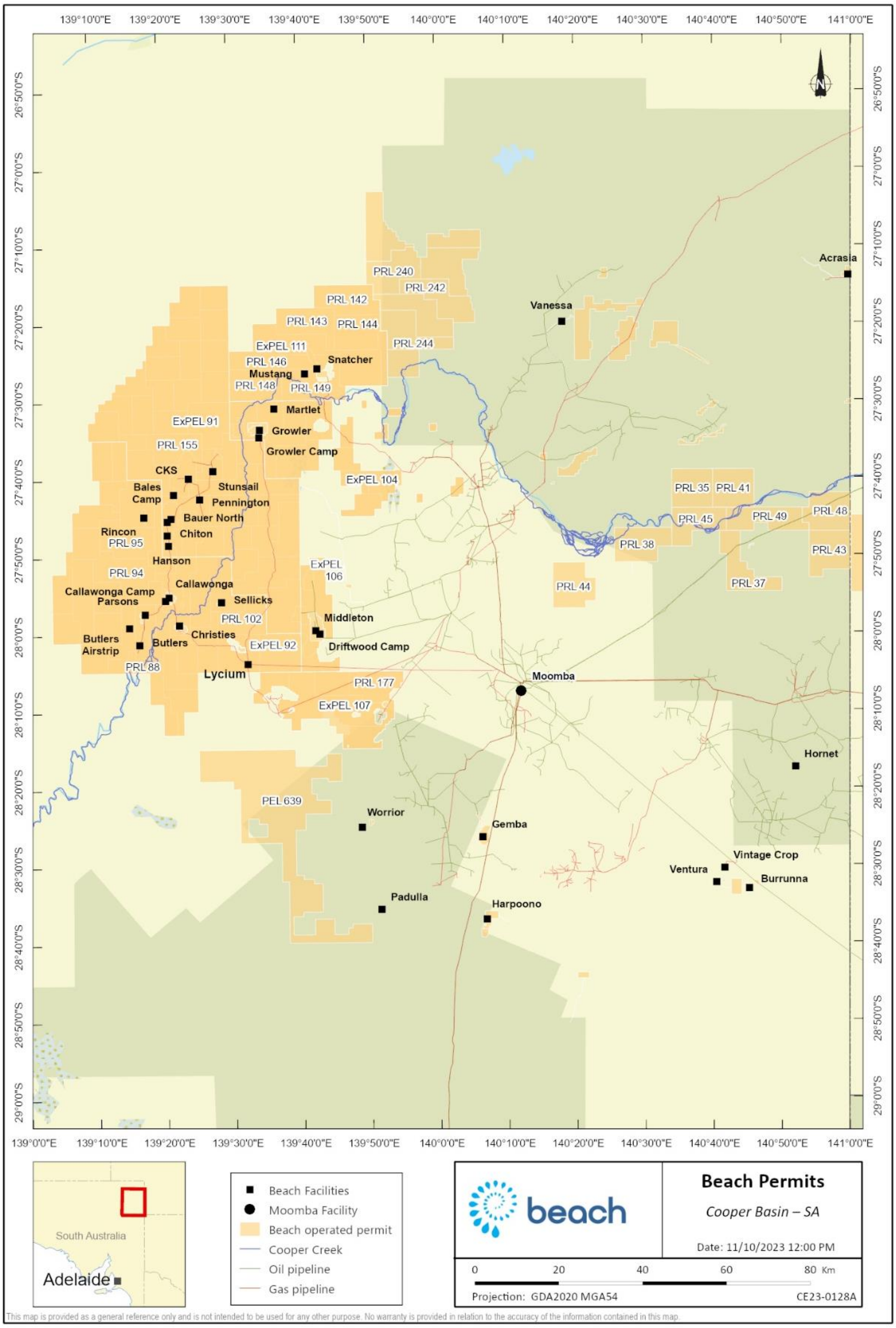


Figure 1: Location of Beach Cooper Basin licence areas

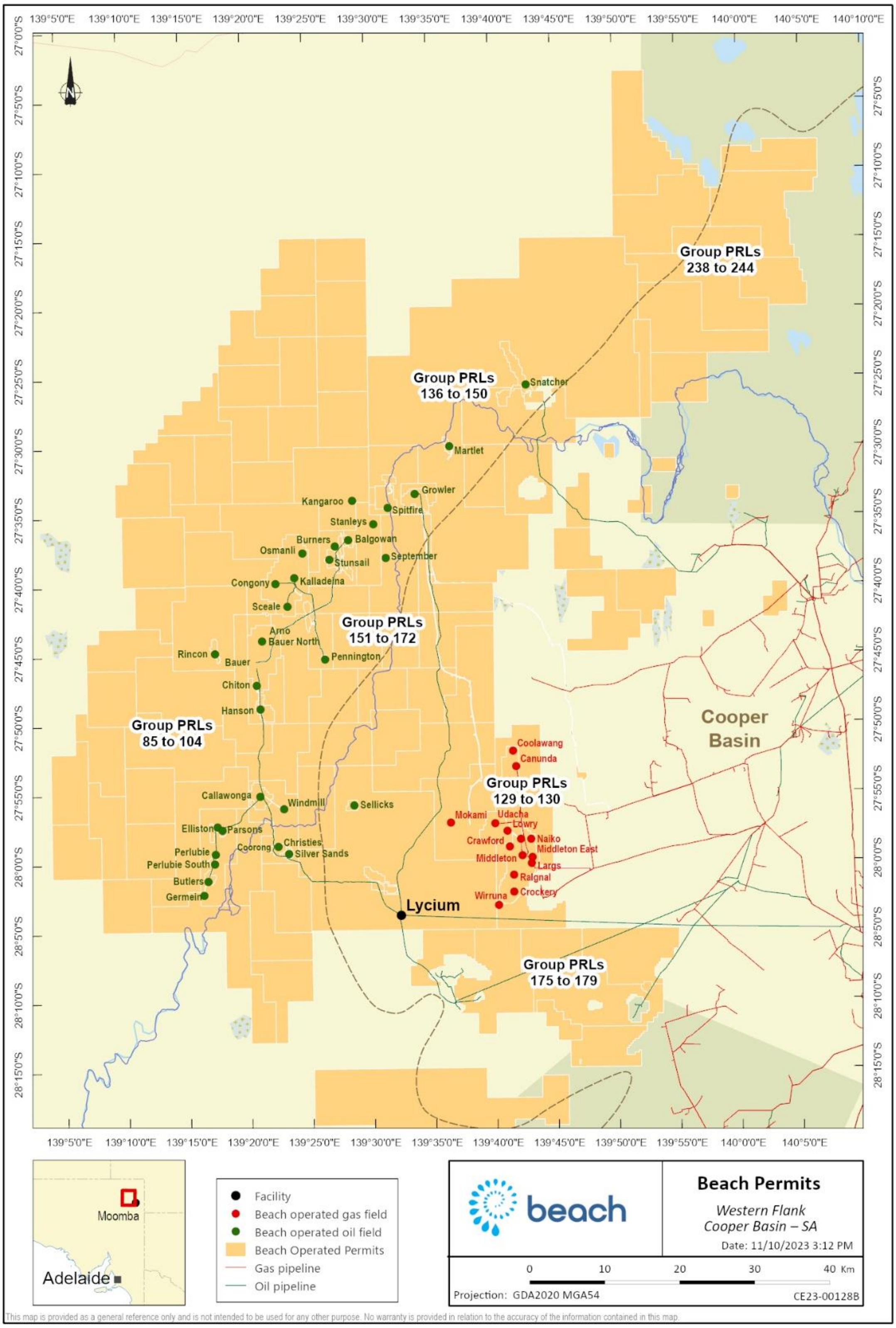


Figure 2: Location of Beach Cooper Basin Western Flank production operations and facilities

3.1 Well Operations

A range of activities related to the operation of wells may be carried out on well sites during the life of a production well. These include but are not limited to completions, workovers, installation and operation of artificial lift, wellhead production skids, gas well deliquification and ongoing well integrity management. These are described in the following sections.

3.1.1 Completions and Workovers

Completion activities to prepare the well for production commence after the well has been drilled, cased and cemented and the wellhead installed. Generally, completion activities commence soon after drilling but may be delayed for longer periods (e.g. if the well is cased and suspended for future production). Some examples of completion activities that may be undertaken include:

- cleaning out the casing of any fill, or to confirm wellbore access
- perforating the casing to access the reservoir fluids / gas to be produced
- setting packers downhole for the installation of tubing or plugs to isolate non-commercial reservoir zones
- cased hole logging and gradient / pressure surveys for evaluation of either wellbore construction elements or reservoir property evaluation with time.

Workover operations with a service rig may also be carried out on a well after the initial completion. They may include but not be limited to:

- repairing, replacing or installing artificial lift systems with either like-for-like repairs or upgrading to a different lift system as well parameters change with time
- cleaning sand out of the well from debris / sand / backfill
- isolation of zones, which may be required due to factors such as:
  - watered out zones
  - non-commercial zones
  - in preparation for final abandonment by isolating formations
  - well integrity purposes to reduce risks to as low as reasonably possible
- zone changes in a multi-zone well that has the ability to open and close sleeves to access different formations or combinations of formations
- repairing corrosion by replacement of equipment or engineered patches
- deepening the wellbore to access previously un-accessed formations
- fishing to recover objects from the wellbore and / or milling obstructions in the well
- perforating / re-perforating new or existing zones to improve or increase production.

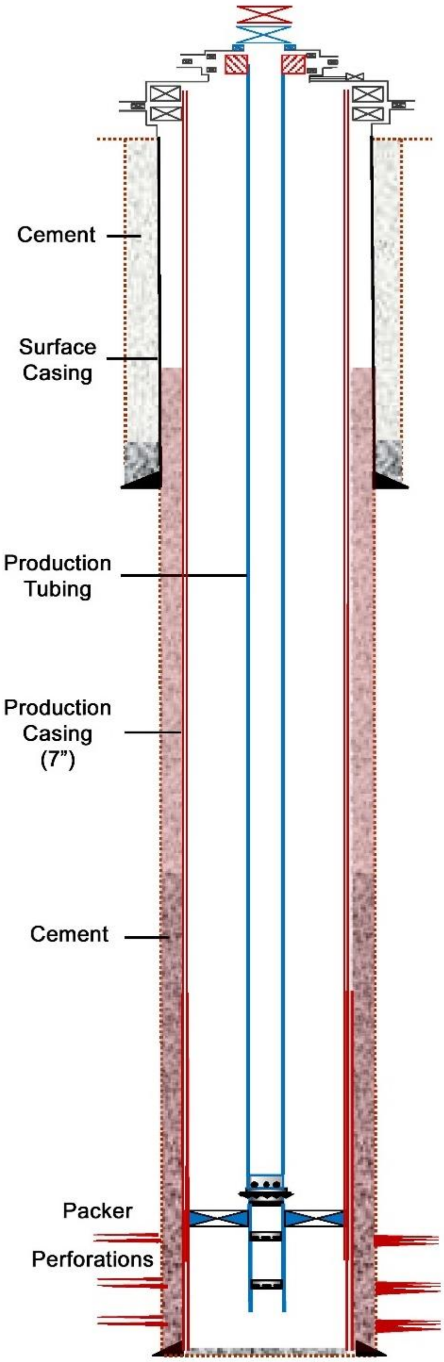
Some well interventions do not need a service rig and require either a smaller unit of slickline and / or wireline equipment to conduct various cased hole operations, such as perforating or setting a plug as mentioned above. In some instances the use of a coiled tubing unit is necessary to enter a live wellbore under pressure to perform an operation similar to that of a service rig, but without having to fill the well full of fluid, which can cause the formation(s) to struggle to produce after the job has been completed. Pumps and storage tanks are used for operations that need to circulate workover fluids in / out of the well.

3.1.2 Well Integrity Management

To assess and maintain the reliability of wells, Beach has implemented a well integrity testing and monitoring program. The intent of this program is to maintain wells in a fit for purpose condition and to protect the environment and people.

The well integrity management process governs the operation and maintenance of wells throughout their lifecycle. The process includes routine visits to evaluate barrier integrity. Following inspection, the asset data is reviewed and wells identified with an elevated risk level undergo a detailed assessment. The outcomes of the risk assessment form the basis of an asset strategy plan, and integrity check frequencies may be modified and scheduled based on the level of risk assigned. Alternatively the well analysis may generate recommendations to perform a well repair or suspension and / or abandonment prioritisation. If a high risk issue is identified, repair or abandonment activities are to be undertaken as soon as practicable.

Figure 3 provides a simplified example of a Wellbore Status Diagram, which shows a schematic of a typical gas well and a summary of the integrity status of the barriers in the well.



Well Information	
Well Name	**Gas Well-1**
Well Type	Gas Producer
Well Status	Operational
Date Drilled	Nov 2000
Well Barrier Elements	**Verification of Barrier Elements**
PRIMARY	
Production packer	Tested on xx/xx/xx to xxx psi.
Production tubing	Tested on xx/xx/xx to xxx psi.
Lower wellhead valve	Tested on xx/xx/xx to xxx psi.
SECONDARY	
7" casing Wellhead Seals	Tested on xx/xx/xx to xxx psi. Tested on xx/xx/xx to xxx psi.
7" casing cement	Cement placed as per program. No losses. Cement bond log shows good bond response.
Upper wellhead valve	Tested on xx/xx/xx to xxx psi.
Tbg hanger w/ seals	Tested on xx/xx/xx to xxx psi.

Figure 3: Simplified wellbore status diagram

3.1.3 Artificial Lift and Wellhead Production Equipment

3.1.3.1 Oil Wells

In the Cooper Basin Western Flank, oil generally 'free flows' to surface under reservoir pressure. In some cases, there may not be sufficient deliverability to produce oil to surface or at an economic rate, and artificial lift may be required to increase production. The type of artificial lift installed depends on numerous factors, which include the depth of the well, well deliverability and reserves.

Types of artificial lift used on oil wells include:

- **Jet pumps** which use a small 'nozzle pump' located down the well and circulate a fluid stream known as power fluid between the surface and the downhole nozzle. This creates a suction force which draws in fluid from the oil reservoir and causes it to be lifted up into the well. Above ground the jet pumps consist of a suction header tank, suction manifold and filtration system, power-fluid pumpset, bulk fuel storage tank, power fluid discharge distribution manifold, and connections to deliver power fluid to the jet-pump wellhead(s).

- **Electric submersible pumps (ESP)** which comprise a multi-stage centrifugal pump attached to an electric motor installed downhole. Power is supplied from the surface by a generator and is transferred to the ESP by a cable which is strapped to tubing. Other surface equipment includes a variable speed drive, transformer, junction box and a bulk fuel storage tank.

- **Rod pumps** are deployed in the wellbore and can be operated by either conventional beam pump units, or small skid mounted electro-hydraulic rod-pumping units. These units are typically powered by a diesel motor or generator and may also include a variable speed drive, transformer, junction box and a bunded bulk fuel storage tank.

All artificial lift systems have a high pressure switch which will shut down the unit if the pumping pressure is too high.

Oil wells may also have other equipment located on the well lease, including telemetry equipment or chemical injection skids (which typically include a chemical storage tank and solar-powered pump to inject emulsion-breaker into the flowline downstream of the wellhead).

Plate 1: Rod pump operated by beam pump unit


Plate 2: Jet pump, showing wellhead (foreground) and jet pump engine and fluid tanks (blue, in background)

3.1.3.2 Gas Wells

Gas wells typically have a wellhead production metering skid and a safety shutdown valve installed on the well lease, immediately downstream of the wellhead.

A wellhead production metering skid may include any or all of the following equipment:

- auto controlled choke
- pressure safety valve
- a meter run and flow recording device
- corrosion inhibitor injection facilities
- telemetry transmission which relays wellhead pressure, flow, temperature and choke position to remote control and monitoring locations.

Additional artificial lift mechanisms may be required in gas wells to assist removal of liquids from the wellbore where excessive liquid production inhibits gas deliverability. These mechanisms, which typically unload water from the well to enable continued gas production, may include:

- plunger lift, which uses bottom hole pressure to lift a plunger from downhole inside the tubing to the surface to push liquid out of the tubing
- velocity string - small internal diameter (ID) tubing, which increases the velocity of the produced fluid moving up hole which can continuously unload the well
- micro-strings, which are a small diameter tube used to inject foamers into a wellbore close to the perforations and help to reduce friction and unload water. Foamer / surfactant selection and dosage rate would be based on the type of the fluids to be foamed, downhole temperature and pressure, the environmental properties of the chemical and corrosivity of the foamer.

Methods such as Nitrogen lifting are usually temporary measures typically associated with a wellbore clean-up post fracture stimulation and are not considered a permanent artificial lift installation. A work program would be issued for these types of operations and fluid returns dealt with as per flowback processes discussed in Section 3.2.

Plate 3: Gas well showing wellhead production metering skid

3.1.4 Gas Well Deliquification

As productivity declines in gas wells, they often require unloading of reservoir fluid (primarily water) that has accumulated in the well and created a static column preventing it from flowing continuously. Deliquification typically involves unloading the liquids in the well's production tubing by expelling the gas and flowing the liquids to a pit or tank. This allows the well to continue to flow for longer periods of time. When a well requires frequent unloading it may become a candidate for a smaller diameter tubing installation or artificial lift (as discussed in Section 3.1.2) depending upon the economics of the project and remaining reserves in place.

Unloading of wet gas streams to a pit are performed in a controlled manner down a blowdown line, for a brief duration until flowline pressure can be simulated, then the well is typically diverted back to inline flow. Where possible the gas stream mix is flared depending on the gas / fluid ratio, however often the stream is too wet to ignite. In this case, the gas vented is negligible and it is mainly a column of fluid being expelled into an impervious clay lined pit.

3.1.5 Downhole Abandonment Following Production

Once a well has reached the end of its productive life, a decision is made on whether to abandon the cased wellbore or leave it in a suspended state until it can be abandoned. Each well is evaluated individually to design the abandonment program. Abandonment programs are submitted to DEM prior to implementation.

On occasion approvals may be sought from the Regulator to convert a production well to a water supply well if Beach required a new potable water bore for operational activities (e.g. accommodation camp water supply).

The abandonment program usually involves the following:

- all perforated hydrocarbon zones are isolated with cement plugs and / or mechanical plugs
- bond logs, if conducted, are evaluated to ensure that the cement behind the production casing is adequate to avoid crossflow of aquifers with other aquifers or hydrocarbon producing zones

- if isolation is not present, a decision may be made to perforate and squeeze off the aquifer to ensure that there is no crossflow
- pressure testing and / or negative inflow testing is performed on barrier envelopes / components where feasible
- inhibited fluid is placed between barriers where applicable
- final well abandonment at the surface will involve a surface cement plug and cutting or removing the wellhead to below ground level.

Note: This EIR and accompanying SEO apply only to production wells. Surface rehabilitation of well sites following drilling and downhole abandonment of wells following drilling are governed by the Drilling SEO (Santos 2021b) and are not covered by this EIR or the accompanying SEO.

3.2 Fracture Stimulation

Fracture stimulation is a process used in both conventional and unconventional reservoirs to enhance deliverability from the well. It involves the injection of fluid into the target formation at pressures sufficient to split the rock and create high conductivity flow paths to the well. These highly conductive flow paths will enable increased production rates and, in some cases, can add reserves.

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.

Fracture stimulation has been used for over forty years in the Cooper Basin and has been used in several hundred conventional gas wells to improve deliverability and commerciality of these wells. Fracture stimulation of deeper unconventional targets in the Nappamerri Trough has also been undertaken in a number of wells. The industry has also had extensive experience successfully and safely fracture stimulating oil-bearing reservoirs to improve oil recovery and has carried out over 140 fracture stimulation treatments of Eromanga Basin oil reservoirs in the Murta Formation.

A simplified diagram of a fracture stimulation treatment is provided in Figure 4.

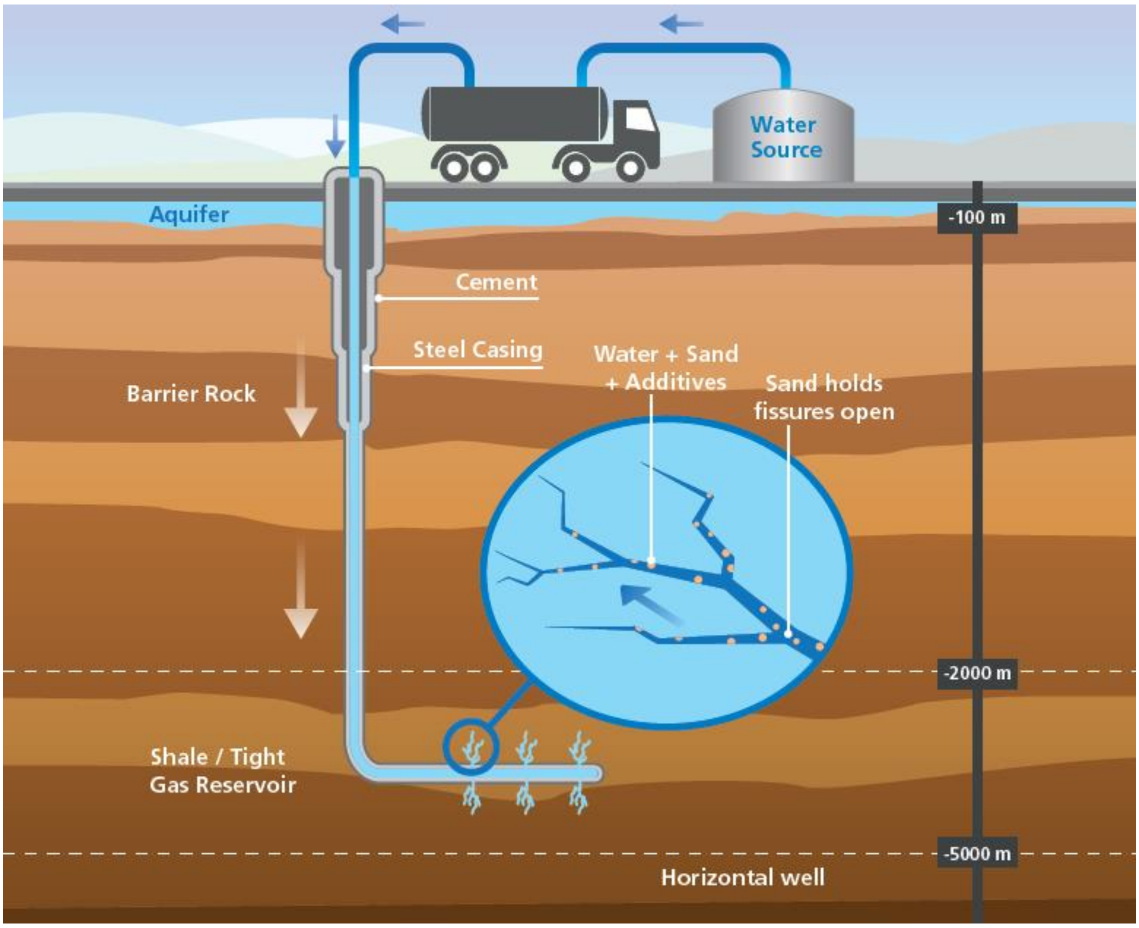


Figure 4: Fracture stimulation (Source: DPC 2017b)

3.2.1 Fracture Stimulation Treatments / Targets

The size and scale of a stimulation treatment is dependent on the target. In the Cooper and Eromanga Basins, there are three typical types of fracture stimulation treatments:

- small scale treatments in the Eromanga Basin reservoirs (typically oil reservoirs) which target small intervals (e.g. 2-20 m thick)
- medium scale treatments in conventional Cooper Basin Permian targets
- medium to large scale treatments in unconventional Cooper Basin Permian targets, where the aim is to maximise the stimulated rock volume by creating a complex fracture network.

These treatments follow the same principles and use similar equipment, however, the size, scale and complexity of the operations are quite different. Treatments in Eromanga Basin oil reservoirs are kept small and are designed to avoid fractures extending into adjacent zones. At the other end of the scale, the unconventional fracture stimulation treatments are typically much larger scale and more complex and are pumped with higher pressures and volumes of fluid at a greater rate. They are designed to stimulate a much larger volume of rock and have much greater fracture lengths. In addition, multiple fracture stimulation treatments are generally applied to each well.

These three types of treatments are discussed further below. Details of the geology of the target formations are provided in Section 4.5.

3.2.1.1 Eromanga Basin Oil

Fracture stimulation treatments in the oil bearing formations of the Eromanga Basin are generally at depths in the order of approximately 1,200 – 1,500 m and are typically smaller than those applied in the deeper Cooper Basin formations. Eromanga Basin treatments require smaller volumes of proppant and lower pump rates which limits fracture network complexity. In most cases, proppant volumes and pump rates are around half of that required for a conventional gas bearing interval in the Cooper Basin.

The hydraulic fractures in stimulation treatments in Eromanga Basin oil reservoirs are purposely kept relatively small, as fracture growth into sands with aquifer properties above or below the oil target will encourage water production, often to the exclusion of oil production. Hydraulic fractures within the oil reservoir are typically designed to remain within tens of metres from the well bore and are contained within the natural top seals to each accumulation, such as the upper Murta horizon aquitard and the lower half of the overlying Cadna-owie Formation (which is classified as an aquitard unit) in the case of a Murta Formation target.

Prior to operations, each stage is modelled using specialist software to provide confidence that the treatment will be confined to the target zone and to ensure that fracture growth does not extend into adjacent formations where adverse impacts to aquifers may be a risk. In most cases, Eromanga Basin stimulation treatments are not expected to grow out of the target reservoir, as the Eromanga sands are often confined by underlying and overlying siltstones and shales which act as natural barriers and limit the potential for fracture propagation outside the target.

During stimulation operations, treatment volumes and pressures are monitored in real time to ensure that the treatment is proceeding as designed. Validation of treatment modelling is achieved by comparing model results with field treatment monitoring results. A summary of these monitoring methods can be found in Section 3.2.4.

Figure 5 provides a modelled example of an oil stimulation treatment in the Murta formation and shows the predicted fracture height, length, depth and proppant concentration.

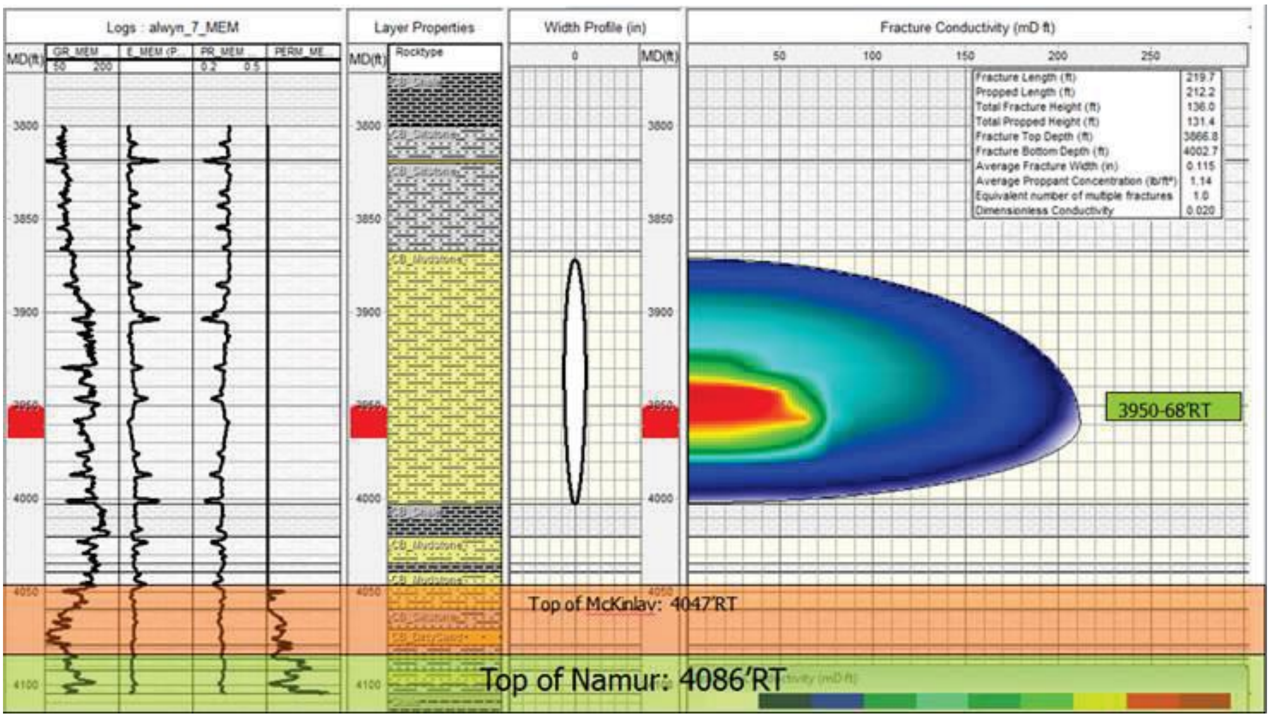


Figure 5: Example of model output for fracture stimulation treatment. (Source: Santos 2021a)

3.2.1.2 Cooper Basin Conventional Gas

Fracture stimulations in Cooper Basin conventional gas targets are typically medium scale treatments, designed to achieve fracture heights based on the thickness of the target interval. The targets are typically at depths of 2,100 to 3,000 m. The conventional Cooper Basin targets have numerous barriers to fracture height growth out of formation, including multiple shales above the target sands and the very thick Nappamerri Group siltstones, which are typically 100 to 500 m thick and provide an additional 'safety barrier'.

Cooper Basin stimulation treatments are also modelled and designed to remain within the hydrocarbon target zone. Cooper Basin targets are often overlain and underlain by siltstone, shale and coal confining beds which act as natural barriers and limit fracture propagation.

3.2.1.3 Cooper Basin Unconventional Gas

Unconventional fracture stimulations are typically larger scale treatments, pumped with higher pressures and volumes of fluid at a greater rate. The targets are often at greater depths than a conventional stimulation target (in the order of approximately 2,600 to 3,800 m) and the treatments are designed to stimulate a larger volume of rock.

The Nappamerri Group rocks which form a seal above the gas bearing formations of the Cooper Basin have their thickest development (up to 500 m) over the unconventional targets (in the Nappamerri Trough) and provide an effective barrier to fracture propagation between the unconventional targets and deep Great Artesian Basin (GAB) aquifers. The shallowest unconventional Permian gas formations (such as the Toolachee) are in the order of 400 m below the deep GAB aquifers (see Figure 6).

Limitations on fracture height growth in unconventional Cooper Basin targets were reviewed in Beach Energy (2012a) with the level of risk posed by fracture propagation into overlying aquifers assessed as low.

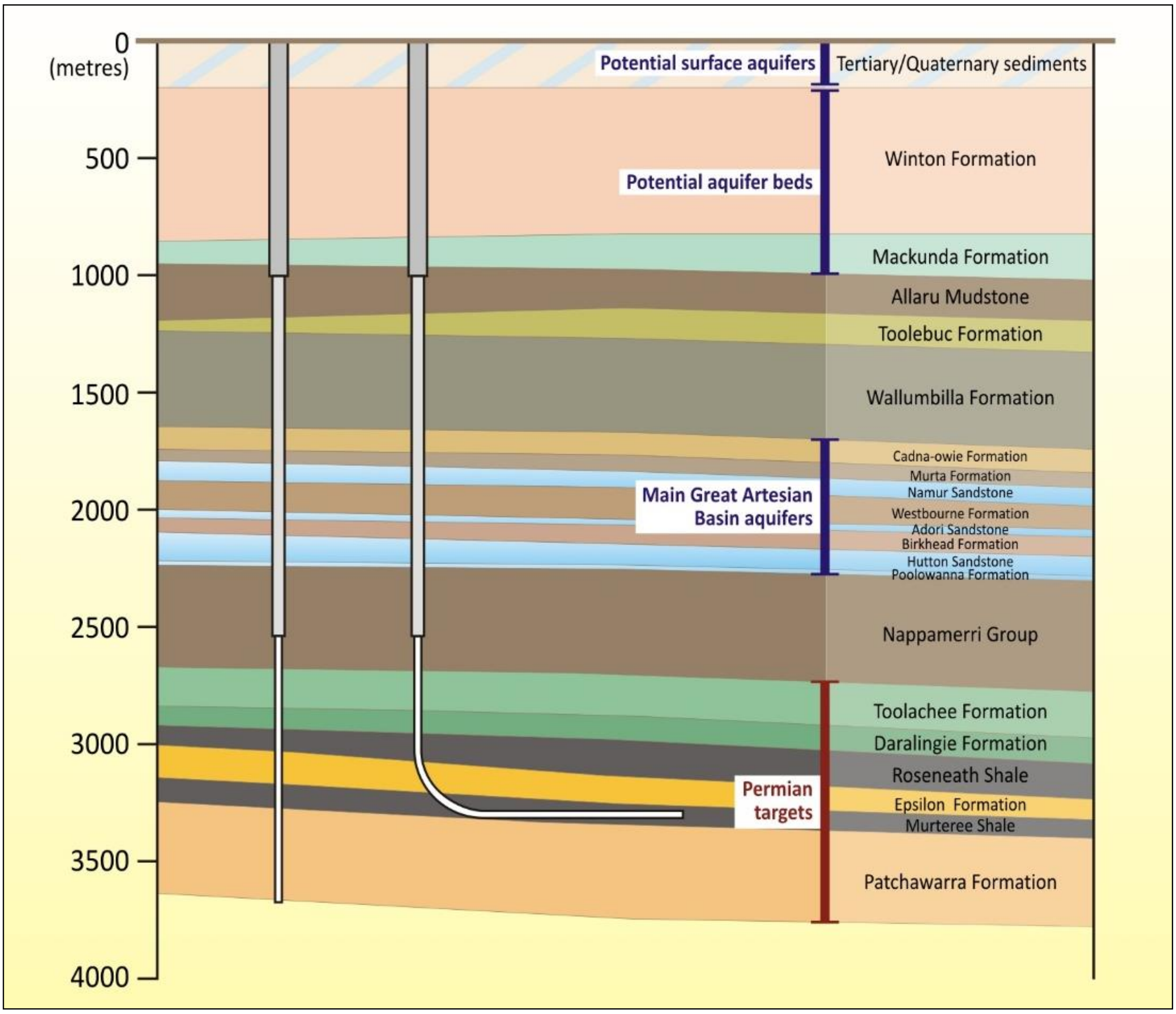


Figure 6: Illustration of separation between unconventional Permian gas targets and GAB aquifers in the Nappamerri Trough

3.2.2 Well Design and Construction

Well design and construction is based on all the operating conditions that the well is expected to experience, and is particularly important when considering high pressure fracture stimulation treatment.

The wellhead, steel casing, cement and production tubing are designed to be suitable for:

- temperatures and pressures expected down-hole
- pressures required to initiate fracture stimulation treatments
- stresses induced when large volumes of cool fluids are pumped, at high pressure, into the well during stimulation
- flow back of reservoir fluids.

When wells are drilled, a series of steel 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 size, strength, coupling and material of the casing string must satisfy the identified operational conditions and industry standard design safety factors.

The surface wellhead is also important for hydrocarbon containment. This equipment provides control measures (or barriers) that can be closed to shut-in the well and isolate production.

Wells are pressure tested prior to commencing fracture stimulation, to confirm the integrity of the wellhead, casing and cement. Routine well integrity checks are also undertaken in accordance with Beach's well integrity management system (see Section 3.1.2).

3.2.3 Fracture Stimulation Design

The fracture stimulation design process uses data collected during drilling and logging to design the treatment for each individual well. Data on reservoir parameters, lithology variations and stress contrast between layers is processed using stimulation software to develop a design which optimises fracture length, fracture conductivity and fracture height within the target reservoir formation. Information from well logs is used to detect water bearing zones which need to be considered in the fracture stimulation design.

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

- depth, thickness, rock strength and lithology of the target zone and bounding layers
- thickness of the 'seals' (aquitard layers) above and below the target reservoir formation
- minimum horizontal stress across all layers (target and bounding)
- stress field analysis to determine the maximum principal stress direction and the minimum
- principal stress direction
- bulk density, elastic properties, compressibility
- bedding planes, jointing and mineralisation
- 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.

The stress field within the reservoir determines fracture growth and orientation during fracture stimulation. Changes in the stresses (e.g. at formation boundaries) also play an important role in containing fractures.

Prior to a fracture stimulation treatment, a fracture model is constructed to investigate, predict and optimise the fracture geometry. A complete layer description is input into the simulator. Various pumping schedules are input into the model to evaluate the simulated fracture geometry and provide optimal geometry within the formation of interest. The treatment design models can predict the fracture geometry including fracture length and height based on the geomechanical rock properties.

Fracture growth into a water bearing zone is undesired on a fracture stimulation, as it would result in the flow being dominated by water rather than hydrocarbons. 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 units and does not extend into non-target formations.

3.2.4 Fracture Stimulation Monitoring

During the fracture stimulation operation itself, parameters are monitored in real time (e.g. surface pressure, bottom-hole pressure, net pressure, injection rate and proppant concentration) to ensure that the treatment is proceeding as designed. The expected pressures generated by the modelling discussed above are compared with the measured pressures and the overall pressure response can provide useful information in evaluating the overall fracture growth and containment achieved. Figure 7 shows a typical example of real-time pressure monitoring output.

During the operation, if an unexpected response is seen (e.g. pressure variation), one or more variables may be altered. If a significantly different response is observed which could indicate height growth beyond design parameters (e.g. a slight dip in net pressure or large decrease in treatment pressure) the stimulation is typically stopped.

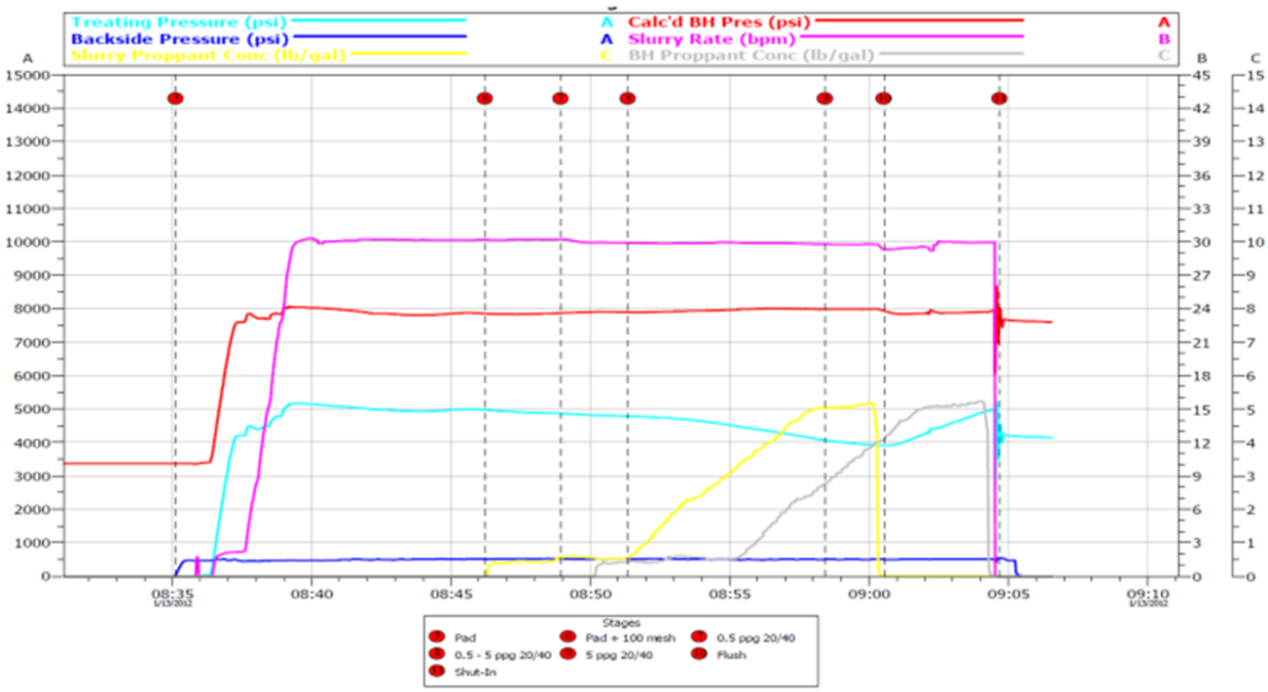


Figure 7: Example of typical real-time monitoring of fracture stimulation (Source: Santos 2021a).

Post-treatment parameters are also monitored and are entered into the model following the treatment to achieve a history match and predict the actual fracture geometry. This calibration process is used to refine and improve subsequent designs.

Other monitoring techniques can also be useful in evaluating fracture geometry and orientation and providing data for calibrating fracture stimulation model predictions. These include microseismic monitoring, surface tiltmeters, proppant tracers, chemical tracers, sonic anisotropy logging and temperature logging and are discussed below.

Microseismic monitoring involves placing sensitive listening devices (geophones) in an adjacent well during stimulation of the target well. During stimulation, small movements of rocks are detected at the monitoring well and the location of those movements is determined by triangulation. This information is used to understand the location and height of fracture growth. The economic feasibility of microseismic monitoring is dependent on the presence of a suitable offset well, which typically needs to be within 200 to 300 m of the well that is being stimulated for smaller scale fracture stimulation treatments, and within 500 to 800 m for large scale treatments.

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 fracture orientation.

Chemical or radioactive tracers can be used to provide information on fracture growth and / or which fractures are contributing to oil and gas production. Non-hazardous chemical tracers may be added in very low concentration to each of the fracture stimulation stages to assist with understanding which zones are contributing to flow back after the treatments. Radioactive bead tracers can also be used during treatments to estimate fracture height, near wellbore proppant concentrations and associated propped widths post-treatment using spectral, gamma-ray logging tools. A variety of isotopes (scandium, iridium, and antimony) can be used to identify movement of different fluids. These radioactive isotopes have a short half-life and rapidly decay in the environment to safe levels.

Sonic anisotropy logging typically involves running pre and post fracture treatment dipole sonic logs and then comparing them to identify changes in sonic amplitude or stress anisotropy caused by the induced near well bore fracture.

Production logging tools can be used to identify flow contribution from individual zones using an array that records information such as fluid density, pressure, temperature and spinners to detect fluid movement. The temperature response may be used to identify where fluids are entering the wellbore or moving within the casing. Temperature logging can also be used to detect fluid movement behind casing. Depending upon the well, a temperature log may also be used to determine fracture height and identify perforations contributing to production.

3.2.5 Fracture Stimulation Stages

A typical fracture stimulation treatment involves pumping of several discrete stages. Each stage represents a single fracture stimulation treatment over a discrete formation interval.

Pad stages: Small volumes of friction reduced water are injected. The initial pad volume, injected at high pressure, is used to split the rock and propagate the fracture.

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, and 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 is injected to push the sand from the well bore into the rock to clean the well bore. In some cases, sand may not be completely displaced from the well bore to create a temporary “sand plug” to isolate the treated zone. This temporary sand plug is used to enable perforation and stimulation of the next interval higher in the well bore and removed from the casing at the conclusion of the stimulation treatments.

Plug / Perforate: Once the stimulation treatment is placed (and a temporary sand plug is not used for isolation as described above), 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 (if multiple zones are to be stimulated). The wireline will also perforate the casing ready for the next stimulation treatment.

Typically, only one zone is stimulated in a standard (vertical) Eromanga Basin oil well. Multiple zones are more commonly stimulated in horizontal wells or wells that access conventional and unconventional gas targets.

3.2.6 Fracture Stimulation Fluids

The main component of oil well fracture treatment fluid is water (which typically makes up 90% or more of the fluid) with the next most abundant component being proppant (typically 10% or less). Chemicals account for a minor proportion of the mixture (typically less than 0.5% for large scale treatments and less than 2% for small scale oil target stimulation treatments).

Proppant is a granulated material typically comprised of sand or small ceramic beads (e.g. sintered bauxite). These grains hold open the fracture allowing oil, gas and water to flow to the wellbore. To ensure a safe and successful operation, other components are added to fracturing fluid, including biocides, buffers, friction reducers, guar gelling agents, crosslinkers and breakers (see Table 2).

Table 2: Additives typically used in fracture stimulation fluids

Additive	Purpose
Acid	Removes scale and cleans wellbore prior to fracturing treatment
Acid inhibitor	Protects wellbore components and treatment equipment from corrosive action of 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. Limits gel destruction due to bacterial action
Breaker	Reduces fluid viscosity after the treatment to aid quick clean up in flowback
Chemical tracer	Compound used to chemically mark individual stage fracturing fluids in a multi-zone completed well
Clay control	Prevents clays from swelling which can stop fluid flow post treatment
Cross linker	Increases fluid viscosity to help activate and carry proppant
Foamer	Used to transport and place proppant into fractures
Friction reducer	Allows fracture fluid to move down the wellbore with the least amount of resistance
Gelling agent	Adds viscosity to the fluid to help carry proppant
Iron chelating agent	Helps prevent the precipitation of hydrated iron oxides from spent acid following an acidising treatment
Neutralising agent	Counteracts the corrosive effect of acids or acidic treatment fluids on equipment
Non-emulsifier	Prevents emulsions forming and keeps oil separate from the fracturing / formation fluids during flowback
pH Buffer	Used to adjust the pH of the fluid and promotes hydration of gel
Proppant	Typically comprised of sand or small ceramic beads which prop open the fracture allowing oil, gas and water to flow to the wellbore
Scale inhibitor	Prevents build-up of certain materials (i.e. scale) on sides of well casing and surface equipment
Surfactant	Assists in recovery of fluid from the well

Additive	Purpose
Surfactant / penetrating agent	Allows for increased matrix penetration of the acid resulting in lower breakdown pressures

Fracturing fluids are a carefully formulated product and each task performed during the operation will use fluid with additives specifically designed for the task. For example, the fluid designed to propagate the fractures is initially injected 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.

The design of the fluids is customised for each well, taking into account source water chemistry, depth, temperatures, pressures, reservoir geology and chemistry, scale build-up, bacteria growth, proppant transport, iron content and fluid stability and breakdown requirements. During the fracture stimulation treatment, regular quality control and monitoring of source water quality is undertaken to adjust the formulation as required.

Appendix A provides further information on fracturing additives and their chemical constituents, based on typical formulations. Fracture stimulation service 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. It is expected that the additives used by different providers in the future are likely to be similar to those outlined in this document. Detail of additives proposed for use in fracture stimulation operations is provided to DEM as part of the activity notification process (see Section 2.1.3).

Most of the chemicals used in fracture fluids are found within products that are used in the home or in industry. 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.

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 (e.g. the target petroleum reservoirs can naturally contain BTEX), Beach does not use additives containing BTEX.

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

3.2.7 Post Stimulation Flowback

Following completion of fracture stimulation operations, the well is flowed back to the surface to recover the injected fluids. The initial flow will be predominantly recovered stimulation fluid and will be directed to a tank, or a lined pond (e.g. in the case of larger stimulation treatments). Water that is flowed back to the surface is metered and sampled on a regular basis to evaluate the composition of the recovered fluid. Samples are also obtained from lined storage ponds for analysis.

After the initial well clean-up phase, the produced fluids are typically diverted to a separator to separate the various phases and capture any liquid hydrocarbons into tanks. In established fields, after a sufficient post stimulation clean up flow period (as described above), wells are typically connected to the gathering network and produced fluids directed to the central production facility. Gas from wells undergoing production testing that are not close to gas gathering networks will be flared after separation and metering.

Published data on recovery of fracture fluid during flowback, which relates almost exclusively to shale gas wells, shows that the volume recovered can range from approximately 5 – 50%. Flowback volume depends on reservoir properties, fracture stimulation design and fracture fluid used. Smaller scale fracture stimulation of oil reservoirs in the Eromanga Basin can have a higher percentage of flowback as opposed to the large slickwater fracture stimulations utilised for unconventional shale targets.

Chemicals returning from a well after a 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 (Friedmann 1986, Howard *et al*. 2009, King 2012) and fluid disposal plans are tailored accordingly. Polymers decompose quickly at reservoir temperature, biocides degrade as they are spent on organic demand and surfactants are adsorbed on rock surfaces (King 2012). Consequently, many of the compounds that are identified as potentially hazardous on their Safety Data Sheets, 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. Monitoring of ion concentrations in the flowback fluids is undertaken to understand the extent to which this is occurring.

3.2.8 Equipment and Materials

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

Fracture stimulation equipment, including proppant, for activities targeting the Eromanga Basin typically requires 10-15-truck trailer-loads. Fracture stimulation equipment, including proppant, in the conventional multi-stage target Cooper Basin typically requires 20-25 truck trailer loads. Unconventional significant multi-stage targets typically requires in the order of 30-40 truck trailer loads. In addition, all activities may require a wireline perforation truck to conduct perforations prior to each fracture and 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.

The volume of fuel (diesel) required to operate equipment on the surface ranges from approximately 2000 L for Eromanga Basin stimulations, 6,000-8,000 L for conventional multi-stage Cooper Basin fracture stimulation and up to 16,000-20,000 L for an unconventional significant stage fracture stimulation. This will be stored on site. Additives required for the fracture stimulation operation will also be stored on site. All chemicals are stored and handled in accordance with relevant guidelines and legislation.

Personnel will typically be accommodated at established camps (see Section 3.3.3).

Following the completion of fracture stimulation activities, all infrastructure, equipment and waste materials not required for production operations are removed off site and are either re-used or disposed at a licensed facility.

3.2.9 Water Use and Management

3.2.9.1 Water Use

The amount of water used in fracture stimulation operations in the Cooper Basin is dependent on the type of treatment being undertaken. Conventional stimulation targets use a comparably small volume of water and make up the majority of projects executed in the Cooper Basin. Unconventional stimulation operations are less frequent but use a larger volume of water per stage.

Fracture stimulation treatments of oil targets in the Eromanga Basin are typically limited to one zone per well and typically require 0.05 – 0.1 ML of water. However, if a horizontal well is used to target the formation, multiple treatments may be required, and the volume of water required will also increase proportionally.

Fracture stimulation of conventional gas targets can use between 0.2 ML and 0.5 ML per stage and typically use an average of 1.6 ML of water per well, however this varies as wells can have a different number of stages as well as a target specific stimulation design.

Unconventional targets require larger volumes of water. To stimulate the thick shale intervals and the low permeability basin-centred gas intervals in the Nappamerri trough, fracture stimulation treatments can require in the order of 1.3 to 1.6 ML per zone. Depending on the number of targets, between five and ten zones may be stimulated in a vertical well, and in the order of 15 or more treatments could potentially be placed in a horizontal well (depending on the length of the horizontal section). Consequently, fracture stimulation of a vertical well would require in the order of 8 to 16 ML of water, and a horizontal well could require up to 24 ML.

Where possible, water for fracture stimulation uses recycled water sources (e.g. from existing production ponds). Alternatively, water may be obtained from shallow water wells which are generally drilled within the lease area of each petroleum well for the purpose of petroleum exploration activities. Water well productivity and water quality uncertainties may also make it necessary for Beach to seek landowner permission to obtain water from existing bores.

Appropriate authorisations, including drilling permits and water licences, are obtained for water well drilling and extraction of groundwater. Beach will consult with landowners regarding any proposed water extraction and use to ensure use does not impact adversely on existing users of groundwater.

3.2.9.2 Water Management

Water for use in fracture stimulation is stored on site in tanks or lined ponds (above ground where possible). As discussed above, flowback from the well after fracture stimulation is completed is directed to a tank or a lined pond. All flowback water is handled and stored in accordance with relevant legislation and guidelines.

Small-scale fracture stimulation treatment of oil targets typically uses steel frac tanks (approximately 80,000 L capacity) to store water and capture flowback. Larger above-ground temporary water storage tanks or excavated ponds may also be used to store water or capture flowback, particularly for larger-scale stimulation treatments of unconventional targets. If ponds are used, they are fenced, lined with UV-stabilised HDPE or equivalent and the sides of the ponds are raised above ground level to prevent surface water runoff into the ponds. Water that has been flowed back from the well to tanks or lined ponds is typically disposed of to an evaporation pond located at or near the site.

Where the well is located near an existing Beach production facility, flowback water that has undergone testing[5] may be disposed of into existing lined ponds at a production facility.

Once any ponds at the site have been emptied or the remaining water has evaporated, pond liners will be removed and disposed of at an appropriately licensed waste disposal facility.

The size of water holding ponds used depends on the fracture stimulation design, but may be in the order of 50 m by 30 m and 2-3 m deep (i.e. approximately 3 ML total volume). If necessary for operational requirements or potential issues with pond integrity, fluids may be transferred between ponds or removed from one location and transferred to another well site for further evaporation.

3.3 Production Facilities

Beach's production facilities in the South Australian Cooper Basin at the time of writing of this EIR are summarised in Table 3:. All but two of these production facilities (the Middleton gas facility and Vanessa Facility) produce oil. As Beach has recently drilled a number of wells that have resulted in gas discoveries, it is likely that one or more additional gas production facilities will be established within the next few years. Additional oil production facilities are also expected to be installed in the future if ongoing exploration drilling results in further oil discoveries. Consequently, the operation of both oil and gas facilities is discussed in Sections 3.3.1 and 3.3.2.

Table 3: Beach production facilities as at October 2023

Field / Facility	Licence	Type (oil / gas)	Ponds	EPT / Facility
Aldinga (not operating)	PPL 210	Oil	-	Y
Acrasia	PPL 203	OIl	6	Y
Bauer	PPL 253	Oil	16	Y
Burruna (not operating)	PPL 251	Oil	2	Y
Butlers	PPL 245	Oil	5	Y
Callawonga	PPL 220	Oil	4	Y
Chiton	PPL 253	Oil	2	Y
Christies / Silver Sands	PPL 205	Oil	5	Y
Congony / Kalladeina / Sceale	PPL 254 / PPL 256	Oil	3	Y
Growler	PPL 242	Oil	3	Y
Hanson / Snellings	PPL 255	Oil	3	Y
Harpoono (not operating)	PPL 209	Oil	3	Y
Kiana (not operating)	PPL 212	Oil	-	-
Lycium Hub	SFL 4	Oil	1	N

[5] If flowback (or initial production from the well) is planned to be disposed to a produced water disposal system, detailed assessment, management and monitoring is undertaken to ensure that potential impacts are appropriately managed and that water entering open systems (i.e. free form areas) meets the requirements of the *Environment Protection (Water Quality) Policy 2015* and meets relevant guidelines for the disposal site (e.g. ANZECC (2000) /ANZG (2018) or EPA guidelines).

Field / Facility	Licence	Type (oil / gas)	Ponds	EPT / Facility
Martlet	PRL 137	Oil	3	Y
Middleton / Brownlow / Canunda / Mokami / Crockery	PPL 239 / PPL 239 / PPL 257 / PRL 151 / PRL 130	Gas	3	Y
Mirage (not operating)	PPL 213	Oil	2	Y
Mustang (not operating)	PPL 243	Oil	3	Y
Parsons	PPL 224 / PRL 85	Oil	6	Y
Pennington	PRL 163	Oil	3	Y
Rincon	PPL 248	Oil	3	Y
Sellicks (not operating)	PPL 204	Oil	-	-
Stanleys	PRL 171	Oil	-	Y
Snatcher	PPL 240	Oil	3	Y
Spitfire	PPL 258	Oil	-	-
Stunsail	PRL 172	Oil	3	Y
Vanessa	PPL 268	Gas	-	Y
Ventura (not operating)	PPL 214	Oil	2	Y
Vintage Crop (not operating)	PPL 241	Oil	2	Y

Camps to accommodate field personnel, which are located either at production facility sites or at stand-alone sites, are discussed further in Section 3.3.3.

3.3.1 Oil Production Facilities

Oil production facilities may consist of:

- gathering system (flowlines) from the oil well(s)
- well facility and pumping systems
- inlet manifold system
- water separator tank(s)
- skimmer tank
- crude oil separation and oil storage tanks
- pigging facilities (launch and receiver stations)
- oil transfer pumps
- drains and sump
- utilities (instrument air, electric power generation, fuel gas and fuel oil systems) at selected facilities

- control hut / office, amenities and accommodation (at selected facilities)
- bulk storage areas or warehouse
- telemetry and communications system
- emergency shutdown and control systems
- produced water treatment facilities, including interceptor ponds, holding ponds and evaporation ponds
- chemical injection system for corrosion prevention and emulsion breaking
- lined and bunded tanker load-out area
- piping connections to an oil pipeline
- hazardous material storage areas
- wastewater and sewage treatment systems (at selected facilities)
- perimeter fencing.

The area of a production facility (excluding ponds for water disposal) is typically in the order of 250 m x 250 m. Bauer (East and West) is Beach Energy's largest facility at approximately 300 m x 200 m.

Electrical power for the facility and the nearby oilfields is provided by electrical generation equipment at the site.

Artificial lift (e.g. rod pumps, jet pumps and electric submersible pumps) may be used on oil wells (discussed in Section 0). Consequently, pumps and high pressure flowlines (Section 3.6) may be located both within and outside the boundary of a production facility.

In the event that additional or new facilities are required, the facilities are located where possible on previously disturbed ground. The majority of facilities are usually located on existing drill pads or adjacent to producing wells. This assists in minimising the extent of any additional earthworks and allows existing access tracks to be utilised. However, an additional area may need to be cleared and / or fill imported to provide for facility foundations or bunds.

Facilities are generally located away from areas that are likely to be flooded, but at some sites, minor earthworks (e.g. bunds) may be required to prevent inundation of the facility during flooding. These earthworks are designed and constructed to ensure that surface water drainage patterns in the area surrounding the facility are not significantly altered.

Laydown / storage areas (for stockpiling materials and equipment) are established at selected sites. These are established in existing areas of disturbance where possible, or in areas with little perennial vegetation. They would typically be located adjacent to existing roads or tracks.

Examples of facilities are shown in Plate 4 to Plate 7.

3.3.1.1 Production Testing Installations

Initial production testing may be performed prior to the construction and installation of permanent production facilities and flowlines. These tests are typically required to assist in the evaluation of the well's productivity in order to justify and/or assist in the design of permanent production facilities. The test duration, and the type and volume of fluids produced are dependent on the characteristics of the well. Tests may range in duration from a few days to up to 6 months.

Installations for initial production testing are typically small-scale, mobile and temporary in nature. They are normally confined to the drilling pad and may consist of one or more separator and storage tanks, with inter-connecting pipework and valving. Testing equipment and personnel may be provided by either a contractor or by Beach Energy in-house, depending on requirements. Over-pressure shutdowns, spill protection and other risk mitigation measures are incorporated in a fit-for-purpose manner. The testing activities may be manned or unmanned, subject to testing requirements and risk assessment.

Produced oil is loaded into tankers and trucked off-site. Produced water may be disposed to either drilling sumps or local ponds for evaporation, or may be trucked off-site.

Plate 4: Bauer oil production facility showing Bauer East and Bauer West tank farms (top) and close-up of Bauer West tank farm (bottom)

Plate 5: Rincon temporary extended production testing (EPT) facility

Plate 6: Growler production facility

Plate 7: Callawonga production facility

3.3.1.2 Processes

Oil production facilities receive fluids from oil producing well(s), separate the gas and water from the oil, and then transfer the processed oil to storage tanks. Oil is then transported from the site to third party facilities either by truck or via pipeline.

The water content of fluid produced from an oil well can vary, with Beach's fields typically varying between nil and 95%. After separation from the oil in separator tanks, produced water flows via pipes to a series of ponds for further separation, as discussed in Section 3.4.

A pressure relief system is installed at sites for both plant venting and emergency relief, and in some cases may also include a flare system.

Management of produced formation water, domestic and other wastes and contaminated soil at oil production facilities is discussed in Sections 3.4 and 3.10.

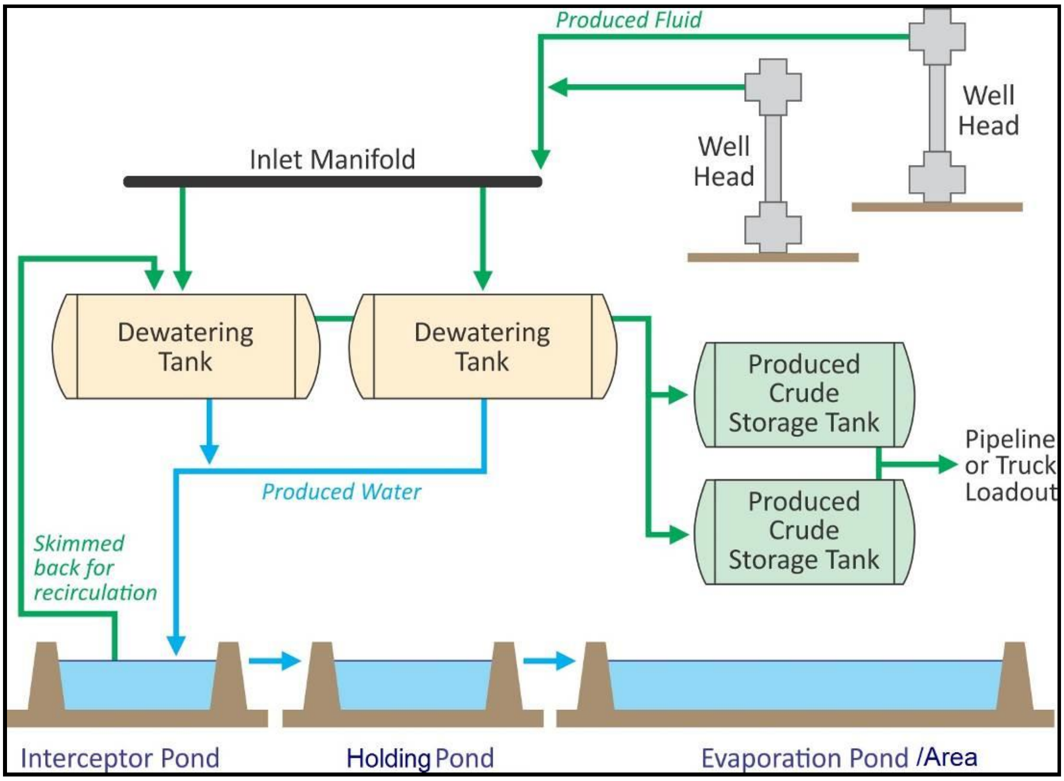


Figure 8: Oil production and water disposal process diagram – free flow, ESP, and rod pump.

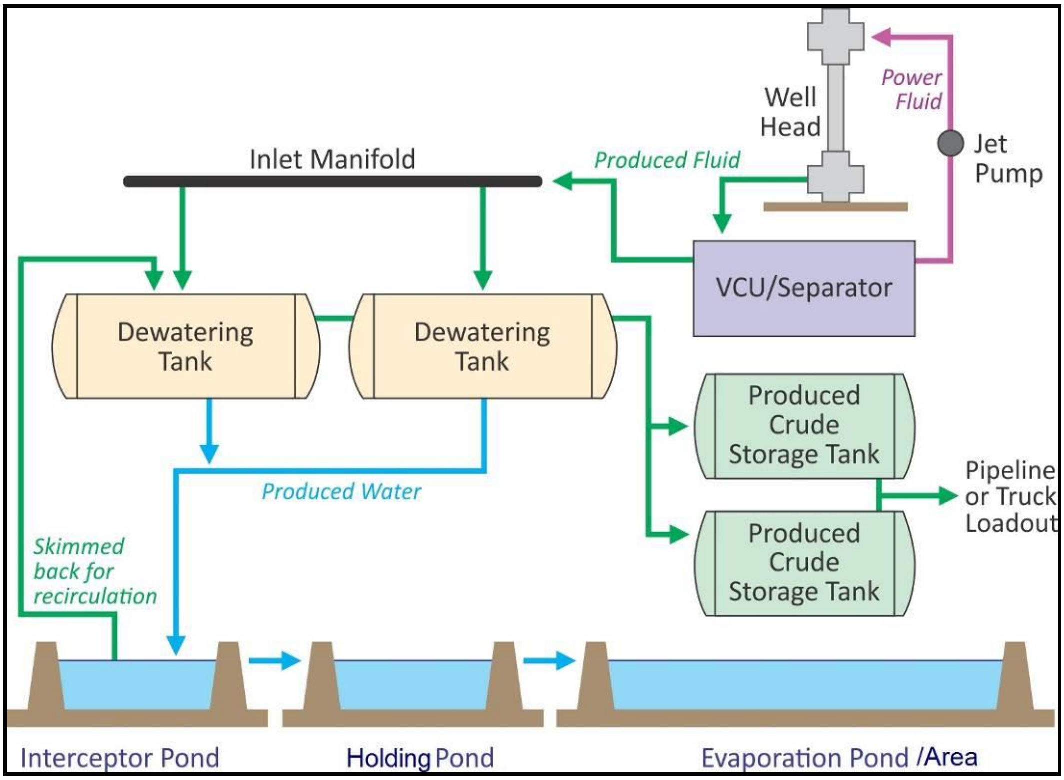


Figure 9: Oil production and water disposal process diagram – jet pump.

3.3.2 Gas Production Facilities

Raw gas is delivered to gas production facilities via pipelines from producing wells. Gas facilities then deliver raw gas (usually pressure-boosted) to the Cooper Basin pipeline network (which feeds the Moomba processing plant).

A typical gas facility incorporates:

- gathering and manifold system from the gas wells
- an inlet header system for raw gas
- gas, liquid hydrocarbon (condensate) and water separation facilities
- gas compression and cooling systems
- gas conditioning (oxygen and CO_2 removal) facilities
- condensate handling facilities
- liquid hydrocarbon recovery
- slug catchers (separation)
- pigging facilities (launch and receiving stations)
- telemetry and communications system
- emergency shutdown and control systems
- utility facilities, including fuel gas system, fire detection, instrument air, evaporative coolers, emergency power generation and wash-down water
- office, amenities and accommodation (at selected facilities)
- produced water treatment facilities, including interceptor ponds and evaporation ponds
- a flare system and vent facilities
- piping connection to a trunkline
- perimeter fencing.

An example of a gas production facility (Beach's Middleton facility) is shown in Plate 8.

Plate 8: Middleton gas production facility

3.3.2.1 Processes

A gas facility generally provides its own fuel gas system. Electrical power is usually generated on-site but may be provided from other sources.

Raw gas enters a gas facility where it is separated into the three component phases - gas, hydrocarbon liquid and water (produced formation water) - inside inlet separator vessels.

Once separated, the natural gas component may then be supplied directly to a third party as raw or compressed gas. Any remaining condensed hydrocarbon liquid in the gas is recovered in separators and generally reinjected into the discharge header or stored and trucked off-site. The gas is transported from the site via a pipeline connection to another gas facility or direct to a third party. Gas and condensate mixture can be piped or trucked but condensate is generally combined with the gas stream for transport via a pipeline connection.

After gas separation in separator vessels, produced water flows via pipes to a series of ponds for further separation, as discussed in Section 3.4. A pressure relief system is provided for both plant venting and emergency relief. During any process anomalies or emergency situation, gas in the plant can be sent directly to the relief system.

During extended production tests that are conducted to evaluate new gas discoveries, gas wells that are not close to an existing gathering network may be flared to allow reservoir parameters and commerciality to be established.

As discussed in Section 3.2, new facilities are located where possible on previously disturbed ground to assist in minimising the extent of any additional earthworks and allow existing access tracks to be utilised.

Management of produced formation water and domestic and other wastes at gas production facilities is discussed in Sections 3.4 and 3.10.

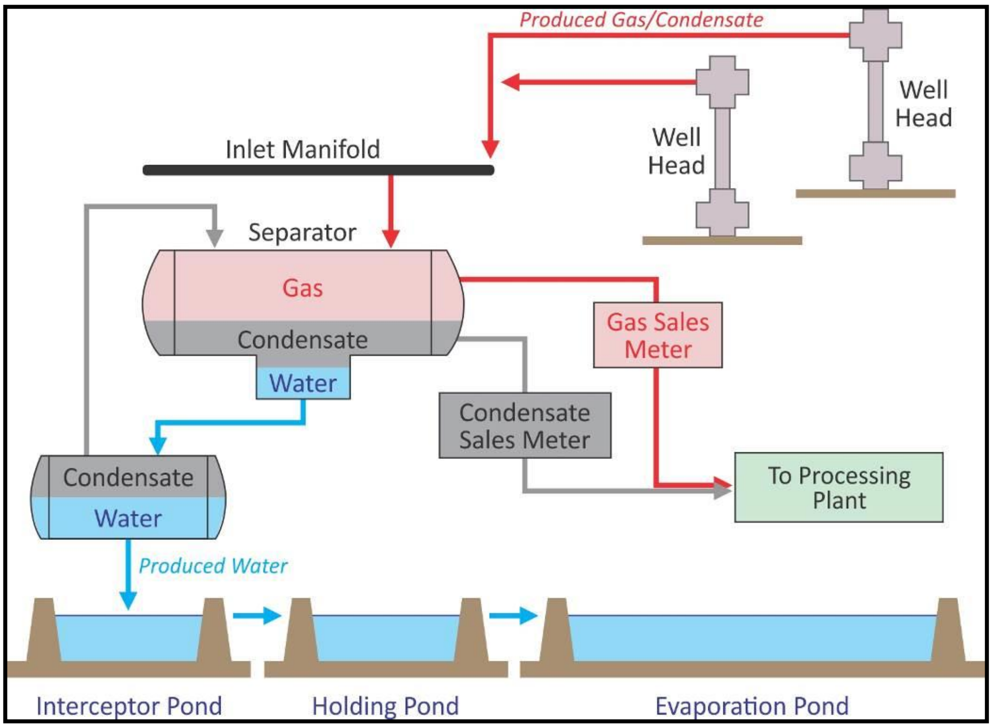


Figure 10: Gas production and water disposal process diagram

3.3.3 Camps

Camps may be located at production facilities or at stand-alone sites. Camps provide accommodation for personnel working at facilities or surrounding areas, as well as offices and other operations support infrastructure, and may include the following:

- accommodation, offices and amenities
- bulk storage areas or warehouse
- electric power generation
- communications systems
- potable water treatment system (e.g. reverse osmosis system) (at some sites)
- wastewater / sewage treatment system and disposal areas
- fuel storage and refuelling areas
- storage areas for waste and hazardous material
- workshop for maintenance of vehicles, plant and equipment.

Camps are established in existing areas of disturbance where possible, or in areas with little perennial vegetation. A site for a camp would typically be located adjacent to existing roads or tracks.

Beach currently has permanent manned camp facilities at Callawonga (capacity approximately 50 personnel), Bales (capacity 45), Growler (capacity 44) and Driftwood Camp (capacity 48) with small accommodation facility's at Middleton and Lycium (capacity 2) intended primarily for short-term use. Beach currently has 2 unmanned and unused camps at Acrasia (capacity 13) and Mirage (capacity 12).

Potable water for use at camps and operational sites may be obtained from third party facilities, or appropriately licensed water bores. Reverse osmosis units may be used to treat bore water to ensure that it is suitable for drinking. For example, the Callawonga camp obtains water from a well completed in the GAB under a water licence, which is treated by reverse osmosis for potable water supply. This water is also used to supply other nearby camps.

Waste management at facilities and camps is discussed further in Section 3.10.

Plate 9: Callawonga camp

Plate 10: Growler Camp

3.4 Produced Formation Water

When oil or gas is produced to the surface it is accompanied by varying quantities of water. This water is known as produced formation water (PFW).

The Minister for Energy and Mining holds a water licence within the Far North Prescribed Wells Area which allocates 21,900 ML per annum (equivalent to 60 ML/day) for the purpose of taking produced formation water. In 2020 and 2021, average daily co-produced water production was close to this allocation. DEM is closely monitoring and working with DEW on forward management of co-produced water (DEM 2021). Beach also has an allocation/licence of 300000kL per year under water licence 396774 and 176000kL per year under licence 231637

Once PFW undergoes primary treatment at the production facility, it is transferred to a lined interceptor pond. From this point, treatment and disposal of the water is generally achieved using evaporation ponds. In the erosion-prone gibber landscape at Acrasia, infiltration is the preferred disposal option (as discussed in Section 3.4.1.4.). Other options that may be used include secondary use (as discussed in Section 3.4.2) or reinjection (as discussed in Section 3.5).

PFW passes via a pipe system into the lined interceptor pond where any entrained hydrocarbons are recovered by manual skimming or vacuum truck. The separated water then passes through a series of ponds (as discussed below in Section 0) to achieve an oil in water content of:

- less than 30 mg/L if the water is being disposed of via closed (bunded) evaporation ponds; or
- less than 10 mg/L if the water is directed to free-form (unbunded) evaporation areas or infiltration basins.

These oil in water content criteria are based on recommended standards that have been provided by the regulator (DEM, formerly PIRSA) for formation water ponds in the South Australian Cooper Basin (Santos 2017a). If secondary use of PFW is proposed, water quality criteria for other analytes are also relevant, as discussed in Section 3.4.2.

The formation water produced at Beach's production facilities is reasonably fresh and salinity is typically well below the level (4,000 mg/L) that can be consumed by stock with no adverse effects (ANZECC 2000). A listing of Beach's PFW disposal facilities is provided in Table 4.

Table 4: Beach PFW treatment facilities as at August 2022

Facility	**Approx. area of ponds (m^2)**	**Indicative free form evaporation area (ha) (nom. max. size)***
Bauer (East, West and North)	50,000 + 55,000	319
Butlers	28,200	27
Callawonga	15,681	137
Christies / Silver Sands	12,240	27
Chiton	7,035	8
Congony / Kalladeina / Sceale	8,450	15
Growler	2,200	4
Hanson / Snellings	7,800	69
Harpoono	2240	4
Hornet	878	-
Lycium Hub	880	1.4
Martlet	1,870	37
Middleton / Brownlow / Canunda	44,740	-
Mustang	13,556	43
Parsons	12,800	39
Pennington	15,000	54
Rincon	2,085	20
Snatcher	4,443	-
Stunsail	13,700	78

*Note: Nominal maximum size reflects predicted maximum extent. Free form areas change over time due to variation in water production rates and seasonal variation in net evaporation and may be significantly less than this value.

3.4.1 PFW Treatment Process

The PFW treatment process is summarised in Figure 11, and discussed further below.

3.4.1.1 Primary Treatment

Primary treatment can consist of either physical (gravity) separation or chemical treatment (emulsion breakers) where needed. Chemical treatment enhances PFW separation and aims to maximise hydrocarbon recovery prior to disposal. Primary treatment takes place in vessels and tanks (the separation plant) located in the vicinity of the PFW disposal facility. Water is discharged from the base of the tanks to a lined interceptor pond in the disposal system as shown previously in Figure 8, Figure 9 and Figure 10.

3.4.1.2 Secondary Treatment - Interceptor Ponds

An interceptor pond is the first pond in any system and is lined with an impervious membrane (e.g. UV stabilised HDPE) and fenced to prevent stock access. The interceptor pond is used as a buffer to ensure that any hydrocarbons carried over from primary separation do not enter the unlined ponds. Hydrocarbons entering the system can be manually skimmed or vacuumed from the surface of the interceptor pond.

Water exits the interceptor pond by an underflow pipe to prevent hydrocarbons on the surface moving further into the system. Water contained in holding ponds should have a concentration of not more than 30 mg/L of total petroleum hydrocarbons.

Plate 11: Interceptor pond at the Bauer facility

3.4.1.3 Tertiary Disposal - Evaporation Systems

The most common means of PFW disposal is the use of a pond system to evaporate water. There are many variables in design of evaporation systems. For example they can be open, closed, bunded or free form. Whether a system is open or closed depends upon water quality considerations and consultation with pastoral lessees and environmental assessment and approval.

Bunded evaporation systems consist of a series of specially constructed shallow ponds to which PFW is discharged, whilst free form water disposal utilises natural landscape features to form the final evaporation area in the system as described above. Bunded evaporation ponds are typically lined with an impermeable membrane (e.g. UV stabilised HDPE).

Free form evaporation systems usually include at least two specially constructed bunded ponds following primary separation and the lined interceptor pond through which the PFW passes prior to discharge to the free form evaporation area. This acts as a safety mechanism in the event of an oil release to the system. Free form evaporation systems most commonly utilise a dune corridor, with bunds constructed at an appropriate distance apart where required, to form the free form evaporation area.

Residence times in the tertiary treatment system are planned to be sufficient for removal of hydrocarbons to meet the relevant oil in water content criteria. Free form evaporation systems require increased residence times of the PFW prior to discharge to the free form area, to ensure that the oil in water content is less than 10 mg/L.

Monitoring of pond water quality[6] is carried out regularly (at least every 12 months), as per the Beach Cooper Basin Environmental Monitoring Plan and associated procedures, to ensure it meets disposal criteria. Monitoring bores may also be installed to monitor potential impacts on groundwater where relevant. Monitoring bores have been installed at most older facilities. Monitoring bores are now a standard component of all new facilities.

In 2020 and 2021 an assessment of the background concentrations and Environmental Values (EVs) of shallow groundwater at facilities was undertaken (LBW Co 2020, LBW Co 2021). This study found that there are no applicable EVs for shallow groundwater at any of the current production facilities.

[6] The monitoring suite for free form evaporation systems typically includes TDS, pH, Total Recoverable Hydrocarbon, BTEXN, PAHs, phenols, dissolved metals (arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, lead, manganese, mercury, nickel, selenium, vanadium, zinc), TDS, Cations (calcium, magnesium, sodium, potassium), Anions (chlorine, sulphate, alkalinity), Ionic balance, Nutrients (Nitrate, Nitrite, Nitrogen, Fluoride, Reactive Phosphorus).

Plate 12: Callawonga West free form area

3.4.1.4 Tertiary Disposal – Infiltration Systems

Gibber landscapes present challenges for water disposal as the underlying soil is highly erosion prone on any slope of more than 2%, if the gibber pavement is disturbed or if water is re-directed. Due to the erosional landscape, the primary objective for water management on gibber land systems is to minimise and mitigate biophysical impacts and to avoid accelerated erosion. The secondary objective is to minimise the extent of permanent or semi-permanent impact from development of water infrastructure, such as large ponds and excavations.

Options for disposal of PFW in gibber land systems were extensively investigated by Stuart Petroleum (Fatchen, various reports 2006-2008) as part of the environmental assessment for the Acrasia oil field development. The outcomes of the investigation found that the use of evaporation ponds on gibber land systems was not considered a viable option for the following reasons:

- potential for a significant permanent, physical footprint from the construction of ponds
- highly erosional nature of the gibber soil types following disturbance of gibber pavement
- requirement for large bunds to be built as no naturally confined areas existing on gibber plains
- long term pondage of water over a large area may result in permanent changes to gibber soil structure, colour and chemistry
- redirection of natural surface drainage and overland flow may result in rapid and irreversible erosion.

Based on outcomes of the environmental assessment (Fatchen, 2006-2008), infiltration was authorised as the approved disposal method in gibber land systems where sloping surfaces and dispersible soils can lead to major and permanent surface impacts and erosion risks. Disposal of PFW by infiltration requires the excavation of a pit through clay layers into permeable material. Treated water[7] is discharged to the pit and gravity infiltrates into permeable sub-surface layers or

[7] Treated water is defined as water that meets discharge criteria of <10mg/L total hydrocarbon (TPH) content

shallow aquifers. The infiltration method poses a risk of groundwater contamination and it is necessary to carry out rigorous testing of water quality both in the infiltration pit and at nearby groundwater bores.

Infiltration is used for disposal of PFW in gibber uplands at the Acrasia field where PFW is gravity infiltrated into near-surface dry unsaturated sands of the Winton Formation. There are no water supply wells in the upper units of the Winton Formation. The water management system allows for clean PFW to percolate to local groundwater consistent with the process of natural infiltration in gibber land systems.

When PFW disposal by infiltration is being undertaken[8], Beach carries out a monitoring program to assess water quality in the Acrasia ponds to ensure water quality meets the discharge requirements, and conducts annual water quality sampling from the Acrasia groundwater monitoring bores to monitor for infiltrated water movement and demonstrate that no groundwater contamination has occurred.

Groundwater modelling was completed as part of the environmental assessment to assess the potential infiltration pathways. Future groundwater modelling will be conducted as required under the EPA licence requirements.

3.4.2 Secondary Use of PFW

As PFW is a potentially contaminated process by-product, its use for secondary purposes such as drilling, fracture stimulation, road construction, hydrotest water, dust stabilisation or livestock watering is carefully managed. Prior to secondary use, monitoring results must have shown that the water quality is consistent with relevant guidelines for the intended use and that the concentration of hydrocarbons in the evaporation pond water is consistently lower than 10 mg/L.

The secondary use of PFW as ballast water for oilfield tankers is acceptable provided that the ballast, when not required, is discharged to an approved PFW disposal facility. PFW may occasionally be used as a water source for drilling or fracture stimulation, depending upon proximity to the site and water quality requirements. Ballast water is discharged directly to interceptor ponds to enable any free residual oil to separate from the water and be recovered via surface skimming. Only ballast water is discharged from oilfield tankers to interceptor ponds and under no circumstances is oil, condensate or fluid with greater than 30 mg/L hydrocarbon content discharged from oilfield tankers to interceptor ponds.

PFW may also be used as a water source for waterflood, as discussed in Section 3.5.

[8] The Acrasia field was shut in at the time of preparation of this EIR and no PFW disposal or monitoring was being undertaken

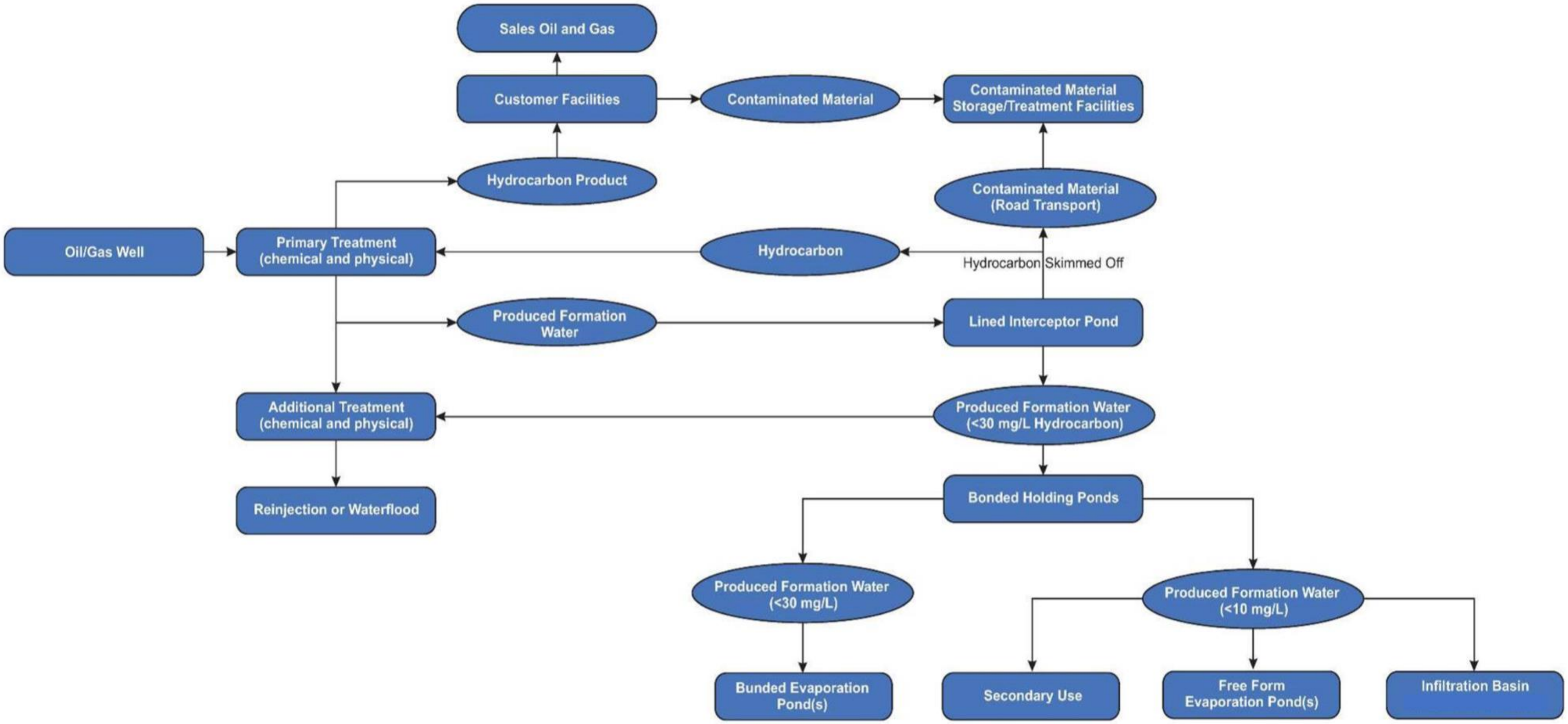


Figure 11: Produced formation water treatment process

3.5 Waterflood and Reinjection

3.5.1.1 Waterflood

Waterflooding is a means of improving oil recovery by maintaining the pressure in the formation. This is achieved by injecting water back into the formation that it was produced from, or injecting water from other produced wells that have compatible water to the target formation.

Prior to a waterflood scheme being initiated the produced water is tested to ensure it meets certain requirements. The injected water must be clear, stable and be of similar quality to the water in the formation that it is to be injected into. It also must not be severely corrosive and must be free of materials that may plug the formation. In order to achieve this, the PFW may be de-aerated, softened, filtered, chemically treated and / or stabilised.

PFW to be used for waterflood is typically produced into tanks, and further separation is undertaken to ensure that all the oil and sediment have been removed from the water prior to reinjecting into the formation. This is typically done using hydrocyclones, with chemicals and / or heating. Water may also be treated to kill any bacteria residing in the water and other chemicals may be added to eliminate the oxygen content or other components in the water that may cause corrosion of tubulars or incompatibility of the water injected formations.

The water is injected into injection wells using pumps, at pressures high enough to enter the target formation. The injection well may be a production well which has been converted to a water injection well or a well specifically designed and drilled for water injection. The location of injection wells may change over the course of the life of the field to ensure that the oil pool is swept in the most efficient manner. The exact nature of an injection scheme will depend on the objectives of the scheme and the geological environment.

3.5.1.2 Reinjection

Reinjection of water for disposal is an alternative to surface treatment and evaporation as a means of water management. Reinjection could be into the formation that the water is produced from, or a different formation. The treatment and injection process is similar to waterflood, however injection for water disposal does not aim to enhance the ability of a formation to produce incremental hydrocarbons.

Reinjection has not commonly been undertaken in the Cooper and Eromanga Basin Region because of the high cost associated with installation and ongoing operation of the infrastructure.

Beach's preliminary plans for treatment and reinjection involve utilising PFW extracted from holding ponds, filtered and treated to achieve required quality before injection. Water quality monitoring will ensure injected water maintains required quality levels.

3.5.2 Tracers

Tracers may be added to injected water to monitor the direction and effectiveness of the waterflood. Tracers are injected into the water injection well and special lab tests are conducted to pick up extremely low levels of tracer in the produced water.

Tracers are usually non-hazardous chemical or low-level radioactive tracers such as tritium or isotopes of iodine. Tritium tracer, which is effectively tritiated water (HTO), is a weak beta emitting isotope that has negligible external radiological effect. The radiotracer is typically contained in small volumes (e.g. less than 15 mL) inside approved injection vessels, resulting in negligible internal radiological hazard from possible ingestion of tracer as it is in a sealed system. A beta emitting tracer (e.g. iodine 131) may be added to the vessels to indicate when the tracer has moved through the vessels into the injection well. Tracers such as tritium and iodine tracers are used due to their inherent safety and low cost.

3.6 Pipelines / Flowlines

Pipelines and flowlines are used to connect wellheads to production facilities, and to connect production facilities to the Cooper Basin pipeline network or directly to the Moomba plant. They are typically constructed of steel, glass reinforced epoxy (GRE) or spoolable composite pipe and may be installed above or below ground.

Flowlines generally connect wellheads to facilities. They may carry well fluids extracted from wells via free flow or via artificial lift (e.g. jet pumps or electric submersible pumps - see Section 0). Flowlines typically range from 3" to 4" (75 mm to 100 mm) in diameter. Above-ground steel flowlines are typically used for oil. Buried flowlines of other materials are sometimes used for crossings and for gas applications. Gas flowlines are generally buried. Above-ground steel flowlines are usually located on supports to minimise contact with corrosive soils.

Buried pipelines that interconnect facilities are usually constructed of composite material (e.g. GRE or spoolable composite pipe). They typically have a larger diameter (in the order of 100 mm to 200 mm or more) and carry larger volumes of fluids than flowlines. Beach generally installs optic fibre cable with buried pipelines, to improve operations and monitoring of upset conditions.

High density polyethylene (HDPE) pipelines can also be used, primarily for transferring water (typically PFW) between facilities and disposal ponds.

All pipeline design, construction and operation is undertaken in accordance with relevant Australian Standards, in particular:

- AS 2885: Pipelines – Gas and Liquid Petroleum.

Adherence to design standards minimises the risk of pipeline failure, which may have serious environmental implications in sensitive locations such as in floodplains or creek lines. Design standards which aim to protect pipeline integrity and prevent loss of hydrocarbons to the environment include:

- design of the pipeline to have an appropriate diameter and wall thickness for the operating pressure requirements
- application of external interference protection measures, including physical and procedural controls (such as increased depth of burial and increased use of marker signs) to mitigate threats identified in the Safety Management Study undertaken under AS 2885.1
- specification of appropriate threat mitigation measures (such as deeper cover where the pipeline is buried under rivers, creeks and roadways
- on floodplains and under creeks, it may be necessary to use welded lines and / or concrete weighting to counter the buoyancy of the pipeline when the soil is saturated with water
- use of high integrity external coating and cathodic protection devices for buried steel pipe to protect against corrosion
- use of supports for aboveground pipelines to maintain them clear of corrosive soils
- provision of failure detection systems with remote shutdown on major export pipelines

- installation of overpressure protection devices to prevent line rupture which may include some or all of the following:
  - a high pressure shutdown valve to isolate the well from the pipeline
  - a pressure safety valve (PSV) designed to relieve the pressure above design operating pressure of the pipeline
  - liquid pipelines may be equipped with thermal PSVs and check valves to prevent line rupture as a result of temperature induced expansion
- PSVs and pipeline bleed points are provided with sumps or drums of sufficient capacity to contain discharged fluids
- if required, launching and receiving facilities for pipe cleaning devices (referred to as pigs) are constructed to contain minor spills during removal / insertion of pigs and with a sump for draining the receiver / launcher prior to opening. Pigs are typically not used on flowlines due to their short length, smaller pipe diameter and higher temperature well fluids.

Environmental management of pipeline construction and operation is consistent with the guidance provided by the Australian Pipelines and Gas Association (APGA) Code of Environmental Practice: Onshore Pipelines, which has been incorporated in and expanded on in Beach's environmental management procedures.

3.6.1 Route Selection, Survey and Site Preparation

A preferred route alignment is selected according to evaluation criteria, such as constructability, accessibility, environmental and cultural heritage sensitivity, safety and cost. The route alignment selection is initially undertaken as a desktop exercise which is validated and revised in the field during the Work Area Clearance process. Once the pipeline route is selected, the centreline is pegged and Pipeline Alignment Survey drawings are drafted. These drawings are used during the pipeline Safety Management Study to risk assess locational hazards.

For buried pipelines, the right of way (ROW) is cleared, with topsoil and vegetation stockpiled separately. The width of the right of way for a buried pipeline depends on the pipeline diameter, but is typically in the order of 15 – 20 m wide. Large diameter pipe may require the greater width to provide a safe construction area for personnel and equipment. Additional width may be required in some areas to allow room for laydown of pipe and equipment and to allow trucks and vehicles to pass locations where construction is being carried out. Dune crossings may also require a greater width to be disturbed (e.g. up to 100 m or more for large dunes) to achieve sufficient depth of cover without the curvature of the pipe exceeding allowable limits, and to ensure access and construction activities can be carried out safely.

During construction of above ground pipelines the construction easement may be cleared but is not usually graded. Above ground pipelines often require a narrower easement and so result in reduced disturbance to vegetation and topsoil. Above ground pipelines and pipeline stations require ongoing control of vegetation to manage the risk of damage due to fire.

3.6.2 Pipeline Construction

Construction of a buried pipeline involves trenching or ploughing along the alignment after the construction easement is cleared. Trenching to a depth of two metres or more may be necessary in locations where lines pass through sand dunes, areas subject to inundation, wash out areas or under roads. Breaks are left in the trench to facilitate fauna movement across and out of the open trench.

Steel and GRE pipe is transported to the pipeline easement in sections and pipe is typically laid end-to-end adjacent to the trench on raised skids (typically timber blocks) to protect the pipe coating from damage. This process is known as 'pipe stringing'. In the case of above ground pipelines, sections of steel pipe are laid out on raised skids adjacent to the eventual pipeline supports.

Steel pipes are either screwed together (e.g. for smaller flowlines) or welded in lengths. Welds are subjected to non-destructive testing (NDT), including radiography, to test for construction defects and to comply with specifications. GRE pipes are typically joined by threaded joins with O-ring seals with each pipe screwed to the torque recommended by the pipe manufacturer. Spoolable composite pipe joins typically use proprietary steel joiners.

The joined pipe sections are lowered into the trench or laid on the surface using sideboom tractors. Above ground pipelines are buried under roads, at river and channel crossings and on floodplains where required.

Spoolable composite pipe is supplied on large reels and is transported to locations along the alignment on a carousel located on a truck. Pipe is pulled off the carousel using mobile plant and placed in the trench.

On some pipelines, a 'spider plough' may be used to plough composite pipe directly into the ground. This machine ploughs a trench, lays the pipe and refills the trench in one continuous motion, avoiding the need for an open trench.

Where necessary, soil and / or padding from approved borrow pits may be placed into the trench to protect and stabilise the pipe. The trench is then backfilled and compacted with previously excavated trench spoil material.

Watercourses are typically crossed using standard open-cut (trenching) construction. This technique is suited to the dry conditions which prevail in the Cooper Basin. Watercourse crossings are typically completed within the shortest period practicable and the trench is generally not completed through the watercourse channel and banks until immediately prior to pipe installation. Construction is generally undertaken in dry conditions. If water is present, flow diversion techniques may be employed, such as pumping of water around the work area using barrier dykes or head walls to keep the work area dry, or diverting the flow through a pipe.

Horizontal directional drilling (HDD) can be used to cross watercourses when water is present or other infrastructure (e.g. major roads) however it is generally not used in the Cooper Basin. HDD involves drilling a hole at a shallow angle beneath the surface, then pulling the welded pipe string back through the hole. A HDD drilling rig and a variety of associated equipment is required, and excavations are required for a cuttings settlement pit and mud containment pits at the drill entry and exit points.

3.6.3 Pipeline Testing

The integrity of pipelines is verified using hydrostatic testing conducted in accordance with AS 2885. During hydrostatic testing the pipeline is capped with test manifolds, filled with water and pressurised in accordance with the standard. Large sections of the pipeline trench may be kept open during testing to allow identification and repair of any leaks that are detected.

The use of biocides and chemicals with hydrostatic test water may be required under some circumstances to prevent internal bacterial corrosion of the pipeline metal components. Hydrostatic test water may be sourced from existing water bores. Produced formation water may also be utilised as a water source provided that it is adequately treated with biocide to remove potential for bacterial contamination of the pipeline.

Disposal of hydrostatic test water which contains biocide and other chemicals may be to existing lined and fenced interceptor ponds, or to specifically constructed pits sited to prevent the contamination of shallow groundwater and surface waters. Hydrostatic test water that has no biocides or deleterious chemicals added may be disposed of to the land surface (e.g. through road watering) but is not disposed to water or any areas where it is likely to enter waters (including groundwater).

3.6.4 Site Restoration

The easement is reinstated and restored as soon as possible after pipe laying, testing and backfill. This involves removal of all construction generated refuse, re-contouring of the site, re-establishment of natural drainage lines, bank restoration (if necessary), topsoil respreading and respreading of any cleared vegetation.

3.6.5 Operation

Pipeline operation and maintenance is approached in a systematic manner over the life of the assets, in accordance with AS 2885. Inspection and monitoring of pipelines are carried out and operating procedures are followed to ensure that they are operated within their design capability. The Beach Energy management system is outlined in the Pipeline Integrity Management Plan (PIMP) and Pipeline Management System (PMS). The Safety Management Study (SMS) and remaining life assessments are periodically reviewed, in accordance with AS 2885 requirements.

3.7 Road Construction and Maintenance

Beach currently maintains approximately 1000 km of access roads to production wells and facilities, some of which are also station tracks. The remainder of the road network in the Cooper Basin is maintained by third parties (e.g. Santos, DIT).

Where possible, existing roads, station tracks and exploration well access tracks are utilised and maintained for production access. However, some road construction or upgrading and realignment will be required for access to future production operations. Within Regional Reserves, the creation of new access tracks is kept to a minimum and where appropriate disused roads will be rehabilitated at the conclusion of activities.

Once surveys are complete and a preferred road alignment is selected, a road is constructed according to the land system(s) it will pass through, in accordance with Beach design standards and procedures. In most cases the easement will be rolled or capping may be laid over the natural surface material (e.g. in gibber plains or where the terrain is naturally flat and susceptible to erosion when disturbed). Alternative road surface preparation methods may also be trialled and used with DEM approval. Table 5 provides information on the road construction methods applied to land systems in the Cooper Basin.

Table 5: Road construction methods for land systems in the Cooper Basin

Construction Method	Land System					
	Dunefields	Floodplains	Gibber plains	Salt lakes	Tablelands	Wetlands
Avoid construction on land system				✓		
Utilise naturally cleared areas	✓	✓	✓		✓	✓
Avoid steep slopes	Susceptible to erosion. Ensure controls are in place		✓		✓	
Weave road between trees and large shrubs	✓	✓	✓		✓	✓
Clear and grade	✓	✓	*			✓
Roll			✓		✓	
Cap road surface with clay or similar borrow material	✓	✓	✓		✓	✓
Bridges, culverts or floodways installed on drainage line crossing as required	✓	✓	✓		✓	✓

*Non-standard practice, which may be undertaken in some circumstances, with adequate erosion controls in place. Detailed site-specific assessment, planning, management, monitoring and rehabilitation would be required.

Road construction styles are assessed according to the amount of anticipated use as well as the environmental sensitivity of the area. Roadside borrow pits are used to source material for road fill. Erosion controls are implemented during and after construction and particular attention is given to flood and water flow areas.

Appropriate planning and construction is undertaken for roads in floodplains and watercourses to avoid disturbance to significant vegetation and natural drainage patterns. Culverts or other structures may be installed where required to ensure that surface water flows are not impeded by the road and in some circumstances, structures such as raised roads or bridges may be installed (see Plate 13). Detailed hydrological assessment would typically be undertaken for these structures to ensure that there are no significant impacts on surface water flows or aquatic fauna.

In gibber plains minimal disturbance techniques are implemented, such as retaining the gibber pavement protective layer to control erosion as far as practicable.

Following construction, rehabilitation is undertaken to ensure that surrounding surface drainage is restored and erosion control structures are installed in erosion prone areas.

Supplies of suitable construction material, such as soil (or occasionally gravel), are usually extracted from sites referred to as borrow pits. Borrow pits are excavated to provide:

- soft earth for trench backfilling
- rubble and clay for maintaining, upgrading or constructing roads and production facilities
- rubble and earth for the construction of above ground pipeline crossings.

Borrow pits vary considerably in dimension depending upon the quality and quantity of material contained in them.

Site selection, environmental management and restoration of borrow pits is undertaken in accordance with Beach procedures, guidelines contained in the SEO, and industry-wide standards for borrow pit management developed by DEM[9]. Existing borrow pits are used in preference to new ones where appropriate.

In the event that damage occurs to public roads as a result of Beach's operations, maintenance activities are undertaken to restore and maintain the road at an acceptable standard (as a minimum to pre-existing standard) in consultation with the relevant authority.

Plate 13: Bridge at crossing of channel of Cooper Creek near Callawonga

[9] DSD (now DEM) commissioned a review of the Goal Attainment Scaling (GAS) criteria for borrow pit construction and rehabilitation (Jacobs SKM 2014). Following the recommendations of the Jacobs SKM report, GAS tables were developed by DSD in consultation with other relevant government agencies and industry and released in November 2014 for incorporation into relevant Statement of Environmental Objectives.

3.8 Aircraft Landing Area

Beach currently operates a single aircraft landing area (airstrip) in PRL 89, north-west of the Butlers facility with an aerodrome. Butlers Airstrip is classified as an uncertified aerodrome (Certain Other Aerodromes as per Civil Aviation Safety Regulations (CASR)) capable of servicing passenger transport operations as well as emergency medical evacuations by agencies such as the Royal Flying Doctors Service (RFDS). As well as facilitating access to an enhanced emergency response capability like the RFDS, the airstrip enables Beach to; reduce road traffic and driving-related risks, achieve a reduction in overall travel times, avoid rain induced delays due to road closures and enable access to operational areas when road access is restricted by inundation from flood events.

Butler's Airstrip has been designed to the physical standards referenced in the Civil Aviation Safety Authority (CASA) Manual of Standards Part 139 (MOS139). Although the airstrip is not certified, the acknowledgement of the higher order standard provides an increase in safety margins (and oversight) of this critical infrastructure. Audits are conducted against MOS139 by an independent CASA approved inspector to provide assurance passenger transport and RFDS operations (e.g., PC12, PC24 and KingAir) can be conducted safely under the current regulatory requirements.

To satisfy the aircraft performance and other operational requirements, the compacted runway has a design that is of 1,200 m long and 30 m wide. The overall approach, takeoff and adjacent flyover areas (which must be clear of vegetation) totalling approximately 1,800 m by 90 m.

Aircraft landing areas are primarily used in the daytime but may be suitable for night-time RFDS retrievals in case of emergencies. They are fenced to exclude cattle, and gates and signage are also installed to restrict vehicle and personnel movement through the landing strip area.

3.8.1 Helicopter Landing Sites

Beach currently operates a number of prepared Helicopter Landing Sites (HLSs). The locations of these landing sites are varied, with the main HLSs co-located with office and accommodation facilities e.g., Callawonga. HLSs are used for contingency operations (flood response) and to facilitate Helicopter Emergency Medical operations for the retrieval of medical cases.

Beach HLSs have been designed to the guidance and advisory publications governed by the Civil Aviation Safety Authority (CASA) i.e., CASA AC 91-29 v1.0 Guidelines for helicopters - suitable places to take off and land. This acknowledges that helicopter HLSs are not regulated by CASA and is a requirement for companies and aircraft operators to assure the safety of this infrastructure.

To meet the operational and performance requirements for helicopter operations, Beach HLSs are prepared with a clear final approach and take-off (FATO) area of 40 m2. HLSs have minimal surface treatment with clay / sand surfaces predominating.

Plate 14: Butlers airstrip in PRL 89

3.9 Oil Transport

Oil from Beach's production facilities is transported either by pipeline or tankers, to third party facilities in the Cooper Basin or to other facilities in South Australia or Queensland. There may be several tankers per day travelling from a facility along access roads and in some cases along public roads. Tanker load out areas at the facilities are lined and bunded to contain any spills and are operated in accordance with the Australian Standard (AS) 1940.

Access roads in the Cooper Basin may cross creek beds, including the Cooper and Strzelecki Creeks. These creeks are generally dry; the lower Cooper flows once every 2-5 years on average and flows in Strzelecki Creek occur even less frequently.

Safe transportation of the oil from the well site to the delivery point is the prime responsibility of the transporters, under the *Dangerous Substances Act 1979* and the *Environment Protection Act 1993*. Suitably licensed, trained and experienced contractors are used to transport oil.

Plate 15: Oil tanker load-out

3.10 Waste Management

Waste management is an important issue and Beach will continue to incorporate appropriate waste management practices into the construction, operation and abandonment phases of its developments.

Beach follows the principles of the waste management hierarchy as far as possible (Avoid, Reduce, Reuse, Recycle, Recover, Treat, Dispose) and has put measures in place to prevent pollution by reducing the use of energy, water, material resources, and recycling waste where possible.

Beach is responsible for the management of all the wastes it generates and for its disposal in accordance with regulatory requirements and industry standards. Waste from operations is generated from two main streams: operational waste and domestic waste (Table 6).

Table 6: Typical waste streams

Waste Type	Disposal
Operational Waste	
Gaseous waste	Flared or vented – gaseous hydrocarbons, CO_2, H_2S, CO Generator and vehicle emissions
Produced formation water	Interceptor ponds and then to evaporation ponds, reinjection or reuse
Waste oil / water (slops) hydrocarbon / water mixtures or emulsions	Directly skimmed from ponds and where possible, returned to the production facilities for processing. Stored in a bunded area for collection and transport off-site by a licensed regulated waste contractor to a licensed regulated waste facility for treatment, recycling or disposal
Pig-receiver / slugcatcher scale	Lime scale and sludge collected for transport off-site by a licensed regulated waste contractor to a licensed regulated waste facility for disposal
Contaminated soil	Soils contaminated with chemicals are to be managed as specified in the Safety Data Sheet (SDS) for the spilt chemical Soils contaminated with hydrocarbons are to be treated in situ or collected and stored in the designated soil containment areas located at Beach sites If not treated in situ or at a Beach soil remediation area, collected for transport off-site by a licensed regulated waste contractor to a licensed regulated waste facility for disposal Ultimate reuse or disposal of treated soil consistent with the principles of the National Environment Protection Measure for contaminated sites and relevant EPA guidelines
Hydrotest water	Recycled for each hydrotest section Evaporation pond or to ground if consistent with ANZECC (2000) / ANZG (2018) and EPA criteria
Completions / fracture stimulation fluids	Collected in lined ponds or tanks for disposal in evaporation ponds or to an appropriate facility
Completions / fracture stimulation flowback solids	Disposal at an appropriately licensed facility or disposal on site during pond rehabilitation if testing demonstrates that appropriate criteria (e.g. waste fill guidelines) are met
Empty drums – plastic fuel, lubricant and chemical containers	Drums to be transported off-site by waste contractor for reuse, recycling or disposal
Chemical waste	Stored in accordance with Australian Standards and EPA guidelines in bunded areas for transport off-site by a licensed regulated waste contractor to a licensed regulated waste facility for recycling or disposal
Plastic pond liner (e.g. HDPE)	Transported to a licensed recycling facility (where possible) or sent for disposal at an appropriately licensed facility
Metals – empty steel drums, bulk scrap steel, pipe, bolts, wire / cables, mini rings	Segregate (stored separately from other waste) metals from other wastes and store for recycling
Timber pallets (skids)	Recycled where possible
Batteries	Collected for transport off-site by a licensed regulated waste contractor to a licensed regulated waste facility for treatment, recycling or disposal
Vehicle tyres	Collected for transport off-site by a licensed regulated waste contractor to a licensed regulated waste facility for treatment, recycling or disposal

Waste Type	Disposal
Workshop waste – filters, rags, grease and lubricants	Recycle where possible and remainder for disposal to EPA licensed landfill Oil and lubricants to be collected and stored in bunded areas awaiting transport off-site by a licensed regulated waste contractor to a licensed regulated waste facility for treatment, recycling or disposal
Domestic waste	
Storm water runoff (camp)	Runoff to vegetation
Sewage and grey water	Treated at facility in septic tank or approved aerobic system in accordance with SA Public Health (Wastewater) Regulations Sludge and residue collected by a licensed contractor as required and disposed of at an appropriately licensed facility
General wastes – food waste, food wrappers, plastic bags, packaging	Securely stored in covered bins (to prevent wildlife access) for regular removal to general landfill. Rubbish contained and controlled to minimise odours and maintain hygiene
Comingled recyclable material – paper and cardboard, timber pallets, plastics and aluminium cans	Segregated and placed in bins or skips for recycling
Grease trap wastes	Collected for transport off-site by a licensed regulated waste contractor to a licensed regulated waste facility for treatment, recycling or disposal

3.10.1 Landfill – Domestic Waste

Beach does not currently operate landfill sites in South Australia. Waste that is to be disposed to landfill is taken to appropriately licensed landfills (e.g. Moomba). However, Beach is undertaking a review of waste management, which may result in changes to the current waste disposal strategy.

If Beach were to establish a landfill site, it would be constructed in accordance with EPA requirements and all necessary approvals would be sought through the EPA and in consultation with DEM.

Beach has previously obtained EPA approval for disposal of putrescible waste to land during extensive Cooper Creek flooding in 2010-11, when road access to the Callawonga camp was extremely limited and access to Moomba to transport waste from the Callawonga camp was not possible. This practice is not preferred, and would only be undertaken (subject to regulatory approval) on a temporary basis during extreme flood conditions if there were no feasible alternatives.

3.10.2 Sewage Waste Management

Sewage wastes at production facilities are disposed using on-site systems that are approved and managed under the *South Australian Public Health (Wastewater) Regulations 2013* and in compliance with *the South Australian Health On-site Wastewater Systems Code*, or to the satisfaction of the Department of Health. Wastewater effluent is disposed to evaporation ponds or irrigated to land in a location where it will not enter surface waters, to ensure compliance with Clause 17 of the *Environment Protection (Water Quality) Policy 2015*.

3.10.3 Contaminated Soil Treatment / Soil Remediation Areas

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 to an approved land treatment facility or to a suitable EPA licensed facility for treatment or disposal.

Beach operates an approved land treatment facility, also referred to as a soil remediation area (SRA), in the Bauer field that is used for the bioremediation and treatment of hydrocarbon contaminated soils. The SRA consists of an impermeable lined, bunded and fenced area, which is subject to ongoing management and monitoring. Land treatment is undertaken in accordance with relevant EPA guidelines, including the EPA *Guidelines for the assessment and remediation of site contamination* (EPA 2019). The reuse or disposal of treated soil is consistent with the principles of the National Environment Protection Measure for contaminated sites and relevant EPA guidelines. There is also a temporary soil remediation area located in the Growler field which is expected to be removed and consolidated with the Bauer soil remediation area.

3.10.4 Fracture Stimulation Flowback Solids

Fracture stimulation flowback solids (e.g. proppant) remaining in ponds may be disposed on site during pond rehabilitation if testing demonstrates that they meet appropriate criteria (e.g. waste fill guidelines) or are disposed of at an appropriately licensed facility (e.g. soil remediation area or waste disposal facility).

3.10.5 Sludge Treatment

Oily sludge (generally derived from tanks) is currently stored on-site before transport to a suitable licensed facility for treatment and disposal. Beach may, in the future, develop a sludge treatment plant to recover useable hydrocarbons and reduce the amount of solids removed off-site for treatment and disposal. A sludge treatment plant would typically involve physical (e.g. centrifuge, heat) and chemical treatment (e.g. demulsifying agents) to separate out hydrocarbons, water and solids. Hydrocarbons and water would be returned to the production facility provided the quality is suitable. Solids may undergo further treatment (e.g. bioremediation in a land treatment area) and would eventually be transported off-site for reuse or disposal in accordance with relevant EPA guidelines.

A sludge treatment plant would be likely to be located at or adjacent to an existing facility. Installation and operation of a sludge treatment plant would require approval by DEM and EPA.

3.11 Decommissioning / Rehabilitation

Production facilities, wells and associated infrastructure (including pipelines, roads, laydown areas, camp sites and borrow pits) that are no longer required will be progressively decommissioned and rehabilitated by Beach. Decommissioning, abandonment and rehabilitation activities will be tailored to the site and the landform, and will typically include:

- staged removal of surface infrastructure (e.g. tanks, pipework, cabling, buildings, engines) and waste
- removal of footings
- decommissioning ponds (liner removal and backfill)
- removal of bunds and berms (including liner removal and disposal)
- undertaking targeted soil assessments to detect any residual hydrocarbon contamination

- treatment of contaminated soil to meet end point criteria and subsequent disposal
- removal of hardstand/capping
- final testing for contamination of groundwater
- abandonment of production wells (see Section 3.1.5), including plugging and cellar and wellhead removal
- abandonment of pipelines in accordance with AS 2885, which typically involves:
  - pigging to remove residual hydrocarbons and sludges
  - removing above-ground pipes and supports for either disposal, salvage or re-use
  - cutting off all underground pipe work a minimum depth below the natural surface (in accordance with AS 2885) or at pipeline depth, removing and blinding remaining pipeline below the surface
  - removing all aboveground infrastructure including signs and markers
  - removing all pipeline protection systems to allow the pipeline to degrade in situ
  - mapping and recording of all pipelines which are partially or wholly left in situ
- abandonment of water bores (production or monitoring) including plugging (as prescribed in Far North Prescribed Wells Area Water Allocation Plan)
- restoration of borrow pits. Final restoration typically involves:
  - contouring slopes to minimise erosion
  - constructing erosion control measures where appropriate
  - where available, returning clay to the pit
  - spreading stockpiled topsoil
  - ripping access tracks to relieve compaction, minimise erosion and encourage revegetation
- restoration of roads or access tracks where use of operations is no longer required. Final surface restoration typically involves:
  - removal of capping from the access track or road and returning to the borrow pit
  - ripping of the contour to promote revegetation and minimise erosion (gibber terrain is track rolled only)
  - removing windrows to ensure that surface water flows are not impeded
- re-contouring or re-profiling of soils or land surfaces to reinstate natural contours and drainage lines

- ripping compacted areas where appropriate (except in gibber systems) to alleviate compaction and encourage revegetation

Site-specific plans or procedures are typically developed for decommissioning of facilities.

As discussed in Section 2.1.4, DEM is particularly focussed on progressively reducing the proportion of expired wells[10]. Beach is undertaking annual rehabilitation of expired wells in accordance with the expired well rehabilitation plan approved by DEM under the ELMP (DEM 2020[11]).

[10] For the purposes of the Environmental Liability Management Policy (DEM ,2020) an expired well is a well that has not produced / injected for more than 24 consecutive months and where the licensee has either declared the well expired or has not demonstrated a bona fide future use acceptable to DEM.
[11] Licensees are required to rehabilitate a minimum 5% of expired wells each year. At least 2 expired wells must be decommissioned and rehabilitated each year until a licensee has no expired wells.

4 Existing Environment

The Cooper Basin covers a total area of 130,000 km^2 of which approximately 50,000 km^2 lies within north-eastern South Australia. The South Australian sector of the Cooper Basin can generally be described as arid with a uniform climate. It contains a wide diversity of land systems that are defined by geological, geomorphological and hydrological influences.

This section provides an overview of the environment of the Cooper Basin. Detailed information is also available in the South Australia Cooper Basin Production and Processing EIR (Santos 2017a). Where relevant, this section refers to Santos (2017a) as a source of additional detail.

4.1 Climate

The region has an arid climate, with low average rainfall and high evaporation. Seasons are generally characterised by hot dry summers and mild dry winters. Rainfall in the area is highly erratic; the annual average is generally less than 250 mm however annual rainfall can be recorded in one event. There is no distinct seasonal rainfall pattern with rainfall often associated with thunderstorm activity and as a consequence can be localised and intense. Average annual evaporation is over 3,500 mm. A summary of climate records for Moomba Airport (Station 017123; BOM 2022) is provided in Table 7:.

Table 7:Temperature and rainfall records for Moomba Airport

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Mean Daily Max (°C)	38.9	37.0	34.0	29.3	23.8	19.9	19.9	22.5	27.3	30.9	34.2	36.9	29.6
Mean Daily Min (°C)	24.9	23.6	20.5	15.7	10.6	7.3	6.3	7.9	12.0	15.8	19.5	22.6	15.6
Mean Rainfall (mm)	17.6	24.1	25.3	7.8	9.6	10.2	11.9	5.1	14.9	9.4	18.1	14.0	166.2
Median Rainfall (mm)	3.4	4.0	3.0	.8	3.7	5.8	0.8	0.8	1.6	3.0	7.2	6.2	157.6
Mean Daily Evaporation (mm)*	15.9	14.4	12.5	8.4	5.2	3.7	3.9	5.5	8.2	10.6	13.2	15.3	9.7

*Evaporation data are from Moomba, Station 017096, for the period 1972-2005

4.2 Bioregions, Landforms and Land Systems

The Cooper Basin falls predominantly within the Channel Country and Simpson Strzelecki Dunefields biogeographical regions, and the far south-western margins of the Cooper Basin are in the Stony Plains biogeographic region[12].

A number of named land systems[13] have been mapped across the Cooper Basin as part of broader land system mapping in the pastoral areas of South Australia (Marree SCB 2004, DWLBC 2007). These land systems and their soil and vegetation characteristics are summarised in Appendix 2.

[12] 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.
[13] Land systems subdivide the IBRA bioregions and are areas throughout which there is a recurring pattern of geology, topography, soils and vegetation (DEH 2005).

Six major landforms are found in the Cooper Basin. Table 8 describes these landforms, and indicates the land systems in which they occur. The distribution of these landforms across the Cooper Basin and accompanying photographic examples are shown in

Figure 12.

The sensitivity of each landform to disturbance depends upon its basic characteristics of geology, topography, soils, hydrology, flora and fauna. These sensitivities are outlined in this EIR in Table 23 in Section 5.7. Each landform is also discussed in detail with respect to these characteristics in Santos (2017a).

Table 8: Cooper Basin landforms and descriptions

Landform	Land system	Description
Dunefields	Bloodwood, Collina, Cooper, Diamantina, Eulpa, Hope, Jeljendi, Ketitoonga, Koonchera, Marqualpie, Mulligan, Simpson. Strzelecki, Tingana, Tirari, Warburton, Wirringina	Generally parallel dunes of red or yellow sands of height 5 – 20 m separated by flat interdune corridors which are often sandy, but also often contain claypans due to limited drainage. Salt lakes are sometimes present in interdune corridors where infiltration is limited. In the Cooper Basin dunes trend approximately north-south. Soils are red-yellow-siliceous sands on dunes and red massive earths or grey self-mulching clays in swales.
Gibber plains	Bloodwood, Koonchera, Lamamour, Merninie, Sturts	An undulating stony plain, sometimes with occasional small dunes or small silcrete capped mesas. Highly polished stones or gibbers are usually embedded in a clayey crust, thereby protecting the underlying soil from erosion. Soils are crusty red duplex soils.
Floodplains	Cooper, Diamantina, Kachumba, Mulligan, Tirari, Warburton	Extensive flood-out areas adjacent to Cooper Creek, Strzelecki Creek, Wilson River and Diamantina River. Floodplains are periodically inundated when creeks and rivers overflow their banks. Characterised by grey sediments which are deposited on plains by floodwaters. In places, dunes are either co-dominant or occasionally present. Soils are grey self-mulching cracking clays and pale sandy clays.
Salt lakes	Blanche, Collina, Wirringina (Note: Small salt lakes are also present in many dunefield land systems)	Terminal lakes or pans of varying sizes where evaporation has resulted in concentration of soluble salts as a surface crust. Are periodically inundated, but are usually dry. Soils are salty overlying grey self-mulching cracking clays.
Tablelands	Lamamour, Merninie, Mumpie, Sturts	Uplifted and eroded gibber plains that have resulted in formation of low but steep silcrete capped hills, escarpments and mesas and extensive gibber covered footslopes. Tablelands are separated by undulating gibber plains. Highly polished stones or gibbers are usually embedded in a clayey crust, thereby protecting the underlying soil from erosion. Soils are crusty red duplex soils and brown self-mulching cracking clays on slopes. Soils on plains are reddish powdery calcareous loams.
Wetlands	Cooper, Diamantina, Mulligan	Channels, waterholes, swamps and lakes associated with Cooper Creek, Strzelecki Creek, Wilson River and Diamantina River. Some waterholes always contain water, but channels, swamps, and lakes are frequently dry. Are located on or close to main watercourses and are therefore inundated more frequently than surrounding floodplain. Soils are predominantly grey self-mulching cracking clays.

Source: Dobrzinski (1998).

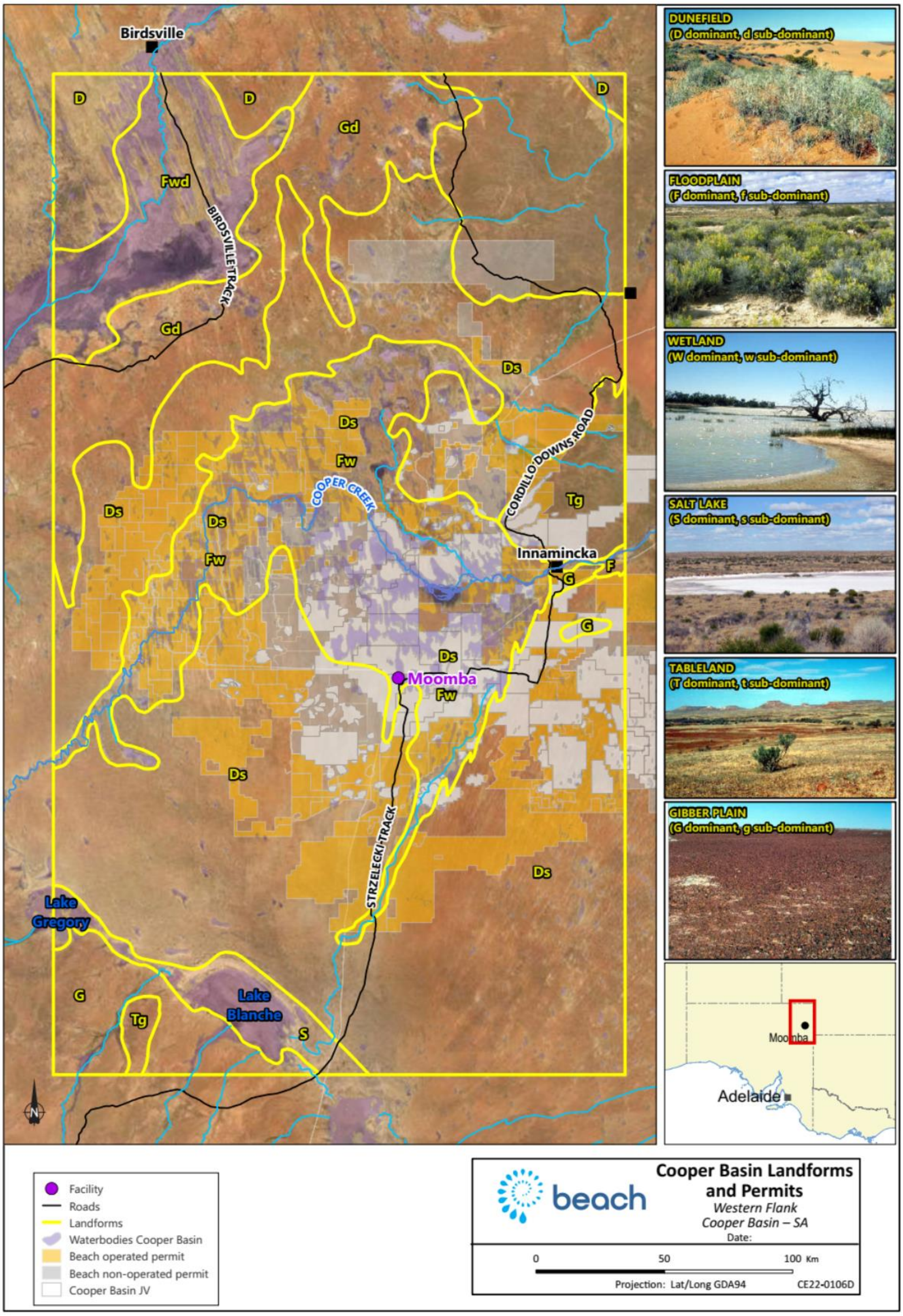


Figure 12: Cooper Basin landforms

Beach's production facilities are predominantly located in dunefield and floodplain land systems. The location of Beach production facilities and the relevant landforms and land systems are set out in Table 9.

Table 9: Beach production facility locations, relevant landforms and land systems (August 2022)

Field / Facility	Licence	Landform	Land system
Acrasia	PPL 203	Gibber plains	Merninie
Aldinga (not operating)	PPL 210	Dunefield	Tingana
Bauer	PPL 253	Dunefield	Strzelecki
Burruna	PPL 251	Dunefield	Tingana
Butlers	PPL 245	Dunefield	Strzelecki
Callawonga	PPL 220	Dunefield / floodplain	Cooper / Strzelecki
Chiton	PPL 253	Dunefield	Strzelecki
Christies / Silver Sands	PPL 205	Dunefield / floodplain	Cooper
Congony / Kalladeina / Sceale	PPL 254 / PPL 256	Dunefield	Strzelecki
Growler	PPL 242	Dunefield / floodplain	Cooper
Hanson / Snellings	PPL 255	Dunefield	Strzelecki
Harpoono	PPL 209	Dunefield	Tingana
Hornet	PRL 105	Dunefield	Tingana
Kiana (not operating)	PPL 212	Dunefield	Hope
Lycium Hub	SFL 4	Dunefield	Cooper
Martlet	PRL137	Floodplain	Cooper
Middleton / Brownlow / Canunda / Mokami / Crockery	PPL 239 / PPL 239 / PPL257 / PRL 151 / PRL 130	Dunefield	Hope
Mirage	PPL 213	Dunefield	Tingana
Mustang	PPL 243	Dunefield	Cooper
Parsons	PPL 224 / PRL 85	Dunefield	Strzelecki
Pennington	PRL 163	Dunefield / floodplain	Strzelecki
Rincon	PPL 248	Dunefield	Strzelecki
Sellicks (not operating)	PPL 204	Dunefield / floodplain	Cooper / Hope
Snatcher	PPL 240	Dunefield / floodplain	Cooper
Spitfire	PPL 258	Dunefield / floodplain	Cooper
Stunsail	PRL 172	Dunefield	Cooper / Strzelecki
Vanessa	PPL 268	Dunefield	Cooper
Ventura	PPL 214	Dunefield	Tingana
Vintage Crop	PPL 241	Dunefield	Tingana

Field / Facility	Licence	Landform	Land system
Stand-alone camps / warehouse facilities			
Bales	AAL 220	Dunefield	Strzelecki
Habanero	SFL 11	Gibber plain	Merninie
Driftwood	PRL 239	Dunefield	Hope

4.3 Flora and Fauna

4.3.1 Flora

The vegetation characteristics of the landforms in the Cooper Basin are outlined in Table 10 and are described for each named land system in Appendix B. Further detail is also provided in Santos (2017a). Detailed descriptions and mapping of the flora and fauna communities of the Cooper Basin are also provided in Hobbs *et al.* (2017).

Table 10: Typical vegetation characteristics of landforms in the Cooper Basin

Landform	Typical Vegetation Characteristics
Dunefields	Vegetation on dunes includes herbs and ephemeral herbs on dune crests, open shrublands of sandhill wattle, whitewood or hakea and hummock grassland of spinifex and sandhill canegrass. Vegetation in interdune areas is largely dependent on dune spacing and may consist of hummock grassland, chenopod shrubland, open shrubland or low open woodland.
Floodplains	Major intermittent watercourses are characterised by woodlands of river red gum, coolibah or gidgee with a tall shrub layer fringing the floodplains, channels and semi-permanent waterholes. Open coolibah woodland and with an understorey of lignum, chenopod shrubland and grasses is common in frequently flooded areas with outer floodplain areas often consisting of open shrubland. Groundcover on floodplains has a high ephemeral content.
Gibber plains	Vegetation ranges from relatively dense low open shrubland to naturally bare tussock grasslands, or short-lived copperburrs and ephemeral grasses. Low woodland of gidgee and mulga on drainage lines.
Salt lakes	Immediate surrounds usually fringed with samphire grading to low open chenopod shrubland in the outer surrounds.
Tablelands	Low open woodlands, shrublands and low open chenopod shrublands, with more heavily wooded areas of mulga, red mulga and gidgee along drainage lines and more permanent waterholes.
Wetlands	Vegetation similar to floodplains is present, with open woodlands of river red gum or coolibah with an understorey of lignum and chenopod shrubland typically bordering the margins of wetland areas.

Beach also utilises a priority plant list (Appendix D), which assigns a conservation priority to a variety of trees, shrubs, grasses and herbs that occur in the Cooper Basin. The conservation priorities are based on characteristics including longevity, growth rate, abundance and status under State / Commonwealth legislation. They are used to guide native vegetation avoidance and management measures during operations that involve vegetation clearance, as indicated in Section 5.

4.3.2 Fauna

Terrestrial and avian fauna species present in the area include:

- **Mammals**: Small mammals such as Fat-tailed and Stripe-faced Dunnarts, Giles Planigale, Sandy Inland Mouse and House Mouse are common. Other mammals present include Little Broad-nosed Bat and Lesser Long-eared Bat. Larger mammal species include the Red Kangaroo, Dingo, and non-native species including cattle, cat, rabbit and fox.

- **Reptiles:** Common reptiles include Fat-tailed Gecko, Eastern Brown Snake, Sand Goanna, Sandplain Ctenotus, Ghost Skink, Painted Dragon and Curl Snake.

- **Amphibians**: Ten frog species have been recorded in the Cooper Creek system including several species of burrowing frog (e.g. Trilling Frog, Water-holding Frog) which may be relatively widespread and others (Desert Froglet, Green Tree Frog, Broad-palmed Frog) that would be restricted to areas near water (i.e. the Cooper Creek) except during flooding.

- **Birds**: Bird species present include Australian Magpie, Galah, Brown Falcon, Budgerigar, Black-faced Woodswallow and Little Corella. The region also supports a diverse assemblage of waterbirds, as discussed below.

The Cooper Creek system supports a diverse array of aquatic fauna including waterbirds, fish, frogs and aquatic invertebrates. The wetlands associated with the North-West Branch of the Cooper Creek, including Coongie Lakes, are recognised as a region of exceptional ecological value. They provide a feeding, resting and breeding site for large numbers of migratory and nomadic birds. The most abundant species during flooding include Grey Teal, Pink-eared Duck, Wood Duck, Australian Pelican, Great Cormorant, Black Swan, Eurasian Coot, Black-tailed Native-hen, and Red-necked Avocet. They also support rare or threatened waterbird species including Freckled Duck, Musk Duck, Little Egret and Intermediate Egret (DEWNR 2014). They are listed as internationally important wetlands under the Ramsar convention, as discussed in Section 4.7.4.

In dry periods, aquatic fauna is concentrated in refuges such as Coongie Lakes and the permanent waterholes on the upstream reaches of the Cooper in South Australia. During flooding, these fauna increase rapidly in abundance and occur across the vast area of channels, waterholes, swamps and floodplains in the Cooper Creek system.

4.3.3 Threatened Species and Communities

A number of species listed under Commonwealth (*Environment Protection and Biodiversity Conservation Act 1999*) and State (*National Parks and Wildlife Act 1972*) legislation are known to occur in the Cooper Basin. Listed rare or threatened species that have been recorded or predicted to occur in the region are listed in Appendix C.

One threatened ecological community listed under the EPBC Act occurs in the broader region – the community of native species dependent on natural discharge of groundwater from the GAB. This community occurs at GAB springs, which are located outside Beach licence areas and beyond the margins of the Cooper Basin region (see Figure 18).

Five ecological communities identified as threatened in the South Australian Arid Lands Biodiversity Strategy occur in the broader region (DEH 2009a, b, c):

- Coolibah and River Red Gum woodland on regularly inundated floodplains

- Old-man Saltbush on floodplains

- Queensland Bluebush shrubland on cracking clay depressions subject to periodic waterlogging
- Broughton Willow and Coolibah +/- Queensland Bean Tree woodland on drainage lines and floodplains
- Mulga low woodland on low dunes and sand plains.

The primary threat to these ecological communities is habitat modification or inhibited regeneration associated with total grazing pressure (DEH 2009a, b and c).

Beach is confident that significant impacts to listed threatened species, communities and migratory species that are likely to occur in the Cooper Basin region can be avoided, due to the nature and limited area of production activities and the management measures that are implemented. Site-specific assessments are carried out for all sites prior to commencement of operations (as discussed in Section 2.1.3) to ensure that any potential impacts are identified and are minimised or avoided.

4.3.4 Weeds

Introduced plant species recorded in databases as occurring in the region include declared weeds such as Buffel Grass (*Cenchrus ciliaris*), Athel Pine (*Tamarix aphylla*), Caltrop (*Tribulus terrestris*) and Noogoora Burr (*Xanthium strumarium*) and other introduced species including Mexican Poppy (*Argemone ochroleuca* ssp. *ochroleuca*), Wild Turnip (*Brassica tournefortii*), Colocynth (*Citrullus colocynthis*), Creeping Heliotrope (*Heliotropium supinum*), Rosy Dock (*Rumex vesicarius*), Black Nightshade (*Solanum nigrum*), Common Sow-thistle (*Sonchus oleraceus*), Mimosa Bush (*Vachellia farnesiana*), Common Verbena (*Verbena officinalis*), and Wandering Speedwell (*Veronica peregrina* ssp. *xalapensis*).

The density of weed species is generally relatively low, and the majority of the introduced plants known to occur in the Cooper Basin are naturalised or widespread species of limited concern to the environmental or pastoral values of the region. Invasive species of particular concern include Buffel Grass and Noogoora Burr.

Pest animals in the region include rabbits, feral cats and foxes, feral pigs, donkeys, horses and camels.

4.4 Surface Water

4.4.1 Wetland and Floodplain Land Systems

The Cooper Creek system is the dominant surface water feature in the region. The Cooper Creek originates in catchments in south-west Queensland. During periods of low flow, most water flows through the North-West Branch of the Cooper Creek into the Ramsar-listed Coongie Lakes and Lake Goyder. If flows are large enough to fill these lakes, additional water flows down the main branch of the Cooper towards Lake Hope and eventually discharges into Lake Eyre.

The main channel of the Cooper Creek is generally well defined and connects a series of ephemeral swamps and permanent and semi-permanent waterholes. During floods, the main channels overflow and floodwaters spill into the vast floodplain via numerous distributory channels.

Significant local rainfall events can also result in shallow inundation of floodplains, interdune claypans and other areas of poorly drained impermeable soil, which can persist for days to weeks or longer. Local rainfall and run-off also results in flow in ephemeral watercourses, most of which drain into either the Cooper or Strzelecki Creeks.

Cooper Creek flows are unregulated and extremely variable. Flow occurs in one or more discrete pulses each year and several months may pass without flow (Puckridge *et al.* 1999). Flow in the Cooper Creek occurs in almost every year, and in most years it reaches the Coongie Lakes (DEH 2008).

The mean annual flow in the Cooper Creek is in the order of 1.33 million megalitres, with a median annual flow (at Cullyamurra Waterhole, near Innamincka) of 367284 ML (WaterConnect 2022). The highest annual flow was over 14 million megalitres in 1974. Flow can occur in any month, and zero flows have also been recorded in all months of the year. It has been estimated that there is a 98% chance that flow rates will exceed 1m^3/s at Innamincka each year (Kotwicki 1986).

During periods of high flow, floodwaters overtop the banks of the Cooper and flow southwards down the Strzelecki and Ooranie Creeks. Cooper Creek floods that are large enough to flow into Strzelecki Creek and its floodplain are relatively rare events. Previous investigations have estimated that floods of this size have an average frequency of approximately one in ten years (Puckridge *et al.* 1999).

Puckridge *et al.* (1999) developed nine flood classes for the lower Cooper Basin floodplain based on the 25-year Cullyamurra record. Table 11 provides expected frequencies and volumes for each of these flood classes. The predicted extent of flooding for each class is based on satellite imagery of previous flood events in the Cooper Basin region (Puckridge *et al.* 1999).

Table 11: Cooper Creek flood classes, volumes and frequency

Flood class	Daily flow volume (ML / day)	Total volume (ML)	Frequency	Comment
1	600 - 1,200	14,000 - 40,000	Annual	Since 1973 have been Class 1 floods, or larger, every year. All water flows into North-West Branch of Cooper Creek.
2	1,200 - 2,500	40,000 - 130,000	1-2 years	Most water flows into North-West Branch, but a proportion flows into main branch of Cooper Creek.
3	2,500 - 5,400	130,000 - 220,000	1-2 years	Significant part of flows into main branch as far as Embarka Swamp.
4	5,400 - 18,000	220,000 - 400,000	2 years	Significant flow enters main branch, to lower main branch and lower Cooper Creek.
5	18,000 - 40, 000	400, 000 - 1,400,000	2-5 years	Significant flow occurs out of Coongie Lakes into lower Cooper Creek as far as Lake Hope.
6	40,000 - 100,000	1,400,000 - 2,400,000	5 years	Results in flows into Wilpinnie Creek. Flow into this area can disrupt gasfield installations.
7	100,000 - 180,000	2,400,000 - 4,500,000	10 years	Results in flows into Strzelecki Creek but not as far as Lake Blanche. Flows occur along lower Cooper Creek. Class 7 flood was largest in 2005.
8	180,000 - 450,000	4,500,000 - 10,750,000	20 years	Flow into Lake Eyre North and fill Lake Blanche. Class 8 flood was the largest flood in 1990.
9	> 450,000	> 10,750,000	100 years	A Class 9 flood occurred in 1974, but no satellite images are available to determine flood extent.

Strzelecki Creek is predominantly dry. It can receive some localised inflow from heavy rainfall events but generally only flows during large Cooper Creek floods (e.g. 2010 floods), when water flows southwards from Innamincka towards Lake Blanche (a distance of approximately 200 km).

During very large floods, much of the floodplain area within the Cooper land system becomes inundated. However, within this land system, there are areas of dunefield, isolated sand dunes and patches of higher ground that are not subject to flooding.

4.4.2 Dunefield Land Systems

Dunefields are extremely arid, lacking any permanent surface water with significant drainage lines generally absent. Surface water catchments are typically restricted to individual interdune corridors. Surface water ponds in interdune corridors, often collecting in claypans and occasionally salt lakes within the interdune. Infiltration rates are generally low, and surface water may remain in the swales and claypans for a few days to a few weeks or more, depending on the rainfall event and rates of evaporation.

4.4.3 Tableland and Gibber Plain Land Systems

Permanent surface water is scarce in the elevated areas of the tablelands and on the gibber plains, however temporary pools of water often form after rain in gilgais and low depressions. Networks of small, defined drainage lines start as shallow diffuse linked depressions on gibber summits. Flows are intermittent coinciding with rain, and as gradients are slight, the streams tend to be almost laminar, like local overland flow. The substrate of these diffuse drains is similar to the surrounds, but with a harder packed stone surface. With increasing slope, streamlines become incised, very stony, with occasional alluvial terraces. Major streams and watercourses may have ephemeral waterholes, but generally stream flows are ephemeral, short duration, for only a few hours after rain (e.g. six to twelve hours). Major rainfall events result in very high-volume flows building up over a very short time span (one to two hours) and very high energy for the short duration.

4.4.4 Salt Lakes

Salt lakes are predominantly dry, but are occasionally filled by floodwaters from the major river systems. During flooding, water may remain fresh and can support abundant fish populations. Lakes become increasingly saline as they dry. The frequency of flooding and inundation is highly variable.

4.5 Geology

The Eromanga and Cooper Basins are located in central and eastern Australia. The Cooper Basin is a north-east, south-west trending basin that extends over an area of about 153,000 km^2 in north-east South Australia and south-west Queensland (Stanmore 1989), as shown in Figure 13. It is unconformably overlain by the Eromanga Basin. The saucer-shaped Eromanga Basin extends over a much larger area of around one million square kilometres in Queensland, New South Wales, South Australia, and the south-east of the Northern Territory. The Eromanga Basin is overlain by the Lake Eyre Basin.

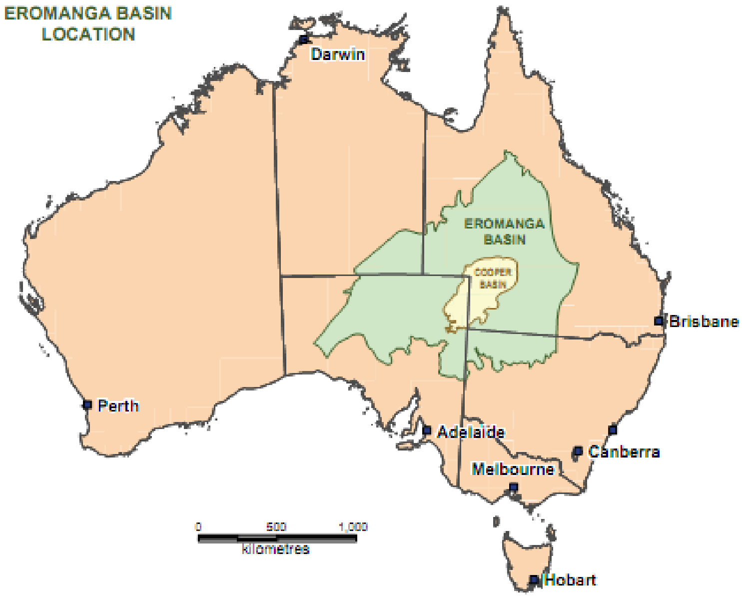


Figure 13: Cooper and Eromanga Basin location map

In the north-east of South Australia, the Lake Eyre Basin consists of surface sediments on floodplains, wetlands, tablelands, gibbers, salt pans. At depth, units include the Yandruwantha Sand (medium to coarse grained sand), the Namba Formation (deltaic and lacustrine clay, silt and sand), and the Eyre Formation (sandstone and shale). The thickness of Lake Eyre Basin sediments in the Moomba area is generally in the range 200 – 300 m (Drexel and Preiss 1995).

Below the Lake Eyre Basin section lie the Eromanga Basin sediments which are between 1,200 m and 2,700 m thick (Gallagher and Lambeck 1989). These sediments were deposited under fluvial (river), lacustrine (lake) and later shallow-marine conditions, and are broadly continuous across the basin (Vine 1976). These sediments are gently folded in some areas and contain a succession of geographically extensive sandstone formations that serve as oil reservoirs and regional aquifers known as the Great Artesian Basin.

Located underneath the Eromanga Basin section, the total Cooper Basin sediment accumulations exceed 1,500 m in some places and are characterized by fluvial, deltaic and swamp deposits that include some coal measures (Thornton 1979). These sediments contain petroleum reservoirs (mainly gas) and aquifers.

The South Australian end of the Cooper Basin includes several north-east to south-west-trending depocentres, including the Patchawarra and Nappamerri Troughs. In the deepest and most central portion of the Cooper Basin (the Nappamerri Trough), high pressure gas cells with reservoir pressures in excess of 7,000 psi are present.

The stratigraphy of the Cooper and Eromanga Basins is shown in Figure 14.

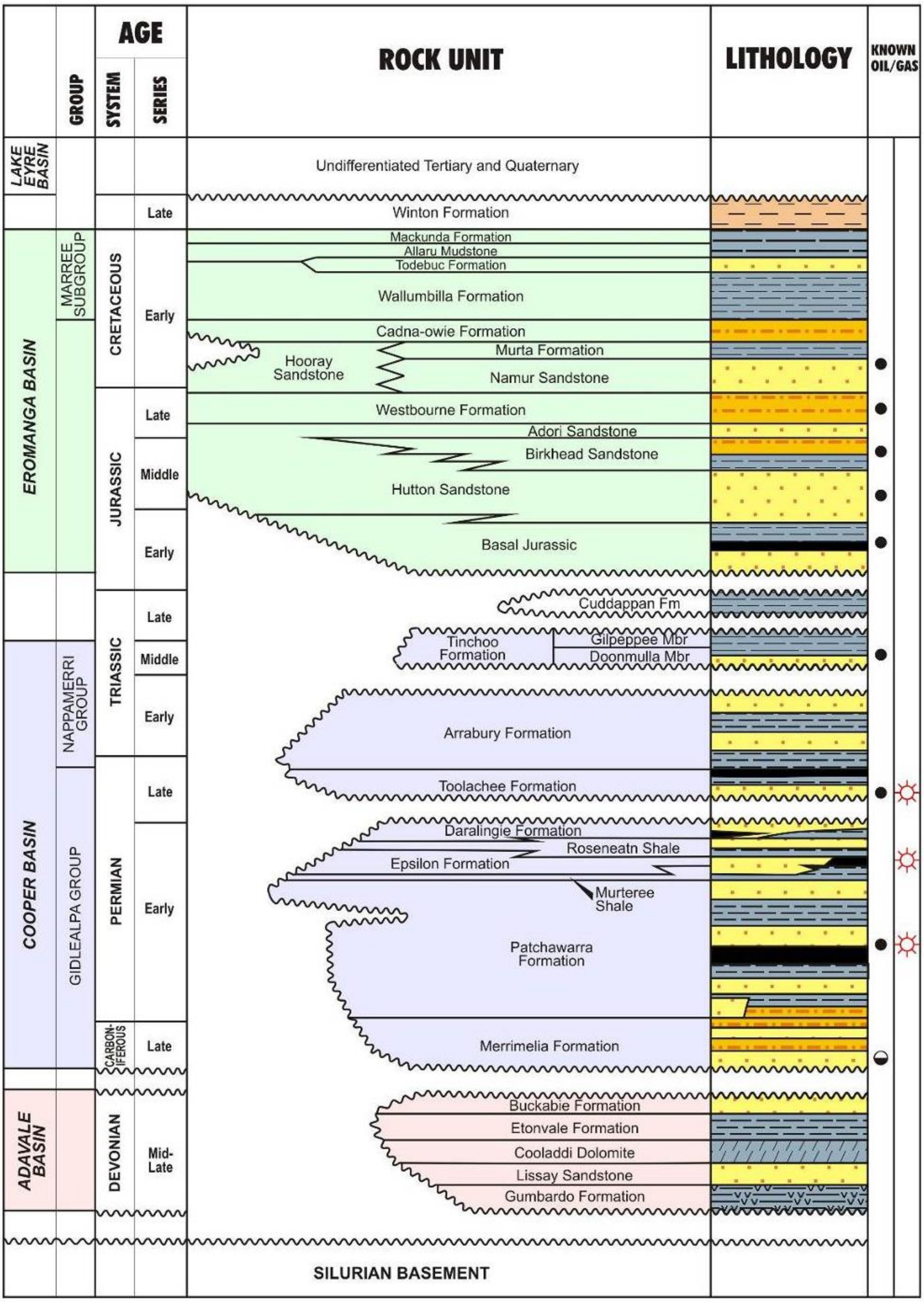


Figure 14: Cooper and Eromanga Basin stratigraphic chart

The tectonic history of the Cooper and Eromanga Basins is complex and has been characterised by several periods of rift-related subsidence and compressional uplift and erosion. This history has resulted in the Cooper Basin being subdivided into a number of large-scale sub-troughs separated by fault bounded ridges. The historical evolution of the Cooper and Eromanga Basins is discussed by Kuang (1985), Finlayson *et al.* (1988), Gallagher (1988), Hunt et al. (1989) and Stanmore (1989).

The Cooper and Eromanga Basins are currently subject to a regionally compressive stress regime. Motion along fault bounded basement blocks results in strong local stress variations. Evidence from well bore geomechanics shows that conditions for movement on faults are present and that the structural evolution of the area is ongoing. The relative stress magnitudes and orientations that make up the stress regime are an important consideration in fracture stimulation as they define the direction of fracture propagation and its vertical extent.

Geothermal gradients in the Cooper and Eromanga range from 30°C per km on the margins to 60°C per km in the Nappamerri Trough. Temperatures in the basal Cooper sediments here reach approximately 250°C.

4.5.1 Conventional and Unconventional Hydrocarbon Reservoirs

This subsection provides background on conventional and unconventional hydrocarbon reservoirs. Specific detail on the conventional and unconventional targets in the Cooper and Eromanga basins is then provided in Sections 4.5.2 to 4.5.4.

4.5.1.1 Conventional Oil

Conventional oil is typically found in sandstone formations in sedimentary basins. The oil resources are usually from another formation but move into the sandstone and are trapped by an impermeable ‘cap’ rock. Conventional oil resources are extracted using traditional methods of drilling down through the ‘cap’ rock and allowing oil to flow (or pumping it) up the well. In some formations where the permeability is lower, fracture stimulation techniques are required to recover the oil.

4.5.1.2 Conventional and Unconventional Gas

Natural gas is found in a number of geological settings and within various rock types. All natural gas is composed predominantly of methane (CH_4), with varying, usually minor, quantities of other hydrocarbons and inert compounds (e.g. N_2, CO_2). The descriptor of conventional versus unconventional does not refer to the gas itself; rather it refers to the rocks or formations that the gas is trapped in and the methods required to extract it commercially.

Conventional gas is trapped in porous and permeable reservoir rocks, such as sandstones, in favourable geological structures or traps and within sedimentary basins. To date, most of the gas that has been produced, globally and in Australia, has been conventional gas. Conventional gas will flow naturally at economic rates from wells drilled into the gas bearing formations. Fracture stimulation of conventional gas (including stimulation of low deliverability gas pay less than 1 mD) has been used in the Cooper Basin for over 30 years, to reduce formation damage and enhance well deliverability. Low permeability conventional gas has been referred to as tight gas in the past.

Unconventional gas, which includes tight gas, shale gas and basin-centred gas, is found in reservoirs that require specialised extraction technology such as dewatering or fracture stimulation to extract the gas from the formation at economic rates. **Tight gas** is not dissimilar to conventional gas in terms of geological setting, except that the reservoir rock has lower permeability than conventional sands, meaning that it is more difficult to extract the gas. Tight gas is less likely to produce without fracture stimulation than is the case for conventional, higher permeability sandstones. Tight gas has been produced in Australia in the Cooper Basin for over 30 years through the use of fracture stimulation. **Shale gas** occurs in very fine-grained, low permeability organic-rich sediments usually in deeper parts of basins. **Basin-centred gas**

is found in very low permeability formations where gas becomes regionally trapped by an inability to migrate further. Basin-centred gas plays tend to extend over large distances.

In both shale gas and basin-centred gas targets, it is necessary to create permeability to allow the gas to flow from the rock. This is typically done by combination of horizontal wells (wells with long horizontal or lateral sections giving them greater contact with the reservoir rock) and fracture stimulation.

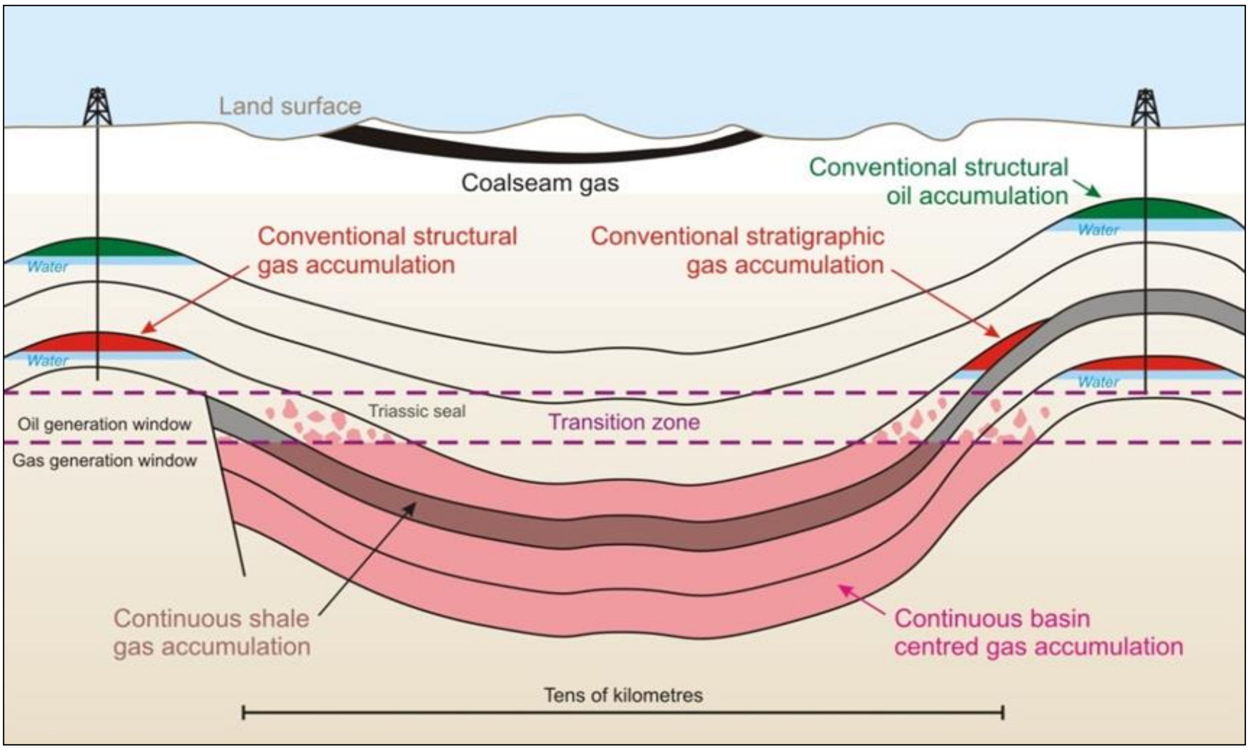


Figure 15: Illustration of different types of hydrocarbon reservoirs (after Schenk and Pollastro 2002).

4.5.2 Conventional Oil Targets (Eromanga Basin)

The conventional oil reservoirs in the study area are associated with sandstone formations of the Eromanga Basin. The oil is present in discontinuous oil reservoirs (in the sandstone units of the Cadna-owie, Murta, Poolowanna and Birkhead formations) within interbedded sandstone beds or larger sandstone formations (in the Hutton and Namur Sandstone) with reservoirs typically comprising structural and sedimentary traps.

The primary oil reservoir formations are separated by low permeability formations comprising shale-mudstone-siltstones of the Eromanga Basin, themselves situated at depth within a thick sequence of highly variable sedimentary rock types (see Figure 14).

The majority of the oil in the Eromanga Basin occurs within geological formations that form the aquifers of the GAB. Oil production wells most commonly have little to no associated gas, either dissolved in the oil or as a separate gas cap over the oil. Many oil reservoirs are unable to free flow to surface at commercial rates and require artificial lift to produce economically. Water movement, either from below the reservoir in thick sandstones, or laterally in the case of thin sandstones, is the main drive mechanism and results in water being produced along with the oil.

The quality of the oil reservoirs ranges from low to excellent. The lower quality reservoirs require the use of fracture stimulation techniques to recover oil. Fracture stimulation of these lower quality oil reservoirs has been successfully carried out for many years, and over 140 fracture stimulation treatments of oil reservoirs in the Murta Formation in the Eromanga Basin have been carried out to date.

In general, oil accumulates around the margins of the buried Cooper Basin where the sealing Nappamerri Formation has been eroded (see Figure 16). Oil also accumulates along faults, where it can leak upwards through the Nappamerri seal. The cross-section (Figure 17) shows stacked, multiple pools of oil where it can migrate upwards through the Eromanga succession through imperfect seals.

Figure 16: Cooper Basin structural elements, showing the basin margins where oil accumulates.

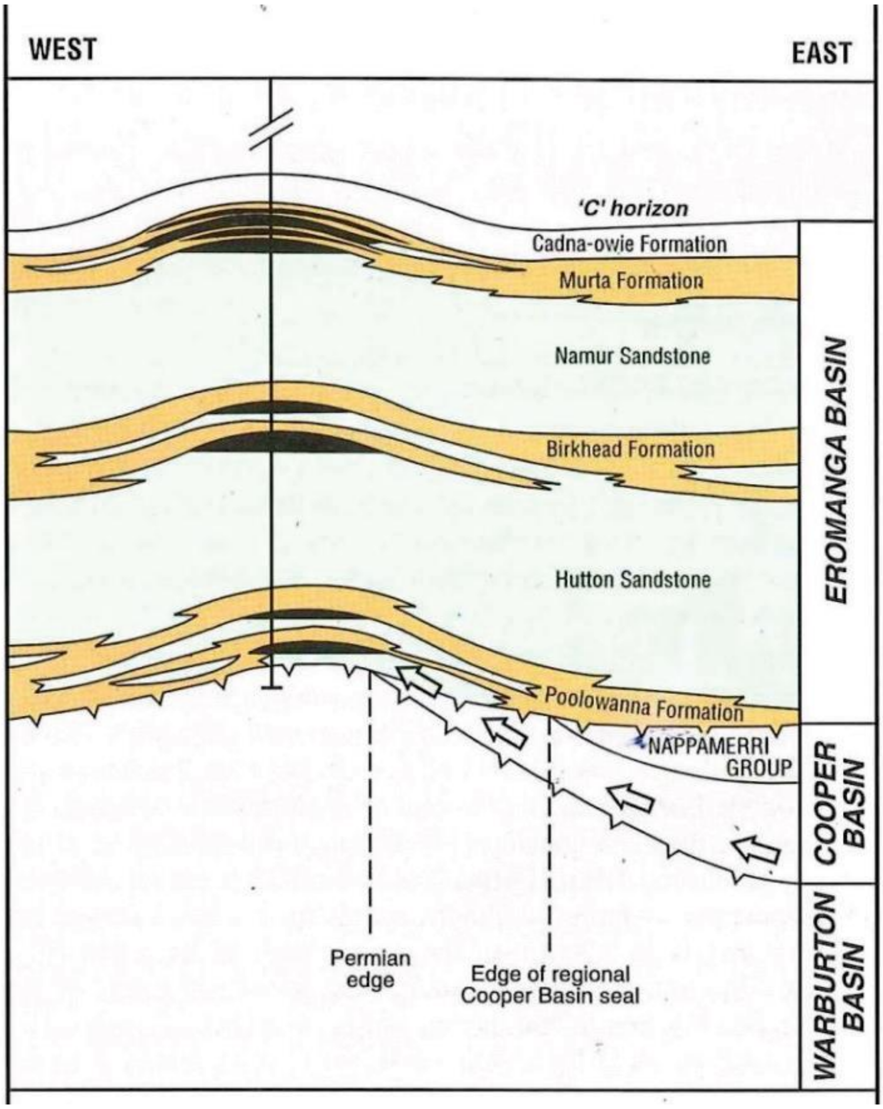


Figure 17: Schematic cross-section of oil accumulations in the Eromanga Basin, South Australia (from Drexel and Preiss (eds) 1995).

4.5.3 Conventional Gas Targets (Cooper Basin)

Conventional gas is produced predominantly from stacked sands of the Toolachee and Patchawarra Formations (in the Gidgealpa Group), which lie within the Cooper Basin. The sandstone reservoirs are separated by shales and coals, which act as intra-formational seals. Minor gas production also occurs from other sediments within the Gidgealpa Group (e.g. the Epsilon Formation) from various localised sediments within the overlying Nappamerri Group (also part of the Cooper Basin), and from the Hutton Sandstone (within the Eromanga Basin). Generally, however, the Nappamerri Group shales act as a regional top-seal for gas.

Gas is predominantly stored as free gas within pore spaces in the sandstone reservoirs. The sandstone reservoirs often have low permeabilities (usually of the order of 0.1 to 10 mD, equivalent to a hydraulic conductivity range of 10^{-2} to 10^{-3}m/d). In such reservoirs with low permeabilities, fracture stimulation is essential in order to achieve economic flow-rates and production volumes.

When a conventional gas well is completed with its final production string, pressure drawdown (i.e. differential pressure between the reservoir and wellbore) is created by opening up the well to the gathering system. Gas is then able to flow to the well via the formations permeability. In general, most gas reservoirs naturally deplete through a gas expansion drive mechanism. In conventional gas reservoirs gas will move from high pressure in the reservoir to low pressure at surface without the aid of mechanical lifting devices.

4.5.4 Unconventional Gas Targets (Cooper Basin)

Unconventional gas targets in the Cooper Basin (summarised in Table 12) are comprised of shales, deep Permian coals or tight sandstones which are largely characterised as self-contained systems (i.e. they provide the full petroleum system of source, seal, reservoir and trap), with the presence of gas not influenced by the structural setting (e.g. presence of anticlines or other structural traps). Because the unconventional reservoirs lie within the same stratigraphy as that of the conventional reservoirs, the hydrocarbon produced is the same as that of a conventional gas well.

A distinguishing feature of unconventional resources is their very low permeabilities, ranging from sub-micro to nanodarcy permeability (i.e. 10-6D to 10-9D). Unconventional gas plays often exist as large, continuous and predictable accumulations such as the Roseneath, Epsilon and Murteree (REM) package in the Moomba/Big Lake area. They also exist in either normally-pressured or over-pressured deep trough areas of the Cooper Basin, such as in the Nappamerri Trough. Fracture stimulation is essential to enable commercialisation of unconventional gas formations.

Table 12: Summary of current and potential unconventional gas targets (after Santos 2021a)

Basin	Formation	Unconventional target	Comments
Eromanga	Winton	Coal (shale)	Possible future targets – no current activity
	Toolebuc	Shale	Possible future target
Cooper	Toolachee	Coal Shale Tight sand	Thick extensive coals may become targets
	Daralingie	Coal Shale Tight sand	Grouped lithologies are possible target
	Roseneath	Shale	Current target
	Epsilon	Coal Shale Tight sand	Grouped lithologies are current target
	Murteree	Shale	Current target
	Patchawarra	Coal Shale Tight sand	Grouped lithologies are current target Tight sands are borderline conventional-unconventional targets

4.6 Hydrogeology

4.6.1 Regional Setting

Regional hydrogeology is dominated by the presence of the Great Artesian Basin, one of the largest multi-layer aquifer systems in the world. The GAB comprises Jurassic and Cretaceous sediments of three large sedimentary basins, the Eromanga, Carpentaria and Surat Basins, of which the Eromanga Basin is the largest and most central. Only the south-western third of the Eromanga Basin extends into South Australia (refer to Figure 13), with the Carpentaria Basin located in Queensland and the Surat Basin located in Queensland and New South Wales.

The groundwater flow in the GAB is generally to the south-west, with recharge occurring in northern Queensland and groundwater discharging as spring flow predominantly around Lake Eyre. In South Australia recharge also occurs along the western basin margin and a component of groundwater flow also comes from the eastern extension of the basin in New South Wales. Groundwater velocity is typically in the order of 0.5 metres per year (usually less in the project area due to low permeability of the aquifer units), and thus travel times from the margins to the discharge areas can be of the order of 1 to 2 million years (CSIRO 2012a, b).

Interpretation of the hydrochemistry of the artesian system (Radke et al., 2000, cited in CSIRO 2012b) indicated major provinces within the GAB that approached stagnation in areas below 1,000 m depth (which could apply to much of the project area). The study identified that significant regional groundwater flow in the GAB is relatively limited to areas adjoining the recharge zones where the aquifer has shallow burial (i.e. remote from the Central Eromanga Basin). The deeper regions of the GAB have very low flow and are characterised as "relatively stagnant" (flow velocities of 0.03 to 0.3 m per year) in contrast to the moderate velocities of 1.2 to 2.5 m per year for shallower regions.

The springs where discharge from the GAB occurs are located beyond the margins of the region where oil and gas exploration and production occur, with the closest springs, in the Lake Frome supergroup, occurring near the margins of the southern Cooper Basin (see Figure 18). GAB springs support an EPBC Act listed ecological community, as discussed in Section 4.3.3.

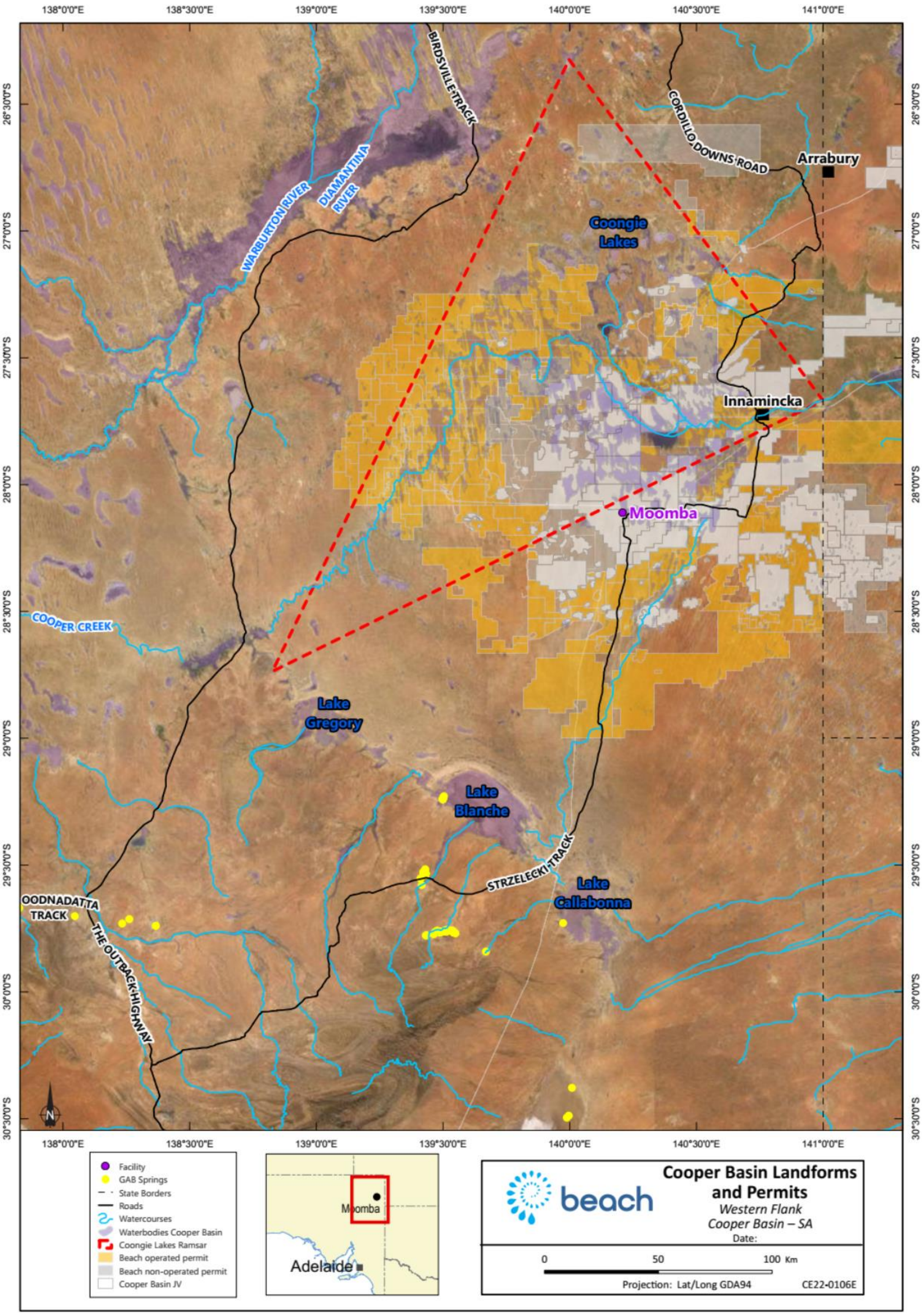


Figure 18: Cooper Basin surface water features and GAB springs

4.6.2 Hydrogeology of the Cooper and Eromanga Basins

The Eromanga and Cooper Basins can be broadly subdivided into aquifers and confining beds (aquitards and seals). Aquifers are porous and permeable units that are able to store and transmit water. In several instances, units of the Eromanga and Cooper Basins are both aquifers and petroleum reservoirs. Aquitards are units that impede the movement of water, and in general have low hydraulic conductivities or permeability. In some Cooper Basin aquitards, the conductivity is so low that no fluid permeates them under natural pressure conditions. Seals are proven by their ability to trap and hold gas under pressure.

In general, the labels of 'aquifer' or 'aquitard' are assigned in relation to geological formations, which is the basic rock unit used to describe a stratigraphic succession. However, a geological formation can contain both aquifers and aquitards. For example, the Cadna-owie Formation is described as one of the main aquifers of the GAB, however the bottom three quarters of the Cadna-owie Formation is siltstone and shale and acts as an aquitard while the upper quarter of the unit is a sandstone that can act as an aquifer (where it is not cemented or too silty).

4.6.2.1 Aquitards and Seals

Large parts of the Poolowanna, Birkhead, Murta and Westbourne formations and most of the Wallumbilla Formation and the Bulldog Shale, Allaru, Toolebuc and Oodnadatta formations are aquitards within the Eromanga Basin.

Within the Cooper Basin, trapping of gas indicates that most of the aquitards are seals. The entire Murteree Shale and Roseneath Shale are seals. The Patchawarra, Epsilon and Toolachee formations are composed of sandstone-shale-coal cycles each of which contain potential aquifer / reservoir systems and a seal or aquitard. In these systems, the formations as a whole act as seals.

The Nappamerri Group, which overlies the coal measures, is a regional seal to the gas sands of the Cooper Basin, except around the eastern southern and western margins of the Cooper where it has been eroded. As a seal, it prevents the vertical movement of gas and oil, diverting the hydrocarbons laterally until they reach the eroded edge of the Nappamerri, where the hydrocarbons can resume their vertical movement.

The hydraulic conductivities of the aquitard beds have previously been estimated by numerical model calibration to be about 10−4 m/day (Audibert, 1976). Recent research on the Bulldog Shale near Lake Eyre in the Western Eromanga Basin indicated a range of vertical hydraulic conductivity values of 9 x 10-4 to 9 x 10-9 m/day (Love et al. 2013) with the higher vertical hydraulic conductivity values reflecting the effects of preferential pathways (faults) in this area of thinner Bulldog Shale.

Despite the low hydraulic conductivities, over geological time the aquitards have allowed hydraulic communication between aquifers such that most are in hydraulic equilibrium and have the same hydraulic head. In addition, many aquitards have been breached naturally in some areas, either by erosion or by faulting. Where this occurs, large scale mixing of the aquifers has taken place and hydraulic equilibrium has or is being reached.

In other regions, such as the Central Nappamerri Trough (where Beach has undertaken fracture stimulation of shale gas and tight gas targets) there is no known communication between the deeper Permian formations and shallower aquifer systems.

4.6.2.2 Aquifers

Aquifers in the region include the Eyre Formation of the Lake Eyre Basin, some parts of the Winton, Coorikiana, Cadna-owie, Murta, Birkhead formations, and large parts of the Mackunda, Namur, Adori, Hutton, Poolowanna and Cuddapan formations (all within the Eromanga Basin). In the Cooper Basin, parts of the Nappamerri Group, Toolachee, Daralingie, Epsilon, Patchawarra and Merrimelia formations, and all of the Tirrawarra Sandstone, may act as aquifers.

The Lake Eyre Basin sediments consist of Tertiary sands and often contain beds of lignite and clay. The sand units can host useful local aquifers that are often exploited for stock water. Localised aquifers can also be found in overlying Quaternary alluvial sands and gravel. Depending on the location in the landscape, groundwater salinity in these shallow aquifers can range from fresh to saline.

Within the Eromanga Basin itself two major regional aquifer systems are described, these being the Cadna-owie Formation and Algebuckina Sandstone (Cadna-owie–Algebuckina aquifer), and the upper confined aquifer consisting of sediments of the Winton and Mackunda Formations. The two aquifer systems are separated by the shales of the Bulldog Shale and Oodnadatta Formation. Aquifers of the Winton and Mackunda Formations are generally confined by clays and shale of the Winton Formation and Tertiary sediments of the Lake Eyre Basin. The Winton and Mackunda Formations are not artesian and are not as widely utilised as the deeper and better quality artesian aquifers of the Cadna-owie–Algebuckina aquifer system. Both aquifer systems can be unconfined near the basin margins.

An intermediate aquifer exists between these two major aquifer systems and is hosted in the Coorikiana Sandstone, which forms a discrete aquifer of high salinity and low permeability in the southern and western Eromanga Basin. Although artesian pressures have been recorded in this aquifer it is generally not exploited due to its poor water quality and low yield.

The Cadna-owie–Algebuckina aquifer comprises the major source of groundwater in the Far North Prescribed Wells Area. To the east of the Birdsville Track Ridge, and overlying the Cooper Basin, the Cadna-owie–Algebuckina aquifer includes sediments of the Murta Formation and the Namur, Adori, Hutton and Poolowanna Sandstones. West of the Birdsville Track Ridge, the confining beds separating these sandstone units pinch out over the ridge and the individual sandstones merge into the Algebuckina Sandstone.

As noted above, in various locations across the Cooper Basin, erosion of the Cooper Basin sediments and deposition of Eromanga Basin sediments over the top has resulted in contact or mixing between the two formations. As a result, over geologic time, hydrocarbons have migrated from the Cooper Basin into the Eromanga Basin. Indications of trace oil and gas are seen in the Jurassic (GAB) aquifers during drilling across the Cooper Basin because of this migration and in certain areas of the basin, the Eromanga Basin sediments (i.e. the GAB aquifers) are targets for oil exploration and production.

Table 13 summarises the general characteristics of the formations which have either aquifer or hydrocarbon reservoir properties from the surface through to the base of the Cooper Basin sediments. This is a general classification and can change in specific study areas.

Figure 19 and Figure 20 show regional cross-sections of the Cooper Basin and also indicate a number of the areas where mixing between Cooper and Eromanga fluids is known to occur.

Table 13: Hydrogeological properties of aquifers and reservoirs (after Santos 2015a)

Reservoir / Aquifer*	Use	Extent	Salinity	Pressure System	Permeability
Phreatic aquifer comprising dunes of Simpson Sand plus associated older dunes, inter-dunes, lakes and channels.	Generally limited to stock watering and petroleum exploration	Basin wide, except where older, underlying units are exposed	Highly variable, 1,000 up to 20,000 mg/l or more	Fully unconfined	High
Eyre Formation	Limited use for petroleum exploration	Basin wide, except where eroded on topographic highs	Unclear, probably variable, like the phreatic aquifer above (1,000 – 20,000+mg/l)	Uppermost aquifer. Unknown, but less than GAB	High
Winton Formation (multiple sands and aquitards)		Basin wide, but sands may be of limited extent	As above	As above	High
Mackunda Formation		Basin wide	Unclear, probably high (>9,000 mg/l)	Uppermost GAB or (Cretaceous (K) aquifer. Known to be less than GAB Jurassic (J) aquifer (Della 20 evidence)	High
Coorikiana Sandstone	Potential reservoir	Restricted to southern marginal and eastern areas of Basin	Unclear, probably high (>9000 mg/l) dataset, may be high or low	Aquifer between Bulldog Shale and Oodnadatta Formation. One data point apparently less than GAB. Not in communication with GAB in Cooper area	Generally low but local areas up to moderate
Cadna-owie Formation (aquifer in the Wyandra SS at top of formation)	Known aquifer in uppermost part of formation only	Basin-wide	Limited data – possibly 2,000 – 5,000 mg/l	Part of main GAB J aquifer system, on a common water pressure system	Often low, locally high
Murta Formation (multiple sands and aquitards)	Known reservoir	Basin wide, but sands may be limited in extent	Limited data (3,000-4,000 mg/l) for Murta sands	Part of main GAB J aquifer (Algebuckina Sandstone equivalent). Data pressures variable and source not verifiable. May be issues with mixing McKinlay Member data.	High
Namur Sandstone (includes McKinlay member of Murta Fm)	Known aquifer and reservoir	Basin wide	300-4,000 mg/l	Part of main GAB aquifer (Algebuckina Sandstone equivalent). May have local depleted zones	High
Adori Sandstone	Known aquifer and reservoir	Restricted to northern part of basin	300-4,000 mg/l	Part of main GAB aquifer (Algebuckina Sandstone equivalent). May have local depleted zones	High
Birkhead Formation (multiple sands)	Known reservoir	Basin wide but sands separated by aquitards	300-4,000 mg/l	Part of GAB J aquifer. May have local depleted zones	Highly variable
Hutton Sandstone	Known aquifer and reservoir	Basin wide	300-4,000 mg/l	Part of main GAB aquifer (Algebuckina Sandstone equivalent). May have local depleted zones	High
Poolowanna Formation	Known reservoir	Basin wide	3,000-4,000 mg/l in Cooper Basin area, but in excess of 9,000 mg/l in northern areas	Part of GAB J aquifer. May have local depleted zones.	High
Cuddapan Formation	Known reservoir	Local channels only between Nappamerri and Jurassic units	Unknown		High
Nappamerri Group (multiple sands and seals)	Known reservoir	Extensive with erosion from the top to the west south and east of Moomba, but sands of local extent. Degree of interconnection across basin unclear.	3,000-7,000 mg/l. Local variations appear to depend on connection with GAB	May be same or greater or less than GAB. May have local depleted zones	Highly variable
Toolachee Formation (multiple sands and seals)	Known reservoir	Extensive, top eroded on structural highs, but sands of local extent. Complex interconnections across basin.	1,500 to 15,000 mg/l apparently depending on connection with GAB. Data set combined with Daralingie.	Potential for very high pressures in centre of basin. May be same or greater or less than GAB. May have local depleted zones. Can prove connection with GAB in Munkarie Brumby area.	Highly variable
Daralingie Formation (multiple sands and seals)	Known reservoir	As above	Data combined with Toolachee.	Potential for very high pressures in centre of basin. May be same or greater or less than GAB. May have local depleted zones.	Highly variable
Epsilon Formation (multiple sands and seals)	Known reservoir	As above	Limited dataset, 2,000 to 10,000 mg/l apparently depending on connection with GAB.	As above	Highly variable
Patchawarra Formation (multiple sands and seals)	Known reservoir	As above	2,000 to 18,000 mg/l. Low salinities in Weena / Tinga Tingana Trough	As above	Highly variable
Tirrawarra / Merrimelia Formation	Known reservoir	Basin wide except for south east and around local highs	Limited dataset for Tirrawarra 5,000 to 17,000 mg/l no data for Merrimelia	As above	Highly variable
Pre Permian Basement	Known reservoir	Basin wide	Unknown	Potential for very high pressures in centre of basin. May be same or greater or less than GAB	Highly variable, may include natural fractures

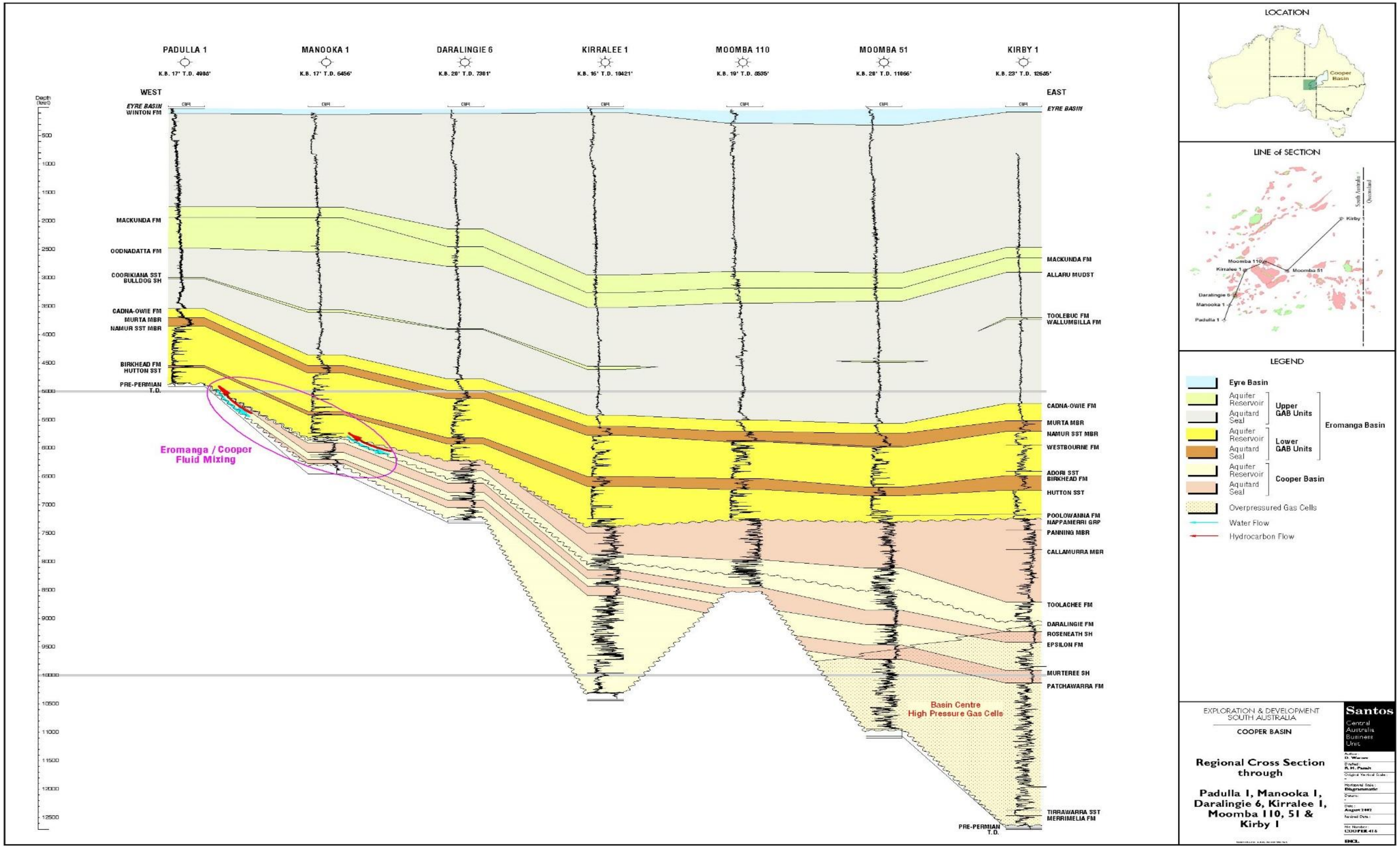


Figure 19: Regional geological cross-sections of the Cooper-Eromanga Basin (1). Source: Santos (201a7). Note: Kirby-1 is in the Central Nappamerri Trough.

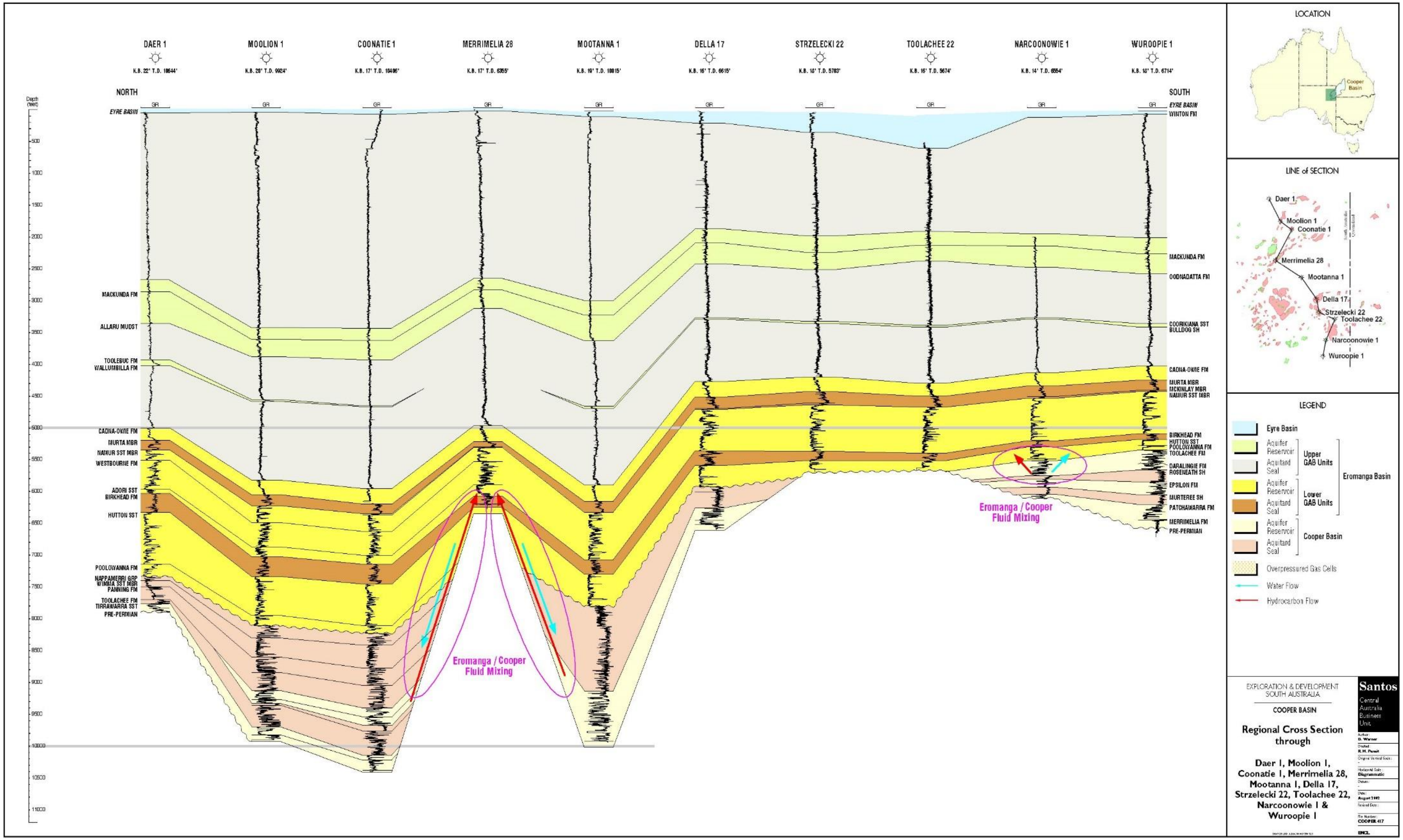


Figure 20: Regional geological cross-sections of the Cooper-Eromanga Basin (2). Source: Santos (2017a)

4.6.3 Aquifer Use

The alluvium along some of the major streams is a frequent source of sub-artesian water across the broader region (Division of Land Utilisation, 1974). In particular, sandy sequences underlying the Cooper Creek provide a shallow aquifer, which may provide baseflow support to semi-permanent waterholes during extended dry periods. Water quality is good, although availability is inconsistent and reliant on infrequent flood recharge events.

The shallow (60 – 200 m) unconfined aquifers of the Tertiary and Quaternary sediments in the greater region generally range from fresh to saline (i.e. <1,000 to 20,000 mg/L or more) with some of these bores suitable for drinking or stock water supply[14]. Water quality in shallow (water table) aquifers in the Moomba region is generally not suitable for stock watering purposes due to a high salt content.

Groundwater quality in the shallow (water table) aquifers in the Cooper Basin region is generally not suitable for potable or stock watering purposes due to a high salt content. Water of up to 5000 mg/L Total Dissolved Solids (TDS) is considered acceptable for stock watering (ANZECC, 2000). The salinity of shallow groundwater resources in the north-east of South Australia is often significantly higher than this value. Likewise, the salinity of water in the uppermost GAB aquifer (Eyre, Winton and Mackunda formations) is also generally too saline for use (Santos 2021a). However, the salinity of the main flowing GAB aquifer is much lower (600 – 2000mg/L TDS) in the eastern part of South Australia and is suitable for stock watering purposes (or potentially drinking water supply if salinity is below 1,200 mg/L), however they are generally too deep for widespread pastoral use (Santos 2021).

Due to the depth of the artesian aquifers in the centre of the basin, the majority of pastoral water use from these aquifers in South Australia occurs along the southern and western margins of the basin where the majority of bores intersect minor / shallow artesian aquifers at less than 600 m (GABCC 1998). On the western margin, these bores coincide approximately with the Oodnadatta Track. There are also a number of flowing artesian bores used for stock watering along the Birdsville track. The use of artesian water in the central portions of the Cooper Basin and Eromanga Basin Region is generally limited to converted petroleum wells due to the expense associated with drilling bores to the depth required to intersect freshwater aquifers.

A review of water bores in the region (Senex 2015) indicated that most groundwater wells in the area where oil and gas exploration and production is undertaken are completed in the shallow aquifers above the main GAB aquifer system. There were no mapped bores in the uppermost main GAB aquifer (Cadna-owie) and a small number of bores at a depth more consistent with the lower main GAB aquifer (Hutton) which were principally converted petroleum wells.

In the Cooper and Eromanga Basins, the petroleum industry also extracts water from the GAB and other aquifers as a result of petroleum production. The majority of oil producing reservoirs in the Cooper and Eromanga Basins are classified as 'water drive' reservoirs. The hydraulic head (pressure) from the water in the sandstone unit provides a source of pressure that flushes the oil through the pore space of the rock towards the wellbore. As a result water is produced with the oil.

The Cooper Basin region has been the subject of a Federal Government risk-assessment study as part of the Bioregional assessment program. Further information on aquifer use in the Cooper Basin region can be found in the Impact Assessment for the Cooper Basin GAB Region – Geological and Bioregional Assessment Stage 3 (https://www.bioregionalassessments.gov.au/gba/cooper-gba-region-synthesis).

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[14] Under the *Environment Protection (Water Quality) Policy 2015*, groundwater is defined as having a number of environmental values depending on its salinity, including drinking water (salinity less than 1,200 mg/L), primary industries – irrigation and general water use (salinity less than 3,000 mg/L) and livestock drinking water (salinity less than 13,000 mg/L).

4.7 Social Environment

4.7.1 Aboriginal Cultural Heritage

The region is culturally significant to the traditional Aboriginal owners. The Cooper Creek region (including the channels and lake shores of the North-West Branch of the Cooper Creek and Coongie Lakes) were an important focus of Aboriginal occupation. Evidence of long term occupation includes rock art, burial sites, trade and ceremonial sites scattered with grinding stones and other artefacts associated with habitation.

Aboriginal sites can still be identified throughout the region and include features of spiritual importance and archaeological sites: for example middens, artefact scatters, rock engravings, arrangement sites, burial sites and quarries (Blackley *et al*. 1996). The eastern section of the Cooper Creek in South Australia has been proclaimed a State Heritage Reserve because of its association with Aboriginal and European history as well as its environmental significance. This area encompasses Innamincka and a one kilometre section either side of Cooper Creek, totalling 120 km^2. It is rich in Aboriginal objects, campsites, quarries and engravings with several unique designs located around Cullyamurra waterhole.

Table 14 summarises the land systems and the archaeological sites and artefacts which may be associated with them.

Table 14: Land systems and Aboriginal heritage

Land system	Site type	Location of sites
Floodplains, wetlands, salt lakes	Burial sites	Isolated dunes and sandy rises
	Campsites	Isolated dunes and sandy rises
	Shell middens	Near lakes and rivers
	Rock art	Near lakes and rivers
	Tree scars: rare	Along rivers and creeks
	Stone artefact scatters	Near lakes and rivers
Sand dunes (including swales and claypans)	Burial sites	Often in eroding sand dunes
	Shell middens	Near sources of permanent water such as Cooper Creek and Coongie Lakes
	Stone artefact scatters	Often found at the base of dunes or on dune swales
Tablelands and gibber plains	Cleared pathways	Near stone arrangements
	Stone tool quarries	Mesa caps
	Stone arrangements	Gibber country

Source: Adapted from Santos (2021a)

Work Area Clearances are carried out with the relevant Native Title group to ensure that culturally sensitive and significant places are excluded from operational areas in advance of all activities

4.7.2 Non-Aboriginal Cultural 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. Many of the historical sites in the region are associated with the failed Burke and Wills expedition of 1860-61 (including the Dig Tree and grave sites) and the subsequent settlement of inland South Australia and Queensland and the establishment of transport routes and pastoralism.

The Burke, Wills, King and Yandruwandha National Heritage Place, Birdsville Track, Innamincka (which was added to the National Heritage List in 2016) covers five individual locations that comprise the Burke and Wills Expedition Site. These sites are located along a 70 km stretch of the Cooper Creek through South Australia and Queensland. Four of the sites (Will's Site, King's Site, Burke's Tree and Howitt's Site) are in South Australia and are also situated within the Innamincka/Cooper Creek State Heritage Area (as well as the broader Innamincka Regional Reserve) which covers a section 1 km either side of the Cooper Creek channel from the Queensland border to 14 km west of Innamincka. A number of sites around Innamincka are also listed on the State Heritage Register, including the Australian Inland Mission Nursing Home at Innamincka (DEW 2022, DAWE 2022a).

4.7.3 Native Title

There are currently three Native Title holders in the South Australian Cooper Basin. Details of each claim are presented in Table 15.

Table 15: Native Title holders in the South Australian Cooper Basin

Title	Location	Status / File no.
Dieri Native Title Holders	From Marree in the south to Cameron Corner in the east, to Haddon Corner in the north east, following the Qld border to Lake Teetatobie, south west of Gypsum Cliff, west to Lake Eyre, south to Marree.	Determined SCD2012/001
Wangkangurru / Yarluyandi Native Title Holders	Northern SA and Queensland.	Determined SCD2014/005
Yandruwandha / Yawarrawarrka Native Title Holders	North east corner of South Australia (SA) extending south to Lake Blanche.	Determined SCD2015/003

Beach has agreements in place for its licence areas with the relevant Native Title holder groups covering exploration and production. Before Beach conducts activities, work area clearances are undertaken with representatives engaged from the relevant group.

4.7.4 Land Use

The major land uses in the Cooper Basin are pastoralism, oil and gas exploration and production, conservation and tourism.

4.7.4.1 Pastoralism

Pastoralism, mainly in the form of cattle grazing, has a long history in the region, beginning in the late 1800s and continuing today. The floodplains surrounding the Cooper Creek in particular provide pasture and reliable water supplies in the form of permanent waterholes. While stocking rates are relatively low the region continues to support a substantial cattle production operation which is an important contributor to the local economy.

Pastoral leases in the region include:

- Alton Downs
- Bollards Lagoon
- Clifton Hills
- Cordillo Downs
- Gidgealpa
- Innamincka
- Lindon
- Merty Merty
- Mulka
- Mungeranie
- Pandie Pandie

There are a number of properties in the region that have achieved certification for organic beef production. Landholders in Beach's operational regions are also certified under Quality Assurance systems such as the Livestock Production Assurance program, which places emphasis on minimising the risk of chemical contamination, bruising and hide damage and ensuring effective herd management and improvement.

4.7.4.2 Oil and Gas

Oil and gas exploration in the Cooper Basin commenced in 1954 and the Cooper Basin has become a major supplier of oil and gas in Australia since the discovery of gas reserves at Gidgealpa, near Moomba, in 1963. The actual area of land utilised for gas production is small, but the supporting infrastructure extends throughout much of the central and north-eastern portion of the Cooper Basin in South Australia. Producing oil and gas fields are spread through pastoral lands and regional reserves and the Ramsar wetland declared area.

Beach is a major oil producer in the South Australian Cooper Basin, with a number of oil production facilities in the Basin and a strong acreage position on the Cooper Basin's western flank..

Beach is the second largest petroleum operator in the region and is also joint venture partner in a number of fields operated by the SA Cooper Basin Joint Venture.

4.7.4.3 Conservation

The region contains some of South Australia's largest reserves dedicated under the *National Parks and Wildlife Act 1972*. The main parks and reserves of the broader region include the Innamincka Regional Reserve, Strzelecki Regional Reserve, Simpson Desert Regional Reserve and the Malkumba-Coongie Lakes National Park.

Regional Reserves are areas proclaimed for the purpose of conserving wildlife, natural or historical features while allowing responsible use of the area's natural resources (including oil and gas production). Together the Innamincka and Strzelecki

Regional Reserves which account for just over two million hectares of land within in the Cooper Basin region while the Simpson Desert Regional Reserve, located on the western margin of the region, is one of the largest protected areas in South Australia and plays an important role for landscape-scale conservation of central Australian arid environments.

In 1987, part of the Cooper Creek system was proclaimed as the Coongie Lakes Wetland of International Importance under the Ramsar Convention. The Ramsar wetland is defined by Lake Moorayepe to the north, the Queensland border at the crossing of Cooper Creek to the east, and a point south-west of Lake Hope (see Figure 18). It is estimated that the Coongie Lakes Wetlands Ramsar area covers 30% of the known oil and gas resources within the South Australian portion of the Cooper Basin (DEHAA 1999).

The Malkumba-Coongie Lakes National Park was proclaimed to conserve significant wetlands, provide tourism experiences and ensure that the core component of the Coongie Lakes system is protected from grazing, petroleum and mining activities. Three special management zones (the No Mining Zone, Walk-In Zone and Controlled Access Zone) have also been established provide additional protection to key riparian and wetland zones adjacent to the Park.

4.7.4.4 Tourism

The Innamincka, Coongie Lakes and Cooper Creek regions in north-eastern South Australia have increased in popularity over the past 30 years as a destination for tourists seeking a bush exploration experience. Based on Department of Infrastructure and Transport (DIT) traffic counts (, it is estimated that more than 20,000 tourists visit the region annually (Santos 2021a). Online booking information for the Innamincka Regional reserve indicates that there were more than 1,000 visitors in 2018-2019, and more than 2,000 people also had access through purchase of a Desert Parks Pass. These numbers are considered an underestimation of visitors as they do not include other visitation information such as camping and accommodation in the town of Innamincka. Vehicle traffic counters on the road to the Malkumba-Coongie Lakes National Park estimated there were approximately 5,000 vehicle trips on the access road in 2018 (NPWS 2019).

Dillons Highway (Strzelecki Track) is a major tourist access route to the region and after connecting with the Adventure Way east of Innamincka, forms part of the outback tourist highway between South Australia and Queensland. The Birdsville Track, which connects the towns of Marree in South Australia and Birdsville in Queensland, is also a major tourist route in the north-west of the region.

4.8 Socio-economic

The region is located in the unincorporated (i.e. out of councils) area of South Australia. Jurisdiction for the area falls under the responsibility of the Outback Communities Authority which provides limited local government-type support.

As discussed above, the major regional industries are pastoralism, oil and gas production and tourism.

The only township in the region is Innamincka, with a population of 44 recorded in the 2016 census (ABS 2022).. The Innamincka Progress Association is responsible for managing many of the town's public facilities, including the Town Common camping area, the airstrip and public amenities.

Moomba, Ballera and the satellite production facilities have accommodation and recreation facilities that house the petroleum industry workforce, which operates on a 'fly-in, fly-out' basis.

Infrastructure in the region is minimal. Unsealed roads service the district, with the Adelaide-Moomba Road and Dillons Highway (which are generally referred to as the Strzelecki Track) being the major route through the region. The oil and gas fields in the region are serviced by a network of unsealed roads and tracks, which are generally not available for public access. The first 50 km of the 472 km Strzelecki Track was sealed during 2021 and the project to seal priority sections of the track is proposed to be completed by mid-2025 (DITRDC 2022, DIT 2022).

Other public roads in the region include the Adventure Way, east of Innamincka, the Cordillo Road and Coongie Lakes track north of Innamincka, Fifteen Mile Track, west of Innamincka and the Walkers Crossing Public Access Route, north-west of Moomba. The Birdsville Track lies on the western edge of the region.

5 Environmental Risk Assessment

This section discusses potential environmental impacts associated with Beach's production operations in the Cooper Basin. The discussion is supported by an environmental risk assessment.

Section 5.1 provides an overview of the risk assessment methodology. Sections 5.2 to 5.12 contain discussions of hazards and tabular summaries of risk assessments and management strategies for Beach's operations and activities in the Cooper Basin. Each risk assessment table outlines:

- environmental hazards associated with the operation or activity
- the potential consequences of the hazard
- an outline of key management measures
- likelihood of occurrence of these consequences, given the management measures in place
- potential severity of the consequences, given the management measures in place, and
- the resultant level of risk.

5.1 Overview of Risk Assessment Process

Environmental risk is a measure of the likelihood and consequences of environmental harm occurring from an activity. Environmental risk assessment is used to separate the minor acceptable risks from the major risks and to provide a basis for the further evaluation and management of the major risks.

The risk assessment process involves:

- identifying the potential hazards or threats posed by the project
- categorising the potential consequences and their likelihood of occurring
- using a risk matrix to characterise the level of risk[15].

The level of risk for Beach's production operations in the Cooper Basin has been assessed based on the assumption that management measures that are discussed in this EIR will be in place. The risk assessment was carried out by Beach environment personnel and relevant members of the Beach Production team, based on knowledge of the existing environment, and experience with production operations in the Cooper Basin undertaken by Beach as well as other companies (e.g. Senex Energy and Santos).

The risk assessment process was based on the procedures outlined in Australian and New Zealand Standard AS/NZS ISO 31000:2018 (Risk Management) and HB 203:2012 (Managing environment-related risk).

[15] The risk assessment process may be iterative for some hazards. For example, the risk assessment may initially indicate that risks are unacceptably high, based on minimum or familiar management practices. In such cases, management practices are reviewed to identify additional management options to lower risk and / or improve environmental outcomes (e.g. elimination, substitution, reduction, engineering controls and management controls). The risk is then re-assessed based on these additional management options. This EIR details the final or residual risk after management options have been applied.

The risk assessment uses the risk matrix and definitions for consequences and likelihood outlined below, which use:

- five categories of consequence (Negligible to Critical) to describe the severity, scale and duration of potential impacts
- five categories of likelihood of potential environmental consequences occurring (Remote to Almost Certain). The likelihood refers to the probability of the particular consequences eventuating, rather than the probability of the hazard or event itself occurring.
- a risk matrix to characterise the risk associated with each hazard as low, medium or high. 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.

5.1.1 Definition of Consequences

To describe the severity, scale and duration of potential impacts, the six categories of consequence listed in the following table are used.

Table 16: Consequence definition

Risk Matrix

CONSEQUENCE	CONSEQUENCE CATEGORY				
	PEOPLE	**ENVIRONMENT**	**REPUTATION**	**FINANCIAL**	**LEGAL**
	Impact to Beach or contracting personnel	**Natural environment**	**Community safety, reputation/social licence, media, items of cultural significance.**	**Financial impact (e.g. due to loss of revenue, business interruption, asset loss etc.)**	**E.G. Breach of law, prosecution, civil action**
6 Catastrophic	Multiple fatalities >4 or severe irreversible disability to large group of people (>10)	Catastrophic offsite or onsite release or spill; long-term destruction of highly significant ecosystems; significant effects on endangered species or habitats; irreversible or very long-term impact	Multiple community fatalities; complete loss of social licence; prolonged negative national media; complete loss of items of cultural significance	> AUD$500m	Prolonged and complex civil and/or regulatory litigation; potential jail terms and/or very high fines and/or damages claim
5 Critical	1-3 fatalities or serious irreversible disability (>30%) to multiple persons (<10)	Significant offsite or onsite release or spill; eradication or impairment of the ecosystem; significant impact on highly valued species or habitats; widespread long-term impact	Community fatality; significant loss of social licence; negative national media for 2 or more days; significant damage to items of cultural significance	AUD$100m-$500m	Civil and/or regulatory litigation; potential significant fines and/or damages claim
4 Major	Serious permanent injury/ illness or moderate irreversible disability (<30%) to one or more persons	Major Offsite or onsite release or spill; very serious environmental effects, such as displacement of species and partial impairment of ecosystem; major impact on highly valued species or habitats; widespread medium and some long-term impact	Serious permanent injury to community member; major damage to social licence; negative national media; major damage to items of cultural significance	AUD$10m-$100m	Civil and/or regulatory litigation; potential major fine and damages claim
3 Serious	Serious reversible/ temporary injury/illness; Lost Time Injury >5 days or Alternate/Restricted Duties > 1 month	Minor offsite or onsite release or spill; serious short-term effect to ecosystem functions; serious impact on valued species or habitats; moderate effects on biological or physical environment	Serious reversible injury to community member; serious damage to social licence; negative state media; serious damage to items of cultural significance	AUD$1m-$10m	Serious potential breach of law; report and investigation by regulator; possible prosecution or regulatory notice (e.g. improvement notice or equivalent), or possible civil litigation and serious damages claim
2 Moderate	Reversible temporary injury/ illness requiring Medical Treatment; Lost Time Injury ≤5 days or Alternate/Restricted Duties for ≤ 1 month	Event contained within site; short-term effects but not affecting ecosystem functions; some impact on valued species or habitats; minor short-term damage to biological and/or physical environment	Moderate injury to community member; moderate impact to social licence; negative local media; moderate damage to items of cultural significance	AUD$100,000-$1m	Potential Breach of law or non-compliance; inquiry by a regulator leading to Low-level legal issues; possible civil litigation and moderate damages claim
1 Minor	First Aid Injury/illness	Spill limited to release location; minor effects but not affecting ecosystem functions; no impact on valued species or habitats; low-level impacts on biological and physical environment	Minor injury to community member, public concern restricted to local complaints, minor damage to items of cultural significance	<AUD$100,000	Minor potential breach of law; not reportable to a regulator; on the spot fine or technical non-compliance

5.1.2 Definition of Likelihood

The likelihood of potential environmental consequences occurring is defined using the five categories shown in the following table. The likelihood refers to the probability of the particular consequences eventuating, rather than the probability of the hazard or event itself occurring.

Table 17: Likelihood definition

LIKELIHOOD					
A. Remote	B. Highly Unlikely	C. Unlikely	D. Possible	E. Likely	F. Almost Certain
<1% chance of occurring within the next year. Requires exceptional circumstances, unlikely event in the long-term future. Only occur as a 100-year event	>1% chance of occurring within the next year. May occur but not anticipated. Could occur years to decades	>5% chance of occurring within the next year. May occur but not for a while. Could occur within a few years	>10% chance of occurring within the next year. May occur shortly but a distinct probability it won't. Could occur within months to years	>50% chance of occurring within the next year. Balance of probability will occur. Could occur within weeks to months	99% chance of occurring within the next year. Impact is occurring now. Could occur within days to weeks

5.1.3 Characterisation of Risk

The risk associated with each hazard was characterised as low, medium, high, severe or extreme using the matrix below.

Risk Matrix

CONSEQUENCE	CONSEQUENCE CATEGORY: PEOPLE Impact to Beach or contracting personnel	ENVIRONMENT Natural environment	REPUTATION Community safety, reputation/social licence, media, items of cultural significance.	FINANCIAL Financial impact (e.g. due to loss of revenue, business interruption, asset loss etc.)	LEGAL E.G. Breach of law, prosecution, civil action	LIKELIHOOD: A. Remote <1% chance of occurring within the next year. Requires exceptional circumstances, unlikely event in the long-term future. Only occur as a 100-year event	B. Highly Unlikely >1% chance of occurring within the next year. May occur but not anticipated. Could occur years to decades	C. Unlikely >5% chance of occurring within the next year. May occur but not for a while. Could occur within a few years	D. Possible >10% chance of occurring within the next year. May occur shortly but a distinct probability it won't. Could occur within months to years	E. Likely >50% chance of occurring within the next year. Balance of probability will occur. Could occur within weeks to months	F. Almost Certain 99% chance of occurring within the next year. Impact is occurring now. Could occur within days to weeks
6 Catastrophic	Multiple fatalities >4 or severe irreversible disability to large group of people (>10)	Catastrophic offsite or onsite release or spill; long-term destruction of highly significant ecosystems; significant effects on endangered species or habitats; irreversible or very long-term impact	Multiple community fatalities; complete loss of social licence; prolonged negative national media; complete loss of items of cultural significance	> AUD$500m	Prolonged and complex civil and/or regulatory litigation; potential jail terms and/or very high fines and/or damages claim	HIGH	HIGH	SEVERE	SEVERE	EXTREME	EXTREME
5 Critical	1-3 fatalities or serious irreversible disability (>30%) to multiple persons (<10)	Significant offsite or onsite release or spill; eradication or impairment of the ecosystem; significant impact on highly valued species or habitats; widespread long-term impact	Community fatality; significant loss of social licence; negative national media for 2 or more days; significant damage to items of cultural significance	AUD$100m-$500m	Civil and/or regulatory litigation; potential significant fines and/or damages claim	MEDIUM	MEDIUM	HIGH	SEVERE	SEVERE	EXTREME
4 Major	Serious permanent injury/ illness or moderate irreversible disability (<30%) to one or more persons	Major Offsite or onsite release or spill; very serious environmental effects, such as displacement of species and partial impairment of ecosystem; major impact on highly valued species or habitats; widespread medium and some long-term impact	Serious permanent injury to community member; major damage to social licence; negative national media; major damage to items of cultural significance	AUD$10m-$100m	Civil and/or regulatory litigation; potential major fine and damages claim	MEDIUM	MEDIUM	MEDIUM	HIGH	SEVERE	SEVERE
3 Serious	Serious reversible/ temporary injury/illness; Lost Time Injury >5 days or Alternate/Restricted Duties > 1 month	Minor offsite or onsite release or spill; serious short-term effect to ecosystem functions; serious impact on valued species or habitats; moderate effects on biological or physical environment	Serious reversible injury to community member; serious damage to social licence; negative state media; serious damage to items of cultural significance	AUD$1m-$10m	Serious potential breach of law; report and investigation by regulator; possible prosecution or regulatory notice (e.g. improvement notice or equivalent), or possible civil litigation and serious damages claim	LOW	MEDIUM	MEDIUM	MEDIUM	HIGH	SEVERE
2 Moderate	Reversible temporary injury/ illness requiring Medical Treatment; Lost Time Injury ≤5 days or Alternate/Restricted Duties for ≤ 1 month	Event contained within site; short-term effects but not affecting ecosystem functions; some impact on valued species or habitats; minor short-term damage to biological and/or physical environment	Moderate injury to community member; moderate impact to social licence; negative local media; moderate damage to items of cultural significance	AUD$100,000-$1m	Potential Breach of law or non-compliance; inquiry by a regulator leading to Low-level legal issues; possible civil litigation and moderate damages claim	LOW	LOW	MEDIUM	MEDIUM	MEDIUM	HIGH
1 Minor	First Aid Injury/illness	Spill limited to release location; minor effects but not affecting ecosystem functions; no impact on valued species or habitats; low-level impacts on biological and physical environment	Minor injury to community member, public concern restricted to local complaints, minor damage to items of cultural significance	<AUD$100,000	Minor potential breach of law; not reportable to a regulator; on the spot fine or technical non-compliance	LOW	LOW	LOW	MEDIUM	MEDIUM	MEDIUM

5.1.4 Risk Assessment Summary Tables

The following sections contain tables which summarise the results of the risk assessment. The tables present the final or residual risk after management measures have been applied. The tables also provide a cross-reference to the relevant SEO objectives for each hazard.

5.2 Well Operations

5.2.1 Completions and Workovers

Environmental hazards associated with completions and workover activities include well control incidents, loss of containment of workover fluids or the possibility of an explosion or fire. The likelihood of a well control issue during completions activities is low because the well is cased and the wellbore is in a stable condition with known downhole pressures.

The Cooper Basin is geologically well-defined with predictable pressure gradients. Guidelines, procedures, design and safety practices take this information into account which in turn reduces the potential for well control issues. Guidelines and procedures specific to workover operations combined with appropriate certification of trained individuals means that the risk of a well control issue in a cased hole is low.

In the event of a well control issue, Beach employs emergency response procedures which may include wellbore, equipment and / or well site isolation. Beach also has expert well control contractors available for mobilisation to assess and secure the situation.

5.2.2 Well Integrity Management

Hazards relating to well integrity management include a failure of casing or cement, which could result in crossflow and contamination between reservoirs and aquifers, and uncontrolled flows at the surface. As discussed in Section 3.1.2, Beach uses a well integrity maintenance program to monitor and assess the reliability of sub-surface assets on a routine basis. Hazards relating to downhole abandonment following production are similar, and have been addressed with well integrity in the risk assessment.

5.2.3 Artificial Lift and Wellhead Production Skids

The main hazards associated with the various wellhead and pumping systems used at well sites include potential spills of hydrocarbon and chemical products that may be stored on-site. Spills and leaks are most likely to be associated with oil well artificial lift installations (e.g. beam pump and jet pump). Stuffing box failure on beam pumps may result in localised contamination of soil and possibly shallow groundwater due to leakage. To minimise the risk associated with spills from stuffing boxes, an Environmental Stuffing Box, a containment device that is fitted above the rod packer and contains any oil / water that has passed by the packer, is installed. In the event that the packing fails to seal, the oil is contained in a receptacle, that once full, initiates beam pump shutdown. Wells are also fitted with impermeable cellars as an additional containment device. Jet pumps are installed on containment bunds that are connected to a sump which will contain hydraulic fluid leaks, spills during maintenance and / or equipment wash down waters.

Artificial lift systems generally require a generator and associated fuel storage and gas well skids may have storage and injection facilities for production chemicals such as corrosion inhibitor. Spills associated with fuel and chemical storage have the potential to result in localised contamination of soil, surface and / or shallow groundwater and potential for uptake by cattle and loss of beef production certifications. Lease construction (i.e. compaction) and installation of appropriate bunding minimises the risk posed to the environment and reduces the potential for environmental impacts.

Regional flooding, particularly along the Cooper and Strzelecki Creeks and associated floodplain areas, or short term (1-2 weeks), shallow and localised flooding due to localised high rainfall events may result in flooding of well leases, with potential to result in localised contamination of soil and watercourses with fuel, oils or chemicals. Work programs in floodplain areas are scheduled to take into account seasonal conditions and rainfall / flood likelihood and activation of the Beach Flood Management Plans reduces the potential impacts of flooding.

Risk assessments are conducted to ensure that the design and installation of production equipment, including artificial lift equipment and wellhead skids, will conform to relevant industry and engineering standards and conventions.

5.2.4 Gas Well Deliquification

The main hazards associated with unloading liquids from gas wells are handling of water produced and expulsion of gas. Inappropriate handling of water produced has the potential to result in localised impacts to soils and shallow groundwater, while the expulsion of gas contributes to operations-related emissions and could result in fire or explosion if not appropriately managed. Management procedures and the use of suitable equipment where necessary (e.g. flowback lines connected to impermeable clay and / or lined pits) are used to minimise the level of risk.

Table 18: Well Operations

Activity / Event	Potential Consequences	SEO Obj	Management Strategy	Consequence	Likelihood	Residual Risk
Completions and Workovers						
Loss of well control (resulting in uncontrolled release of fluids (liquid or gas) to surface)	Contamination of soil, shallow groundwater and / or surface water Danger to health and safety of personnel, contractors and possibly the public Access to contaminants by stock and wildlife Loss of beef production certification Loss of vegetation and fauna habitat Damage to existing producing infrastructure Generation of greenhouse gas emissions, localised reduction in air quality	3, 6, 7, 8	Periodic well integrity processes in place for whole of life well monitoring and management Workover / completion program in place Fit for purpose equipment used Competent site personnel and contractors on site at all times Blowout preventers (BOP) installed Regular BOP drills, testing, certification, and maintenance Continuous observation during operations to mitigate loss of well control events e.g. trip tanks / gas detection Personnel are trained in the use of spill response equipment Implementation of appropriate emergency / spill response procedures Safety equipment on site appropriate to the anticipated gas composition (e.g. H_2S) such as breathing apparatus and gas detectors Restricted access to site	Major	Unlikely	Medium
Explosion or fire at the well site	Contamination of soil, shallow groundwater and / or surface water Danger to health and safety of personnel, contractors and possibly the public Generation of greenhouse gas emissions, localised reduction in air quality Burning of vegetation and habitat Injury to or loss of native fauna	3, 6, 7 8	Fit for purpose equipment used Approved workover / completion program Safety, testing, maintenance and inspection procedures are implemented Establishment of appropriate emergency / spill response procedures for explosion or fire Safety equipment on site appropriate to the anticipated gas composition (e.g. H_2S) such as breathing apparatus and gas detectors Personnel are trained in the use of spill response equipment Erection of signage and, where required, fencing to delineate restricted / hazardous areas Personnel are trained to supervise and instruct individuals entering lease to conduct work Appropriate fire fighting equipment maintained on site Safe work permits must be obtained to ensure only individuals with proper clearance can conduct work on a lease Smoking only in designated areas located away from equipment or activity Restricted access to site	Major	Unlikely	Medium
Spills or leaks associated with chemical and fuel storage and handling	Contamination of soil, shallow groundwater and / or surface water Access to contaminants by stock and wildlife Loss of beef production certification Loss of vegetation and fauna habitat	3, 6	Implementation of appropriate chemical and fuel storage and handling procedures (e.g. bunding and signage) in accordance with relevant standards and guidelines, including AS 1940, EPA guideline 080/16 Bunding and Spill Management and the Australian Dangerous Goods Code (ADG) Regularly educate staff of product, review and monitor chemical and fuel transportation, including signage / labelling, proper packing and tie downs Establish appropriate emergency / spill response procedures for spills or leaks to soil and water Periodic review and exercise of response equipment and procedures to ensure preparedness Appropriate spill containment and clean-up equipment located on site Appropriate spill containment equipment available at sites located adjacent Cooper Creek during flow events e.g. floating containment booms to enable immediate confinement and clean-up.Personnel are trained in the use of spill response equipment Implementation of emergency / spill response procedures Immediate clean-up and remediation to minimise contamination to soil / water Fencing of affected areas if threat is posed to stock or wildlife Monitoring of in situ remediation of spills to confirm that hydrocarbons are decreasing over time Assessment and remediation of uncontained spills with larger scale impact (e.g. any volume to water) undertaken in accordance with the National Environment Protection (Assessment of Site Contamination) Measure Maintain a register of spills and / or leaks and implement corrective actions based on analysis of spill events	Serious	Unlikely	Medium

Activity / Event	Potential Consequences	SEO Obj	Management Strategy	Consequence	Likelihood	Residual Risk
Disposal of hydrocarbon and formation waters	Contamination of soil, shallow groundwater and / or surface water Access to contaminants by stock and wildlife Loss of beef production certification Loss of vegetation and fauna habitat	3, 6	Tanks used for on-site storage of fluids generated during completions and workover activities	Minor	Unlikely	Low
Flooding of surrounding floodplain / watercourses	Contamination of soil, shallow groundwater and / or surface water Damage to infrastructure (e.g. roads, well lease, flare pits) Access to contaminants by stock and wildlife Damage to surrounding vegetation by contaminated water	3, 5, 6	Implementation of appropriate chemical and fuel storage and handling procedures (e.g. bunding and signage) in accordance with relevant standards and guidelines, including AS 1940, EPA guideline 080/16 Bunding and Spill Management and the ADG Code. Work programs in floodplain areas scheduled to take into account seasonal conditions and rainfall / flood likelihood Monitoring of Cooper Creek levels at gauging stations upstream of operations to enable implementation of flood response procedures prior to flooding (which can generally be predicted many weeks to months in advance) Activation of Beach Flood Management Plan where flooding of well lease is likely or imminent Measures undertaken to reduce potential impacts of flooding where appropriate (e.g. installation of bunds, removal of liquids prior to arrival of flood event) If deemed at risk, wellheads may be shut in and chemicals removed prior to flood events Fully containerised tanks used for on-site storage Tanks used for on-site storage of fluids generated during completions and workover activities	Moderate	Unlikely	Medium
Well integrity management						
Cement failure	Communication between formations that are typically hydraulically isolated or to surface Contamination of aquifers	6	Periodic well integrity processes in place for whole of life well monitoring and management Appropriate controls implemented during well drilling (under the Drilling SEO) including: Cement slurry and pumping schedule design Casing centralisation program QA / QC during cement job execution Cement bond logs run where appropriate Remedial cementing undertaken where logs indicate an unacceptable risk Competent site personnel and contractors on site at all times	Moderate	Unlikely	Medium
Down hole production equipment failure (e.g. casing, packer, seal assembly)	Uncontrolled release of fluids (liquid or gas) to surface Communication between formations that are typically hydraulically isolated Contamination of aquifers Contamination of soil, shallow groundwater and / or surface water Danger to health and safety of personnel, contractors and possibly the public Access to contaminants by stock and wildlife Loss of beef production certification Loss of vegetation and fauna habitat Generation of greenhouse gas emissions, localised reduction in air quality Loss of reserves and reservoir pressure	3, 6, 7, 8	Appropriate controls implemented during casing installation (under the Drilling SEO) including casing design, running procedures, pressure testing and casing certification Competent site personnel and contractors on site at all times New or certified wellhead and production equipment installed Downhole production equipment and wellhead equipment designed to meet pressure, temperature, operational stresses and loads. Pressure testing, either inflow (negative test) or positive testing to be performed on barrier envelopes / components where feasible Inhibited static packer fluid, where applicable Monitoring programs implemented (e.g. through well logs, pressure measurements / testing and, or corrosion monitoring programs) to aid in the assessment of wellbore barrier conditions Where monitoring identifies potential issues, working within Beach Management Systems, risk assessment undertaken to identify hazards / scenarios and propose recommendations and mitigation controls where appropriate to reduce or monitor risk Casing annulus pressures are routinely checked and reported, if accessible Downhole abandonment following production Well abandonment program to be submitted to DEM with wireline logs prior to implementation Downhole abandonment carried out to meet worst case expected loads and downhole environmental conditions Appropriate barrier controls put in place to prevent crossflow, contamination or further pressure reduction occurring Pressure testing and / or negative inflow testing performed on barrier envelopes / components where feasible Inhibited fluid placed between barriers where applicable Operational reports for barrier installation and testing submitted and retained	Moderate	Possible	Medium

Activity / Event	Potential Consequences	SEO Obj	Management Strategy	Consequence	Likelihood	Residual Risk
Artificial lift and wellhead production skids						
Spills and leaks from artificial lift and wellhead production equipment	Contamination of soil, shallow groundwater and / or surface water Access to contaminants by stock and wildlife Loss of beef production certification Loss of vegetation and fauna habitat Generation of greenhouse gas emissions, localised reduction in air quality	3, 6, 8	Equipment is fit for purpose and installed in accordance with relevant standards including AS 3000 and AS 60079 series Safety, testing, maintenance and inspection procedures are implemented Over-pressure protection systems, including high-pressure shut downs and environmental stuffing boxes will be installed to suit each type of artificial lift as appropriate Safe work permits must be obtained to ensure only individuals with proper clearance can conduct work on a lease Where appropriate, impervious well cellars are installed at wells Artificial lift installed with adequately sized containment sumps with floats as necessary Flowlines installed as per AS2885 Containment devices are installed on gas well skids See *Completions and Workovers* section in this table (above) for general controls related to spills or leaks	Moderate	Possible	Medium
Gas Well Deliquification						
Gas / water production during operations	Localised contamination of soil, shallow groundwater and / or surface water Danger to health and safety of personnel, contractors and possibly the public Impacts to stock and / or wildlife Loss of beef production certification Ignition of bushfires Loss of fauna vegetation and fauna habitat Generation of greenhouse gas emissions, localised reduction in air quality	3, 6, 7, 8	Water produced during gas well unloading is managed based on level of environmental risk (e.g. proximity to surface water bodies and or presence of sensitive shallow groundwater receptors). Measures may include: • impermeable clay and / or lined pit to contain any produced liquids • tanks • flare stack Assessments undertaken where relevant to identify potential environmental sensitivities and specify required containment measures Wells that are frequently unloaded are reviewed to evaluate whether measures to minimise unloading are appropriate (e.g. installation of small ID tubing or artificial lift installation) Unloading undertaken only when prevailing environmental conditions (e.g. wind speed and direction) are suitable Gas / fluid stream will be flared rather than vented to minimise emissions where possible. This will depend upon fluid ratio in the stream	Moderate	Highly Unlikely	Low

5.3 Fracture Stimulation

The main hazards that potentially (or are perceived to) result from fracture stimulation operations are discussed in the following sections. Sections 5.3.1 to 5.3.5 address aquifers and sections 5.3.6 to 5.3.11 address hazards at the surface.

5.3.1 Leakage into 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 water from the aquifer when the well is flowed. The risk is reduced to as low as possible in the well design process and construction process and managed through operational monitoring.

In particular:

- the well design and construction provides the mechanical integrity that reduces this risk to as low as possible
- pressure testing demonstrates production casing integrity
- cement bond logs are run to review quality of the production casing cementing operation that is pumped into the production casing-wellbore annular space
- pressure safety trip out systems during the fracture stimulation prevent pressure limits of the surface pipework and downhole casing equipment being exceeded
- continuous pressure monitoring during the fracture stimulation treatment enables precautionary equipment shut down if abnormal pressure responses are recorded.

The well design and construction process considers stresses and loads associated with temperatures, pressures and fluids that may be pumped into and produced throughout the life of the well. The casing, production and well head equipment is purchased from established API certified suppliers that have demonstrated their ability to supply the materials that meet or exceed the design specification with appropriate supporting certification documents.

During construction of the well, casing strings are cemented into the bore hole. In addition to anchoring the casing string into the bore, the function of the cement is to provide a barrier to fluid migration between the casing and borehole isolating aquifers and hydrocarbon bearing intervals. Cement design, casing centralisation in the well bore and correct cement pumping procedures are important for achieving good quality cementing and isolation of the formations. This maximises the potential for technical success of the well to mitigate migration of fluids behind casing. Experienced oil and gas industry personnel supervise the on-site well construction operations, including installation and cementing of casing strings, well head equipment is correctly undertaken as per the program.

At completion of the production casing cement displacement, the wellbore is pressure tested to confirm the pressure integrity of the casing and cement at the base of the well. Prior to stimulation, additional pressure testing of the wellbore may be conducted to maximum designed pumping pressure (using water).

A cement bond log (CBL) is usually run after a well is cased and suspended to provide an indication of the production casing cement quality. The log may assist with understanding production results in the event that unexpected production characteristics develop. If anomalous CBL results are recorded and pending further testing and evaluation, remedial work may be performed on the production casing to reduce the risk of communication with aquifers.

Pressure controls are fitted to the pumping equipment that limit the maximum pumping pressure and will automatically shut down the pumps when a pre-set operational maximum pressure is reached. This limit is set below the design rating of the casing and wellhead equipment to avoid over pressure of the system.

Continual monitoring of wellhead pressures is carried out during fracture stimulation to understand how the injection is progressing. If a significant pressure anomaly is observed at surface during the stimulation treatment, this may indicate that well integrity has been compromised. This may arise due to faulty casing material or errors during making up the casing connections while running the casing. As discussed in the well design section, the choice of casing size, weight and connection type, the use of new casing from a reputable supplier and adequate supervision while running the casing reduces the risk of this type of breach.

In the event that the injection pressure does not appear to be correct for the zone being stimulated, the stimulation treatment will be suspended and the data reviewed to assess the implications. If it is determined that a breach has occurred and depending on the location of the breach, the well may be repaired with a casing patch or other isolation method if required. Alternatively, if the zone is below other intervals proposed for stimulation, the stimulation may progress in the upper zones foregoing the intervals deeper in the well. If the zone is significantly higher in the well and there is no suitable way to isolate the interval and successfully stimulate the lower intervals, the well may be plugged and abandoned with appropriate plugs set to isolate intervals as required by the regulations.

5.3.2 Fracture Propagation into GAB Aquifers

Growth of fractures out of the target zone and into an adjacent or overlying aquifer could result in leakage of fracture fluids, formation water and hydrocarbons into the aquifer (although it is noted that aquifers or water-bearing units proximal to oil reservoirs typically contain hydrocarbons and are not suitable for domestic or agricultural use). It could also result in flow from the aquifer into the reservoir when the well is flowed to the surface.

Fracture growth into a water bearing zone is undesired during fracture stimulation, as it would result in the well flow being dominated by water and thus uneconomic. Potential fracture stimulation targets are excluded if there is an identified water risk apparent due to underlying or overlying aquifers that cannot be mitigated (e.g. by alteration of the stimulation design).

As discussed in Section 3.2, fracture stimulation treatments are modelled to predict fracture geometry and designed to stimulate the targets of interest only. The operation is closely monitored against the design, that limits fracture growth within the target units and not extend into non-target formations.

The risk of fracture propagation into overlying or adjacent aquifers is discussed below in the context of fracture stimulation of Eromanga Basin oil targets, Cooper Basin conventional gas targets and Cooper Basin unconventional gas targets.

5.3.2.1 Eromanga Basin Oil Targets

Small-scale fracture stimulation treatments in Eromanga Basin oil reservoirs are used to recover oil from lower quality reservoirs. There have been more than 140 successful fracture stimulation treatments in the Murta Formation, as discussed in Section 3.2.

Senex (2015) provided a detailed assessment of fracture stimulation of Murta Formation targets and concluded that the level of risk is low. In addition to the design and control measures discussed above (and in Section 3.2) which ensure that fracture growth stays within the target units and excludes targets where there is an identified water risk that cannot be mitigated, Senex (2015) concluded that:

- there is significant geological control above the Murta Formation, with the existence of significant aquitard units in the lower two-thirds of the Cadna-owie formation and the upper M1 aquitard unit of the Murta.
- the upper McKinlay Member, underlying the Murta, provides separation and some geological control from the permeable sands that are deeper in the McKinlay Member. The McKinlay Member is a known oil-producing reservoir, but is not identified as a significant aquifer, (e.g. compared to the Hutton Sandstone) and is not targeted for aquifer purposes in this area.
- the small fracture stimulation treatments designed for the Murta are thus constrained by a combination of careful geomechanical design of the fracture stimulation and substantial geological control.
- also, there have been sporadic hydrocarbon shows in the Cadna-owie (i.e. hydrocarbons are potentially present in the Cadna-owie in this area).

As discussed in Senex (2015), there are also further significant limitations on the potential transport of oil / contaminants from Murta stimulations into adjacent GAB aquifers. In particular:

- the Wallumbilla formation forms a regional seal above the Cadna-owie and the local scale stratigraphic traps in which Murta targets are typically located present an additional constraint on transport.
- the "relatively stagnant" low flow velocities (0.03 to 0.3 m per year) in the Central Eromanga Basin, the substantial distance to the nearest GAB springs and the very low number of nearby groundwater users (other than petroleum industry users in the Cooper Basin), mean that there is relatively little regional groundwater flow in the GAB and very little groundwater use in the project area.
- the pressure gradients once flowback commences 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.

Therefore, in addition to the geological and operational controls in place resulting in a very low likelihood of fractures extending into adjacent aquifers, if it did occur the consequences would be very limited.

Senex (2015) also assessed the Birkhead Formation (which has had very few fracture stimulation treatments undertaken to date) as potential target. The assessment identified that there are underlying and overlying aquitard units within the Birkhead Formation which provide hydraulic seal / isolation. It is expected that the level of risk for suitable targets in this formation (following detailed geomechanical analysis and fracture stimulation design) would be similar to the Murta formation (i.e. a low level of risk).

5.3.2.2 Cooper Basin Conventional Targets

The objective of fracture stimulation in conventional Cooper Basin gas targets is to improve deliverability and conductivity along reservoir sands that have skin damage and / or low permeability. Low permeability conventional sands have been referred to as tight gas or low deliverability gas in the past, as these sands are not dissimilar in terms of geological setting but gas pay is interpreted with different petrophysical cut offs (as compared to better quality reservoirs). These include:

- Reservoir sands in the Toolachee, Daralingie, Epsilon, and Patchawarra formations which are relatively thin (1-10 m) and bound above and below by low to very low permeability coals, shales and siltstones, often from 2–30 m or more in thickness.

- The underlying Tirrawarra Sandstone, which is a single sand unit with a highly variable thickness averaging around 70 m (Hill and Gravestock in Drexel and Preiss, 1995).

Significant geological control for fracture stimulation of conventional targets in the Cooper Basin is provided by the units present, which include:

- the Murteree Shale (around 70 m thick) which separates the Patchawarra from the Epsilon formation, and the Roseneath Shale (up to 100 m thick) which separates the Epsilon from the Daralingie or Toolachee formations (apart from areas where these shales are present and not removed by erosion within the depositional succession).

- the Nappamerri Group siltstones (100–500 m thick) which cap the whole of the gas-bearing coal measure succession (Toolachee to Patchawarra inclusive) over the majority of the Cooper Basin.

Excessive fracture height growth outside the targeted formation in Cooper Basin conventional targets is of very low likelihood due to the changes in geomechanical properties within and between formations, which limit vertical fracture propagation. As there are multiple sands in each formation, each separated by shale and in many cases, coal, should a fracture network break through one barrier above or below, there are numerous additional barriers to prevent a fracture breaking out of the target formation.

In addition, the Murteree Shale provides an impenetrable barrier above the Patchawarra Formation, as does the Roseneath Shale to stimulations in the Epsilon Formation. The very thick Nappamerri Group siltstones provide a safety barrier over much of the Cooper Basin, except around the margins where it has been eroded. In these areas, oil and gas has already escaped into the Eromanga Basin.

Fracture stimulation modelling and design for each specific location and operational controls are implemented, as discussed above and in Section 3.2. Along with the geological controls present, these further reduce the likelihood of fracture growth impacting overlying GAB aquifers.

5.3.2.3 Cooper Basin Unconventional Targets

Fracture stimulation into unconventional resource zones is undertaken at a different scale and with a different purpose to treatments in conventional reservoirs. An unconventional stimulation aims to provide a fracture network into rock that would normally be unproductive, as gas is 'locked in' until fractured. The treatments involve pumping at higher pressures with greater volumes of stimulation fluid and at a greater rate, to stimulate a larger volume of rock than a conventional stimulation target.

In the Cooper Basin, the current unconventional targets are found in the deeper areas of the basin, including the Nappamerri Trough (basin centred gas and shale gas). The sealing Nappamerri Group rocks have their thickest development (up to 500 m) in the Nappamerri Trough, above the unconventional targets. Based on extensive fracture height growth monitoring in shale gas plays in the United States and the stress contrasts observed in the formations intersected in the Cooper Basin, the likelihood of vertical fracture growth into a GAB aquifer 400 – 700 m above an unconventional target is considered remote. In addition, the low permeability of the GAB observed in the area and the very large distances to receptors further reduces the likelihood of any impacts.

Fracture stimulation design, modelling and operational controls are implemented for fracture stimulation treatments, as discussed above.

5.3.3 Leakage into GAB Aquifers Through Geological Material

Leakage of stimulation fluids to aquifers through the overlying strata (via transmission through aquitards or faults) is not considered a significant hazard for fracture stimulation.

The rate of flow through a low permeability aquitard overlying the fracture stimulation treatment 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.

Fault structures can be identified with seismic surveys, and stimulation treatments can be avoided in proximity to faults. Suitable pressure and permeability conditions would also be necessary for fluids to flow along any faults. Given the pressure gradients resulting from hydrocarbon production, it is unlikely that sufficiently high upwards pressures required for fluids to flow along any faults would develop and/or be sustained.

5.3.4 Lateral Migration of Injected Fluids

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.

5.3.5 Groundwater Impacts from Water Use

Where possible, fracture stimulation will use recycled water (e.g. recovered fracture stimulation fluids or recycled water from production facility evaporation ponds).

Where groundwater extraction for fracture stimulation is required, it will be undertaken within the regulatory framework of the Landscapes South Australia Act. Appropriate authorisations will be 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. Where potential impacts are identified, further assessment, consultation with the well owner and monitoring would be carried out to ensure that significant drawdown or impacts are avoided or mitigated.

Extraction of large volumes of water from aquifers that provide baseflow to nearby waterholes (e.g. aquifers in sandy sequences underlying and adjacent to the Cooper Creek) will be avoided.

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 (e.g. APPEA 2011, API 2010).

5.3.6 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.

Chemicals and fuel on site will be stored and handled in accordance with relevant standards and guidelines. Any spills will be immediately cleaned up and contaminated material removed off-site for appropriate treatment or disposal.

As discussed in Section 3.2.9, temporary storage tanks or lined ponds will be used to contain fluid associated with fracture stimulation events depending on the volume used (i.e. shallow, small fluid volume programs will use mobile tanks, and deep, unconventional programs with high water volumes will adopt temporary above-ground, lined storage ponds). Quality control during construction of ponds for water / flowback storage will minimise the risk of liner breaches. Fencing will be installed to prevent large fauna and livestock from entering the ponds and damaging the liners. Regular monitoring of the pond and fence condition, visual inspections, regular water balance calculations, operating the ponds with adequate freeboard and construction with above-ground walls that prevent surface runoff into the ponds all minimise the risk of seepage or release from the pond. If longer term use is planned, more stringent leak detection methods would be considered dependent on the level of risk (e.g. depth and quality of groundwater).

The water used for fracture stimulation can be fresh, brackish or saline. Chemicals are generally not added to stored bore water, however low levels of hydrocarbons or other chemicals (e.g. biocides) may be present if recycled water from evaporation ponds is being used. Should a spill or leak of pre-stimulation water occur, the short term nature of utilisation, the general 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.

If a spill or leak from a pond occurs while it contains flowback fluids, containment and clean-up measures would be implemented. Where necessary and possible, escaped fluid may be recovered, (e.g. using a drainage channel to collect the fluid). 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.

In terms of potential impacts to shallow groundwater, the water table in much of the region, where present, is generally not close to the surface, and is predominantly brackish to saline. There is very low population density and very limited use of shallow groundwater. Many of the fracturing fluid additives are biodegradable. 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 and the relatively low permeability of the clay soils that are present at many locations. 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 surface area and result in a moderate level consequence, but is considered unlikely.

An equipment failure or leak during stimulation could result in fracturing fluid being released to the lease area. Equipment design, pressure testing 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.

5.3.7 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
- spills or leaks from the sourcing of and storage of water in preparation for stimulation
- flooding of well leases during fracture stimulation operations.

Measures to ensure safe handling and storage of fuel, chemicals, flowback fluids and waste will be implemented, as discussed in Section 5.3.6.

Several fluid additives (e.g. biocides) have relatively high toxicity to aquatic organisms. Although many of these additives are biodegradable and would be either degraded in the formation or break down further over time, a large release or spill to surface waters would require significant dilution to reduce contaminants to below harmful levels and could result in impacts beyond the immediate area of operations. Such an escape of large volumes could result from structural failure of flowback ponds or significant flooding such that a pond is inundated.

Pond design, location, construction, operation and monitoring would reduce the risk of structural failure such that it is a very unlikely event. If well leases are located in areas where infrequent minor flooding may occur, measures will be undertaken to ensure that any ponds are not vulnerable to flooding (e.g. location of ponds on higher ground).

Broad scale flooding in the region is associated with heavy rainfall in the Cooper Creek catchment hundreds of kilometres upstream of the South Australian border. Gauging stations at various locations upstream monitor the level of the creek and the potential for flooding is understood several weeks or more in advance. If necessary, the Beach Flood Management Plan would be activated and decommissioning and demobilisation activities can be planned and executed to minimise the impact of creek flooding.

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 risks 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.

5.3.8 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.

Safe handling and storage of fuel, chemicals, flowback fluids and waste will be implemented, as discussed in Section 5.3.6.

Measures including fencing of ponds, manning of sites during stimulation operations and immediate clean-up and containment of spills will minimise stock and native fauna access to flowback fluids. 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 Cooper Basin is a very rare occurrence.

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 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. The pH of flowback fluids is expected to be relatively neutral, as acids are neutralised in the fracturing process. If necessary, additional measures to discourage bird use can be implemented, which may include installation of flagging or other devices to discourage bird presence.

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. As discussed previously, the construction, operation and monitoring of ponds reduces the likelihood of a breach occurring to a very low level. Containment, cleanup and fencing of the spill area would be implemented to prevent stock and fauna access to contaminants.

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 Beach 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.

5.3.9 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 are 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 would be at very low concentration and settle out into the lined pond. Appropriate protocols (e.g. risk assessment, monitoring where required) will be implemented where radioactive tracers are used to confirm that radiation levels are well below any levels of concern. All radioactive materials will be handled in accordance with relevant legislation and guidelines (e.g. *Radiation Protection and Control Act 2021*).

Chemical tracers, if used, are non-hazardous and used in very low concentrations. In flowback they are expected to be less than 250 parts per billion in total within the flowback fluid.

5.3.10 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 Eromanga Basin or Cooper Basin targets. The region has low background seismic hazard and is mapped in the lowest category of earthquake hazard in Australia (Geoscience Australia 2012). Fracture stimulation has been carried out in the Cooper Basin for over 40 years without any issues related to seismicity.

Microseismic monitoring may be used at some well locations as part of the resource assessment and will be available to delineate seismic response.

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.

5.3.11 Public Safety and Amenity

Measures to mitigate the risks to the public are in place including signage, fencing, access restrictions, speed restrictions, monitoring of speeds in industry vehicles, education programs and ongoing maintenance of roads and tracks.

The population density in the area is very low and most sites are likely to be relatively remote from public roads and accessed from roads with no public access.

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).

Table 19: Fracture stimulation risk assessment

Activity / Event	Potential Consequences	SEO Obj	Management Strategy	Consequence	Likelihood	Residual Risk
Loss of well integrity	Leakage from / to aquifers Loss of aquifer pressure and contamination of aquifers Contamination of soil, groundwater and surface water Emissions to the atmosphere	6	Aquifers isolated behind casing string(s), cemented in place. New casing and wellhead installed on new wells Casing and wellhead and cement slurry designed to meet pressure, temperature, operational stresses and loads Design reviewed by independent engineering firm where necessary Cement bond logs run to check 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. If significantly lower initiation pressure, stop job and assess for potential casing integrity failure Emergency response plan in place and drills conducted	Moderate	Remote	Low
	Injury / danger to health and safety of employees, contractors and possibly the public	6		Major	Remote	Medium
Fracture propagation from Eromanga Basin targets into adjacent GAB aquifers	Loss of aquifer pressure and contamination of aquifers Adverse impacts to groundwater users	6	Fracture design (including pressures, injectate rate, fluid makeup and proppant concentration) undertaken to provide confidence that the fracture treatment remains within the hydrocarbon target Fracture stimulation treatments modelled prior to treatment Fracture stimulation candidates are excluded where water risk is apparent due to close proximity to overlying and / or underlying aquifers Real time pressure monitoring during treatment Where pressure monitoring suggests loss of zonal containment, operation will be shut down	Serious	Remote	Low
Fracture propagation from Cooper Basin targets into overlying GAB aquifers	Contamination of aquifers Indirect adverse impacts to groundwater users	6	Significant physical separation between targets and overlying GAB aquifers (~400 m thick Nappamerri Group siltstone between Permian targets zones and the overlying GAB) Minimal connecting faulting noted on seismic acquired throughout the basin Pressure differential between GAB aquifers and Upper Permian reservoirs indicates no communication Modelled stimulation treatments demonstrate containment of height growth within acceptable limits between gas targets and any GAB aquifers Real time pressure monitoring during treatment to identify containment Geological risk assessment undertaken as necessary	Moderate	Remote	Low
Leakage of injected fluids to GAB aquifers through overlying strata or faults	Contamination of aquifers Indirect adverse impacts to groundwater users	6	Permian target intervals separated from overlying GAB aquifers by 400 m of limited permeability Nappamerri Group siltstone Pressure differential between the GAB and the Permian Formations indicates that the intervals are not currently connected by faults, and seismic information has not detected large scale faults that connect the GAB to the Permian section Any localised fault structures identified with seismic survey and stimulation treatment is avoided in proximity to faults	Moderate	Highly Unlikely	Low
Lateral migration of injected fluids	Contamination of aquifers	6	In low permeability formations, fracture stimulation fluid highly unlikely to migrate any significant distance beyond the stimulation treatment Stimulation treatments are flowed back as soon as practicable and/or the well is put on line to recover treatment fluids 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	Moderate	Highly Unlikely	Low
Water supply / use	Excessive drawdown of artesian and sub-artesian aquifers Adverse impact on groundwater users Adverse impact on groundwater dependent ecosystems	5	Options for alternative water supplies investigated / used where possible (e.g. produced formation water, recycling, reuse) Water supply wells reviewed to ensure that their use does not impact adversely on existing users of groundwater Monitoring of water extraction volumes Extraction of large volumes of water from aquifers that provide baseflow to nearby waterholes (e.g. aquifers in sandy sequences underlying and adjacent to the Cooper Creek) will be avoided	Moderate	Possible	Medium

Activity / Event	Potential Consequences	SEO Obj	Management Strategy	Consequence	Likelihood	Residual Risk
Leak of brackish or saline pre-stimulation water from holding ponds	Localised salinisation of soil, surface water and groundwater Adverse impacts to flora and vegetation	6	Tanks used for storage of pre-stimulation water where small volumes are required. Larger above-ground tanks or lined ponds used where necessary to hold larger volumes Quality control on pond construction and liner installation to minimise risk of compromised liner integrity Adequate freeboard maintained (to allow for rain events and wave effects) and above-ground walls / bunds to prevent entry of surface runoff Pond operation monitored (e.g. pond wall integrity) and repair undertaken if required	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 Adverse impacts to flora and vegetation	6	See *Completions and Workovers* section in Table 18 for general controls related to spills or leaks.	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 Adverse impacts to flora and vegetation	6		Serious	Unlikely	Medium
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 Adverse impacts to flora and vegetation	6	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 Flowback fluids securely contained in ponds lined with UV stabilised material Pond liner to be UV stabilised HDPE or equivalent and capable of withstanding expected operating conditions Quality control during construction to minimise risk of compromise to integrity of liner Maximum pond fill level not exceeded (allow for rain events and wave effects) Ponds with above-ground walls that prevent surface runoff into ponds Pond operation monitored (e.g. pond wall integrity, visual inspections, regular water balance calculations) 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 chemical additives 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	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 Adverse impacts to flora and vegetation	6		Serious	Unlikely	Medium
Minor leak or spill of flowback fluids to surface water	Localised contamination of surface water Localised death or injury to aquatic fauna	6	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	Moderate	Unlikely	Medium

Activity / Event	Potential Consequences	SEO Obj	Management Strategy	Consequence	Likelihood	Residual Risk
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	6	Flowback fluid securely contained in lined ponds, as discussed above: Ponds lined with UV stabilised HDPE or equivalent 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 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 the Cooper Creek channel or other 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, removal of flowback fluids off-site either during testing or at completion of operations) Monitoring of Cooper Creek levels at gauging stations upstream of the well lease to enable implementation of flood response procedures if flood fronts are identified that are likely to impact on well operability and pond integrity Implementation of additional management measures as identified by site-specific assessments against the stated environmental objective to avoid surface water impacts	Major	Unlikely	Medium
Flooding of well leases during fracture stimulation operations	Contamination of surface water Death or injury to fauna	6	Well leases located on higher ground as far as practicable Fracture stimulation not carried out in floodplain areas if significant flooding is reasonably expected or predicted in the Cooper Creek system Monitoring of Cooper Creek levels at gauging stations upstream of operations to enable implementation of flood response procedures prior to flooding (which can generally be predicted many weeks to months in advance) Activation of Beach Flood Management Plan where flooding of well lease is likely or imminent 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	Serious	Unlikely	Medium
Interaction of stock or native fauna with storage ponds	Death or injury of fauna or stock	1, 3, 6	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 Measures to facilitate escape of smaller fauna from ponds provided where feasible (e.g. geofabric or textile matting 'ladders') Ongoing inspection and monitoring of ponds would detect fauna mortality (if it occurred) and implement appropriate preventative measures if required Bird deterrent measures will be introduced if bird mortality incidents are observed Ponds will be temporary and will be rehabilitated following removal of liner Note: Historically there are very few reports of fauna (small or large) entrapment in similar ponds within the Cooper Basin	Minor	Unlikely	Low
Personnel and third party access to storage ponds	Danger to health and safety of personnel, contractors and possibly the public	1, 7	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	Remote	Low

Activity / Event	Potential Consequences	SEO Obj	Management Strategy	Consequence	Likelihood	Residual Risk
General site activities, presence of personnel and noise emissions	Disturbance to landowners and other third parties Disturbance to stock and wildlife Disturbance to cultural heritage sites	1, 3, 6, 8	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 on the importance of remaining within designated / approved areas If flora with significant conservation value is present in the vicinity 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 Equipment operated and maintained in accordance with manufacturer specifications Remote location of well sites Fracture stimulation would not be carried out in close proximity to Innamincka 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 Minimise lighting where possible	Minor	Unlikely	Low
Flaring or combustion of hydrocarbons Fugitive emissions of methane and organic carbon	Localised reduction in local air quality Release of greenhouse gases	8	Equipment operated and maintained in accordance with manufacturer specifications If possible, well flowback diverted to separator to minimise gas not being captured and sent to flare Flaring during production testing kept to minimum length of time necessary to establish resource and production parameters Connection to the gathering network rather than flaring to atmosphere where feasible Remote location of well sites Fracturing would not be carried out in close proximity to Innamincka or pastoral station residences Monitoring of well parameters during testing operations to check for potential for fugitive emissions at the wellbore Note: Greenhouse gas emissions recorded and reported in accordance with NGER requirements	Minor	Unlikely	Low
Bushfire (resulting from activities)	Loss of vegetation and fauna habitat Disturbance, injury or death of fauna Atmospheric pollution Damage to infrastructure Disruption to land use Danger to health and safety of personnel, contractors and possibly the public	1, 3, 7	Activities undertaken on cleared well lease Combustible materials cleared from area surrounding flowback equipment Fire fighting 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)	Serious	Remote	Low
Seismicity	Ground disturbance	1, 7	Low background seismic hazard Lack of major faulting in most operational areas Historical stimulation work in the Cooper Basin indicates low risk of induced seismicity Microseismic monitoring may be used at some well locations as part of the resource assessment and will be available to delineate seismic response	Minor	Remote	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	1, 6, 7	Flowback ponds lined with HDPE or equivalent Appropriate protocols (e.g. risk assessment, monitoring where required) implemented where radioactive tracers are used to confirm that radiation levels are well below any 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
Disposal of flowback fluids in open systems	Contamination of soil, shallow groundwater and / or surface water Access to contaminants by stock and wildlife Salinisation of operational areas Death of adjacent vegetation Injury to or death of wildlife	1, 3, 6	See *PFW storage and disposal* risk assessment section in Table 21 If flowback (or initial production from the well) is planned to be disposed to a produced water disposal system, detailed assessment, management and monitoring is undertaken to ensure that potential impacts are appropriately managed and that water entering open systems (i.e. free form areas) meets the requirements of the *Environment Protection (Water Quality) Policy 2015* and meets relevant guidelines for the disposal site (e.g. ANZECC (2000) /ANZG (2018) or EPA guidelines)	Minor / Moderate	Possible	Medium

5.4 Production Facilities

5.4.1 Facility Construction

Environmental hazards associated with construction of facilities and associated areas such as camps and laydowns include movement of heavy vehicles, earthworks, vegetation clearance, fire, leaks or spills associated with chemical and fuel storage and waste disposal.

The type and severity of potential consequences of earthworks is dependent, to a certain extent, on the land system in which the activities are being carried out. Disturbance of soils in some land systems, such as gibber plains and tablelands, can lead to substantial erosion by water while other systems, such as dunefields, are generally more resilient and less likely to suffer any long-term impacts from soil disturbance. The potential consequences of specific earthwork activities on different land systems in the Cooper Basin are summarised in Table 23.

Production facilities are usually located to avoid sensitive land systems or areas of high ecological value (e.g. salt lakes, wetlands or other areas of significant habitat). Production facilities are also usually located on or adjacent to previously disturbed areas (e.g. drill pads, access tracks) to minimise the need for additional land disturbance and vegetation clearance. Vegetation clearing can result in loss of vegetation and fauna habitat, increased erosion, siltation of natural drainage lines and watercourses, destabilisation of creek crossings, weed invasion and damage to cultural heritage sites. Vegetation clearance may also impede the movement of fauna around the construction site. Care is taken when planning the location of a facility site to ensure that minimal vegetation is cleared.

A potential source of leaks and / or spills during construction is from chemical and fuel storage areas and refuelling depots associated with construction works. The primary consequence of any leak or spill is localised soil contamination.

Occurrence of flooding or fire during construction works has a number of potential consequences. For flooding these include significant soil erosion and loss of stockpiled soils in areas that have been subject to earthworks and possibly loss of vegetation. In the case of a fire, loss of vegetation and fauna habitat and production of particulate air emissions are possible consequences.

Facility construction generates some waste. Materials such as metal off-cuts or wooden pallets can generally be reused or recycled.

5.4.2 Facility Operation

There are a number of environmental hazards associated with the operation of oil or gas production facilities. They include production of atmospheric emissions (via fugitive, flare, combustion and venting sources), loss of containment of oil and storage of chemicals and fuels. These are outlined in Table 20.

Emissions of environmental significance (i.e. atmospheric pollutants and / or greenhouse gases) are:

- combustion by-products (e.g. oxides of nitrogen, carbon monoxide and sulphur dioxide)
- methane and organic carbon from fugitive sources
- vented gas
- flared hydrocarbons
- vented CO_2, H_2S, and CO.

Beach reports emissions in accordance with statutory requirements such as the National Pollutant Inventory (NPI) and National Greenhouse and Energy Reporting Act (NGER)[16].

Operation of compressors or generators can result in an increase in background noise levels, which may result in disturbance to wildlife, stock or third parties (e.g. if facilities are inappropriately located near pastoral residences or tourist campsites). The presence of personnel and site activities also has the potential to disturb stock or wildlife, particularly if sites are inappropriately located near yards or significant habitats.

There is the potential for accidental spills or leaks of small amounts of process chemicals (e.g. PFW emulsion breakers), cleaning chemicals or fuels during storage or handling and use. Accidental spills / release of oils may also occur as a result of pipe failure or leaks from equipment such as the inlet header, pipeline connection or plant valves. Other potential causes of spills or leaks include corrosion or material degradation (fatigue), mechanical damage, instrument / component failure or errors in design, construction and operation. There is also a potential for accidental overflow of oil storage tanks at production facilities and for spills to occur during tanker loading activities.

Leaks and spills can potentially lead to localised contamination of soil within the production site and may be a potential ignition source for fire. Leaks or spills also have the potential to reach shallow groundwater, if it is present. Unconfined shallow groundwater across much of the Cooper Basin has high salinity, which means that if a leak or spill reaches shallow groundwater, the risk of impacts to groundwater dependent ecosystems or groundwater users is reduced. Surface water impacts can also potentially occur as a result of leaks or spills and facilities are located, designed, constructed and operated to minimise this risk.

The risks associated with leak or spill hazards are minimised through appropriate storage and containment and implementation of storage and handling procedures. All chemicals and fuels (including oil storage tanks) are stored on impervious bunded surfaces. The design, construction and operation of facilities are carried out in accordance with relevant standards, with appropriate supervision and quality control in place and inspection, testing and maintenance procedures implemented.

Due to the nature of petroleum production operations there is also an inherent risk of explosion or fire. However this risk is reduced to As Low As Reasonably Practicable (ALARP) by compliance with relevant standards and implementation of various management measures to minimise the risk, as summarised in Table 20.

Standards of particular relevance to facility design, construction and operation include:

- AS 1940 – The storage and handling of flammable and combustible liquids
- AS 1200 – Pressure equipment
- AS 3788 – Pressure equipment – In-service inspection
- AS 2885 – Pipelines – gas and liquid petroleum
- AS 300 – Electrical installations
- AS 4041 – Pressure piping

[16] Current data is publicly available at the NPI and NGER websites (see http://www.npi.gov.au/npi-data/ and http://www.cleanenergyregulator.gov.au/NGER/). Beach also reports carbon emissions, energy use and NPI data in the annual report to shareholders (available at www.beachenergy.com.au).

- AS 60079 – Explosive atmospheres.

Process critical shutdowns / fail safes are generally hard wired and regularly function tested. Risk assessments are applied at design and during the life of the asset to identify threats and controls to mitigate risks. Asset integrity and maintenance is managed through a web-based technology to ensure compliance with regulations and scheduled maintenance and safety checks on control systems and monitoring are performed in a traceable manner.

Flooding of production facilities in floodplain areas can lead to contamination of soil and water, particularly if flood levels are high enough to overflow bunded areas. Flooding as a result of low to moderate flows of the Cooper Creek is not expected to affect most Beach facilities, which are located to avoid areas subject to frequent inundation. Flood flows that reach the lower Cooper Creek are estimated to occur once every 2 to 5 years or longer and such floods may affect facilities in or near floodplain environments (Inside Infrastructure, 2015). As these facilities are generally located on higher ground, flooding would generally result in alternative or limited access (both to the facility and within the field) and shutting-in of flood-affected wells rather than inundation of the facility (except perhaps in very large Cooper Creek floods). It is noted that the large 2010 flood, which has been estimated to occur every 20-40 years (Costelloe 2013), significantly restricted operations on the western flank, but did not result in loss of containment from facilities or bunded areas, or contamination of soil or water.

Camp accommodation and offices are located at some facilities and at stand-alone camps to house personnel working at the facilities and in surrounding areas. The primary hazards associated with these facilities are the storage and handling of domestic waste and sewage. These hazards are dealt with in Section 5.11.

The presence of facilities, camps and associated infrastructure can also adversely impact visual amenity, particularly in areas where there are significant numbers of tourists (e.g. parts of Innamincka Regional Reserve). Careful location of infrastructure (e.g. away from significant tourist sites) can significantly reduce this impact. In more isolated areas, such as the western flank of the Cooper Basin where there is little or no public access, visual impact is a less significant issue.

Table 20: Production facility risk assessment

Activity / Event	Potential Consequences	SEO Obj	Management Strategy	Consequence	Likelihood	Residual Risk
Earthworks associated with facility construction (e.g. clearing, grading)	Injury or death of fauna / stock in construction area Disturbance to natural drainage patterns Significant damage to third party infrastructure Soil erosion and siltation of watercourses Inversion of soil profile Dust generation Soil compaction of the easement Impeded fauna movement through construction area Damage to native vegetation Temporary loss of visual amenity Disruption to land use (e.g. grazing and recreation)	1, 2, 3, 5, 8, 10	Minimise environmental impact by appropriate site selection to avoid sensitive land systems, vegetation and cultural heritage sites Use existing disturbed areas where possible Liaise with landowners regarding notification and management of works and site issues including livestock management Observe procedures and guidelines for the identification, management and protection of cultural heritage sites, including obtaining heritage clearances by Native Title groups Minimise vegetation disturbance, and plan construction to avoid vegetated areas Avoid removal of gibber mantle as far as practicable in gibber and tableland systems to minimise soil disturbance associated with earthworks Undertake ongoing maintenance in gibber land systems to prevent wheel rutting and water channelling leading to erosion Design and manage construction activities to avoid impeding or altering surface water flows Stabilise and control areas where there is potential for or signs of soil erosion or siltation occurring	Moderate	Unlikely	Medium
	Disturbance to cultural heritage sites Introduction and / or spread of weeds	4 9	Implement dust control measures where required, using water efficient or waterless techniques where feasible Compliance with the Natural Resources Management Act (e.g. in relation to permits for water affecting activities) Avoid significant or priority[17] vegetation and ensure proposed site has been scouted for significant vegetation and wildlife habitats by appropriately trained and experienced personnel Where possible trim vegetation rather than clearing Undertake vehicle and equipment washdown before entering Cooper Basin or after operating in areas of known weed infestations Records of vehicle inspections and wash down are kept where relevant Minimise consequences to fauna by leaving excavated areas open for as little time as possible Locate, manage and rehabilitate borrow pits in accordance with SEO requirements. Use existing borrow pits are used in preference to new ones where appropriate. Utilise earthen fauna ramps to facilitate the movement of fauna out of excavations Regularly inspect excavations for trapped fauna Reinstate temporary construction areas (e.g. laydown) as soon as possible Restore borrow pits or reuse as evaporation or water storage ponds where appropriate Restore natural contours where feasible, to minimise consequences to natural drainage patterns Remove waste to minimise visual impact	Moderate	Unlikely	Medium

Activity / Event	Potential Consequences	SEO Obj	Management Strategy	Consequence	Likelihood	Residual Risk
Explosion or fire at the production facility	Danger to health and safety of personnel, contractors and possibly the public Contamination of soil, shallow groundwater and / or surface water Atmospheric pollution Burning of vegetation and habitat Injury to or loss of native fauna Disruption to land use (e.g. grazing) Access to contaminants by stock and wildlife	3, 6, 7, 8	All production facilities are designed, constructed, operated and maintained in accordance with relevant standards (e.g. AS 3000, AS 1940, AS 2885, AS 4041, ASME/ANSI B31.3, AS 1200, AS 3788, hazardous area compliance to AS 60079 series) Safety, testing, maintenance and inspection procedures implemented Risk assessments applied at design and during the asset life to identify threats and controls to mitigate risks Establishment of appropriate emergency / spill response procedures for explosion or fire Erection of signage and, where required, fencing to delineate restricted / hazardous areas Personnel trained to supervise and instruct individuals entering area to conduct work Appropriate fire fighting equipment at all production facilities Safe work permits must be obtained to ensure only individuals with proper clearance can conduct works Smoking only in designated areas located away from equipment or activity Petrol vehicles to be excluded from restricted areas Appropriate firebreaks are maintained Immediate clean-up and remediation of spills to minimise contamination to soil / water	Major	Unlikely	Medium
Flooding of surrounding floodplains / watercourses	Contamination of soil, shallow groundwater and / or surface water Damage to infrastructure (e.g. evaporation ponds) Access to contaminants by stock and wildlife Damage to surrounding vegetation by contaminated water	3, 6	Production facilities located to avoid areas subject to inundation as far as possible Production operations will cease in event of imminent flood inundation of facility. In floodplain land systems, following steps will be undertaken well in advance if there is a risk of facility flooding: • flood management plan activated • satellite imagery and upstream flood levels used to predict when floodwaters will reach facility (generally take 2-3 months to reach lower Cooper Creek) • construction of bunds around wells where appropriate, to increase protection • additional inspections conducted • storage tanks and flowlines drained, purged and filled with water to reduce buoyancy • interceptor pond (if present) skimmed to remove oil • fuel tanks drained, engines and all hydrocarbons (e.g. fuel and lubricants) removed off-site • office / accommodation units tied down Previous major Cooper Creek floods have inundated Cooper Basin oilfields. With management strategies in place no significant environmental consequences resulted Production facilities designed to avoid spread of hydrocarbons during inundation following localised rainfall (e.g. appropriately sized / elevated bunds)	Moderate	Unlikely	Medium
Spills or leaks associated with chemical and fuel storage and handling	Contamination of soil, shallow groundwater and / or surface water Access to contaminants by stock and wildlife Loss of beef production certification Loss of vegetation and fauna habitat	3, 6	See *Completions and Workovers* section in Table 18 for general controls related to spills or leaks	Minor	Unlikely	Low
Tanker Load-out	Contamination of soil, shallow groundwater and / or surface water Access to contaminants by stock and wildlife	3, 6	Tanker load-out in lined area, with appropriate bunding to contain spills Construction and operation of filling systems, storage tanks and the tankers in accordance with AS 1940 Spill kit/s located at the load-out Hoses with dry-break couplings Personnel attendance at all times during tanker filling Also refer to controls for spills or leaks in the *Completions and Workovers* section in Table 18	Minor	Highly Unlikely	Low

Activity / Event	Potential Consequences	SEO Obj	Management Strategy	Consequence	Likelihood	Residual Risk
Fugitive emissions of methane and organic carbon Venting of CO_2, H_2S, and CO Venting of gas	Release of greenhouse gases Localised reduction in air quality	8	All facilities designed, constructed, operated and maintained in accordance with relevant standards (see *Explosion or fire at facility* above) Safety, testing, maintenance and inspection procedures implemented Risk assessments applied at design and during the asset life to identify threats and controls to mitigate risks Continual review and improvement of operations Facilities are routinely inspected for signs of leaks and / or loss of containment Venting activities are managed and minimised with preference to flare rather than vent where feasible Consideration of weather conditions (e.g. wind direction) prior to commencing venting activities Reporting of emissions in accordance with statutory requirements (e.g. NPI and NGER requirements) See also Explosion or fire at the production facility in this table (above)	Minor	Unlikely	Low
Flaring or combustion of hydrocarbons	Release of greenhouse gases Atmospheric pollution	8	Facilities designed, constructed, operated and maintained in accordance with relevant standards Continual review and improvement of operations Selection of equipment to minimise emissions Maintenance of plant and equipment in accordance with manufacturer's specifications Flaring activities are actively managed and minimised Appropriate firebreaks are maintained Reporting of emissions in accordance with statutory requirements (e.g. NPI and NGER requirements)	Minor	Unlikely	Low
Loss of containment of oil outside area designed to contain spills (pipe rupture, reliefs, fittings or leaks from plant and other sources)	Danger to health and safety of personnel, contractors and possibly the public Contamination of soil, shallow groundwater and / or surface water Access to contaminants by stock and wildlife Loss of vegetation and fauna habitat	3, 6, 7	All facilities designed, constructed, operated and maintained in accordance with relevant standards (see *Explosion or fire at facility* in this table (above)) Safety, testing, maintenance and inspection procedures implemented Risk assessments applied at design and during the asset life to identify threats and controls to mitigate risks Strategies to mitigate threats including high use of corrosion resistant materials, design approach and maintenance systems Construction and operation of filling systems, storage tanks and the tankers in accordance with AS 1940 Use of steel piping and fittings where possible Appropriate areas (e.g. storage tanks) bunded and lined to contain spills in accordance with relevant standards and guidelines including AS 1940, EPA guideline 080/16 Bunding and Spill Management Process critical shutdowns / fail safes generally hard wired and regularly function tested Level control / overfill protection on tanks See *Completions and Workovers* section in Table 18 for general controls related to spills or leaks	Moderate	Possible	Medium
Presence of personnel, site activities and noise emissions	Disturbance to landowners and other third parties Disturbance to stock and wildlife Visual impact	1, 3	Appropriate site selection to avoid site establishment where significant disturbance to wildlife, pastoral residences or tourist sites are likely Liaise with landowners regarding notification and management of works and site issues including livestock management Maintenance of plant and equipment in accordance with manufacturer's specifications Maintain a high standard of 'housekeeping' to minimise visual impact Reasonable practical measures implemented to comply with the requirements of the EPA Environment Protection (Noise) Policy	Minor	Unlikely	Low
Access and activity of personnel outside designated facility area / work areas	Damage to vegetation and habitats	3	Training and induction of all personnel and visitors includes information on restricted areas and activities Vehicle access restricted to designated roads and areas Erection of fencing and signage to delineate restricted areas	Minor	Unlikely	Low
	Damage to cultural heritage sites	9		Moderate	Unlikely	Medium

5.5 Produced Formation Water

One of the most significant hazards associated with the operation of petroleum production facilities is the storage and treatment of large volumes of produced formation water (PFW). PFW can be fresh, brackish or saline and can contain chemicals (both natural and added), residual hydrocarbons and some naturally occurring heavy metals.

Potential contamination of soil and groundwater may result from leaks in separation tanks, interceptor ponds and bunded evaporation ponds. Sub-surface movement of PFW can also lead to upwelling of PFW outside of unlined evaporation ponds. However the likelihood of significant consequences from loss of containment of storage of PFW is considered rare with appropriate control measures and management strategies in place.

The potential environmental consequences associated with PFW disposal include:

- contamination of soil and near surface aquifers by any carried-over hydrocarbon or process chemicals (e.g. emulsion breakers or biocides used to prevent corrosion resulting from sulphur reducing bacteria) or naturally occurring metals
- contamination of soil and associated vegetation with salts and metals naturally occurring, but concentrated in the PFW
- increased soil salinity
- ingestion of contaminants by native fauna or stock.

There is also potential for birds and other wildlife to come into contact with high temperature water, residual hydrocarbons and other contaminants (such as heavy metals) in interceptor ponds. Oiled birds may suffer from restricted movement and distress and often do not survive the effects of ingesting oil and other hydrocarbons.

Access to water in free form evaporation areas by stock can result in increased and ongoing grazing pressure in areas where grazing pressure would otherwise be very low or intermittent. This can lead to changes in vegetation cover, structure and composition, loss of habitat quality, soil disturbance and increased erosion and can directly impact rehabilitation / revegetation efforts. The Native Vegetation Act and Pastoral Land Management and Conservation Act place some restrictions on pastoral landholders regarding artificial waterpoints.

Flooding of PFW ponds can potentially result in impacts to surface water quality. Interceptor ponds and holding ponds are generally located with other facility infrastructure, away from areas subject to inundation and are unlikely to be flooded (see Section 5.4.2). If free form disposal areas are inundated by a large Cooper Creek flood, the large volumes of floodwater involved would cause significant dilution. PFW in free form areas is generally of suitable quality for consumption by stock, and with further dilution, significant impacts to water quality are unlikely.

Co-production of water from oil reservoirs also contributes to the net extraction of water from the Eromanga Basin (which is part of the Great Artesian Basin). Sustainable extraction volumes are set under the Water Allocation Plan (WAP) for the Far North Prescribed Wells Area (SAALLB 2021b), which allocates 21,900 ML/year (60 ML/day) for taking produced formation water. As noted in Section 3.4, this allocation is managed by DEM on behalf of the Minister for Mineral Resources and Energy, and Beach reports PFW extraction volumes to DEM monthly. The WAP (and the Minister's water licence) also place controls on activities that could impact on GAB springs. If an increase in water allocation is required, Beach will need to apply to the Minister and continue to follow the WAP.

In 2021 Beach developed a groundwater monitoring and management strategy for the Eromanga Basin to set drawdown trigger levels and quantify groundwater pressures and any changes in groundwater quality as a result of co-produced water extraction. Monitoring and a review of the plan is conducted annually to assess for potential changes that could influence the monitoring program design such as production forecast, monitoring data and newly available monitoring wells.

The closest GAB springs (which are in the vicinity of Lake Blanche) are over 50 km from the closest Beach PEL and over 100 km from the closest production well (Aldinga-1). The 2021-22 groundwater monitoring report found that current activities are not impacting groundwater pressure or salinity and are not likely to impact GAB springs. Any future production in proximity to GAB springs would be undertaken in compliance with the WAP and the water licence, and appropriate approvals sought where required.

Table 21: PFW storage and disposal risk assessment

Activity / Event	Potential Consequences	SEO Obj	Management Strategy	Consequence	Likelihood	Residual Risk
Storage and disposal of PFW at production facilities	Contamination of soil, shallow groundwater and / or surface water Access to contaminants by stock and wildlife Salinisation of operational areas Death of adjacent vegetation Injury to or death of wildlife	3, 6	Site ponds appropriately[18] to minimise potential consequences Construct ponds using appropriate materials and suitable design criteria including adequate freeboard, depths, lining, bunding etc Site and construct ponds with regard to EPA Guideline *509/19 Wastewater lagoon construction* Ensure that newly built interceptor ponds are appropriately lined with an impermeable liner (e.g. HDPE) Ensure that lining of subsequent ponds is commensurate with level of environmental risk. Standard Beach practice is to line all new interceptor and holding ponds Surface of interceptor ponds to be regularly skimmed Ensure that tanks are well maintained and regularly emptied Ensure adequate freeboard is maintained on ponds Monitor ponds for surrounding upwelling of PFW Install monitoring bores at all new facilities and other locations where relevant (e.g. where shallow groundwater exists in vicinity of PFW ponds) and conduct regular water quality monitoring Monitor and audit evaporation pond water annually to ensure that relevant oil in water criteria are met Periodic review of PFW and implementation of audit recommendations Minimise use of process chemicals (e.g. biocides, emulsion breakers) and use biodegradable or UV degradable chemicals where available Interceptor holding ponds are contained within the fenced facility area to prevent wildlife and stock access Maintain a register of spills and / or leaks and remediate Breaker siphon installed between interceptor pond and evaporation ponds Record fauna entrapment or deaths if they occur and implement appropriate preventative measures if required Investigate alternatives to surface disposal of PFW (e.g. reinjection) Infiltration basins Install monitoring bores to monitor infiltration ponds for groundwater movement, upwelling of PFW and changes to groundwater quality Implement four stage treatment of PFW to level suitable (<10mg/L TPH) for disposal by infiltration without potential for impacts to surface water or groundwater Undertake visual inspection of watercourses near infiltration ponds to identify any surface breakout of disposed infiltration water	Moderate	Possible	Medium
Secondary use of PFW	Contamination of soil and / or groundwater Access to contaminants by stock and wildlife Salinisation of operational areas Death of adjacent vegetation	3, 6	Quality of water analysed prior to secondary use to confirm that it is consistent with relevant guidelines (e.g. ANZECC (2000) / ANZG (2018) or EPA guidelines) for the intended site / use Visual monitoring undertaken at secondary use sites as appropriate (e.g. salinity, vegetation health, contamination) Relevant approvals obtained where required (e.g. DEM, landholder) Liaison with landholder regarding grazing management near PFW facilities Secondary use for road watering or dust suppression avoided in areas where contaminants may enter surface waters	Moderate	Highly Unlikely	Low
	Increased grazing pressure leading to degradation of soils, vegetation and habitat			Serious	Possible	Medium
Flooding of surrounding floodplain / watercourses	Refer to Production Facility Risk Assessment (Table 20)	3, 6				
Production / extraction of water from the GAB	Depletion of GAB water supplies Impact on GAB springs (if co-produced water extracted in close proximity)	5	Reuse PFW where possible to minimise use of other water sources Water extraction in accordance with licences and allocations Monitor well production and minimise water content where possible (when water is co-produced with oil and gas) Co-produced water volumes reported to DEM and total volumes produced are within the industry allocation specified in the Water Allocation Plan Compliance with the Water Allocation Plan and water licence conditions (e.g. regarding Zone B, GAB springs and state border) Investigate reinjection of PFW to reduce net water extraction from the GAB	Moderate	Highly Unlikely	Low

[18] Appropriately manage means to take into consideration and assess relevant environmental factors (including location of surface water, potential flooding, location of vegetation, etc.) and take measures to reduce the potential impact on these factors through the use of best practice.

5.6 Waterflood / Reinjection

The major hazards associated with water injection schemes include packer failure or loss of well integrity, injection of non-compatible waters into the aquifer and the potential for spills of saline waters and / or any chemical product that may be used for treating the water prior to injection.

Packer failures are unlikely and injection wells are routinely tested for leaks of the packer or tubulars. If the packer fails there may be little or no hazard to third parties or to the reservoir (e.g. if there are no perforations above the packer). Other downhole issues such as well casing and cementing failure are unlikely as injection pressures will be well below the pressure rating of the casing.

Quality and compatibility testing would be conducted on the injection water to ensure that there is no contamination of the aquifer / reservoir being injected into. The injection water would generally have scale inhibitor and a biocide added to condition the water. The amount added is minute in comparison to the volume of water in the reservoir with which it will be in contact. Water quality testing would be conducted with on-line monitoring to ensure consistency of injection water quality.

Reinjection activities are only undertaken in reservoirs with good containment (i.e. overlying and / or underlying aquitards). This ensures that the injection water will stay within the target formation.

Tracers (if used) are injected into the water injection well under controlled procedures by licensed contractors using a sealed system. The tracers that are typically used (e.g. tritium and iodine) are specifically used due to their safety and low cost. These types of tracers are indicated to have a negligible external radiological effect and are generally not considered to be harmful to people or animals.

The injection water would likely be transferred through new installed polyethylene, steel or composite lines that are rated and tested to meet project requirements. Water injection skids would have high-low shutdowns and be monitored by telemetry. A spill of produced formation water intended for injection would be expected to pose a relatively low hazard.

Waterflood / reinjection programs would be subject to detailed assessment and would require approval from DEM (and possibly EPA and / or DEW depending on injection parameters) before commencement.

Table 22: Waterflood / reinjection risk assessment

Activity / Event	Potential Consequences	SEO Obj	Management Strategy	Consequence	Likelihood	Residual Risk
Packer failure or loss of well integrity during injection	Contamination of aquifers	6	Well contents (i.e. injected water) isolated from shallower aquifers by tubing and casing in well Regular pressure measurements undertaken to ensure well integrity is maintained (e.g. to ensure no communication between the tubing and casing) Cement bond logs run to test for poor cement bonds Integrity of the wellbore and packer are routinely tested	Moderate	Unlikely	Medium
Injection of contaminated water into the target or other aquifer zones	Aquifer or reservoir contamination	6	Frequent quality testing of injection waters Compatibility studies conducted prior to injection Filtering of water to promote efficient injection into formation On-line water quality monitoring	Minor	Unlikely	Low
Spill or leak associated with transportation of waters from the production facility to the water injection well	Localised acidification and / or salinisation of soil	6	Equipment designed and operated in accordance with relevant standards and guidelines Water injection skid equipped with shutdowns and injection monitoring New steel, polypropylene or composite piping tested and maintained to design conditions Pipeline monitored for leaks (pressure gauges and visual inspection) Produced water may be treated in a hydro-cyclone to reduce oil in water content where required Maintain register of spills / leaks Immediate clean-up and remediation if any spills or leaks occur	Minor	Unlikely	Low
Spill of radioactive waterflood tracer	Localised contamination of soil Danger to health and safety of personnel and contractors	6, 7	Radiological Safety procedures conducted by specialists hired to conduct work State controls on radiotracer substances followed Conduct of regular inspections, and regular maintenance, follow specific operating procedures for working with tracers. Ensure individuals in areas of responsibility are trained to handle events In the event of a spill or leak follow appropriate emergency response procedures	Minor	Unlikely	Low

5.7 Pipelines / Flowlines

5.7.1 Pipeline Construction

Environmental hazards associated with pipeline construction include movement of heavy vehicles, earthworks, vegetation clearance, fire, spills associated with chemical and fuel storage and waste disposal. Flooding (of the Cooper Creek or Strzelecki Creek floodplain and associated watercourses) may also need to be considered to be as a potential environmental hazard if pipeline construction is required in the vicinity of these areas.

Movement of heavy vehicles (e.g. trucks and side boom tractors) along the construction easement and access tracks is an environmental hazard as there is a possibility that vehicles may inadvertently damage vegetation or existing infrastructure, generate dust and / or compact soil if not appropriately managed. Earthworks can result in similar consequences as well as potentially disturbing sites of cultural significance and exposing soils to wind and water erosion.

The type and severity of potential consequences of earthworks is dependent, to a certain extent, on the land system in which the activities are being carried out. Disturbance of soils in some land systems, such as gibber plains and tablelands, can lead to substantial erosion by water while other systems, such as dunefields, are generally more resilient and less likely to suffer any long-term impacts from soil disturbance. Studies of seismic lines in dunefields in the Cooper Basin have indicated that natural rates of erosion on dunes were not accelerated as a result of disturbance to the soil surface (SEA 1999).

Wetlands are avoided under most circumstances when planning pipeline routes as they are often of high ecological value and sensitivity. Salt lakes are also avoided as rehabilitation is difficult to undertake and they are therefore likely to be severely scarred by pipeline construction activities. The potential consequences of specific earthwork activities on different land systems in the Cooper Basin are summarised in Table 23. Other activities along the construction easement, such as vegetation clearing, can result in loss of vegetation and fauna habitat, siltation of natural drainage lines and watercourses, destabilisation of creek crossings, weed invasion and damage to cultural heritage sites. Vegetation clearance may also impede the movement of fauna within the construction zone. Particular care is taken to ensure that minimal vegetation is cleared in Coolibah woodland during easement preparation. The easement is generally minimised (to approximately 10 m for smaller diameter flowlines) in any heavily wooded areas. Watercourse crossings are typically undertaken in dry conditions and promptly reinstated to minimise the potential for sedimentation of surface water or interruption to water flows.

Gibber areas are a naturally erosional landscape (not a depositional landscape as found in flood plain and dune field systems) therefore gibber landforms present a risk of potential major erosion impacts where the gibber (dense stone) pavement is disturbed or removed and underlying erosional soils are exposed to wind and water. No natural stabilisation occurs following the removal of the protective gibber pavement, which can result in severe and long-term erosion, particularly where surface water flows cause accelerated erosion. Even in gently sloping areas (>2%), gully erosion can continue to erode to the underlying weathered rock layer and to enlarge laterally. The following methods are considered to minimise disturbance and control erosion risk in gibber landscapes:

- roll gibber where surface is naturally smooth, stable and trafficable
- remove gibber mantle to windrows, grade underlying surface smooth, replace gibber mantle, water and roll
- leave existing natural surface, over-cap large rocks and wearing areas with borrow material that contains clay and stone
- construct erosion control berms, banks and drains where required

- undertake ongoing maintenance to prevent wheel rutting and water channelling.

The presence of an open trench during construction of buried pipelines has the potential to result in fauna entrapment and mortality. The length of time the trench is open is minimised as far as practicable, but for some pipeline installations (e.g. GRE pipe) there may be a need to keep the trench open for long periods (several weeks or more) to allow for identification and repair of any leaks that are detected during hydrostatic testing. Measures such as installation of trench plugs or escape ramps are implemented, and the trench is regularly inspected (by appropriately trained project personnel or fauna monitors where appropriate) to detect and release any trapped fauna.

A potential source of leaks and / or spills during construction is from chemical and fuel storage areas and refuelling depots associated with construction works. The primary consequence of any leak or spill is localised contamination of soil. Discharge of hydrostatic test water to ground surface is another potential source of localised soil and groundwater contamination.

The use of biocides and chemicals in hydrostatic test water is required under some circumstances to prevent internal corrosion of the pipeline. Disposal of hydrostatic test water which contains biocide or other chemicals may be into existing lined evaporation ponds (i.e. produced formation water facilities) or to specifically constructed pits sited to prevent contamination of surface or near surface waters. Test water that is free of additives may be disposed of to land adjacent to the construction zone, away from surface water or any areas where it is likely to enter waters (including groundwater).

Occurrence of flooding or fire during construction works has a number of potential consequences. For flooding these include significant soil erosion in areas that have been subject to earthworks and possibly loss of vegetation. In the case of a fire, loss of vegetation and fauna habitat and production of particulate air emissions are possible consequences.

Pipeline construction generates very little waste. Many materials such as pipe off cuts, rope spacers and timber skids can generally be reused or recycled. Excess soil / fill from pipeline trenching will be respread over pipeline and along the ROW. All remaining waste materials are removed from the work area and disposed of at an appropriately licensed waste facility.

As discussed in Section 3.6, pipeline design and construction is undertaken in accordance with relevant standards, in particular AS 2885.

Table 23: Potential consequences associated with earthworks in various Cooper Basin landforms

Landform	**Activity / Event**			
	Grading	**Trenching and backfilling**	**Excavation / digging (e.g. borrow pits)**	**Soil stockpiling**
Dunefields	Soil erosion (wind and water erosion) Disturbance to cultural heritage sites (dunefields near waterholes are typically of high cultural significance)	Soil erosion (wind and water erosion) Disturbance to cultural heritage sites (dunefields near waterholes are typically of high cultural significance) Inversion of the soil profile Impeded fauna movement	Soil erosion (wind and water erosion) Disturbance to cultural heritage sites (dunefields near waterholes are typically of high cultural significance) Inversion of the soil profile	Soil erosion (wind erosion) Inversion of the soil profile

Landform	Activity / Event			
	Grading	**Trenching and backfilling**	**Excavation / digging (e.g. borrow pits)**	**Soil stockpiling**
Floodplains and wetlands **(Note: Wetlands are generally avoided)**	Soil erosion (wind and water) Soil compaction Disturbance of natural drainage systems (construction easement typically restricted to less than 10 m at creek crossings on small diameter pipelines) Disturbance to cultural heritage sites (generally low density of sites in floodplains)	Disturbance of natural drainage systems (construction easement typically restricted to less than 10 m at creek crossings on smaller diameter pipelines) Inversion of the soil profile Disturbance to cultural heritage sites (generally low density of sites in floodplains) Impeded fauna movement	Soil erosion (wind and water) Disturbance of natural drainage systems Disturbance to cultural heritage sites (generally low density of sites in floodplains)	Disturbance of natural drainage systems (e.g. siltation) Soil erosion (wind and water)
Gibber plains	N/A	Soil erosion (particularly susceptible to water erosion e.g. severe gullying) Disturbance of natural drainage systems (e.g. siltation) Inversion of the soil profile Disturbance to cultural heritage sites Impeded fauna movement	Soil erosion (particularly susceptible to water erosion e.g. severe gullying) Disturbance of natural drainage systems (e.g. siltation) Inversion of the soil profile Disturbance to cultural heritage sites	Soil erosion (wind and water) Disturbance of natural drainage systems Inversion of the soil profile
Salt lakes	N/A	N/A	N/A	N/A
Tablelands	N/A	Soil erosion (particularly susceptible to water erosion e.g. severe gullying) Soil compaction Disturbance of natural drainage systems (e.g. siltation) Inversion of the soil profile Disturbance to cultural heritage sites Impeded fauna movement	N/A	Soil erosion (wind and water) Disturbance of natural drainage systems Inversion of the soil profile

N/A – not applicable as the activity is not carried out in this land system.

5.7.2 Pipeline Operation

The primary hazard associated with the pipeline operation is the loss of containment of oil or natural gas. Accidental spills and leaks may result from pipeline failure, which may be caused by:

- heavy vehicle traffic (e.g. collision with an above ground pipeline)
- corrosion of steel pipelines (external or internal)
- natural events which stress the pipeline (e.g. flood / earthquake)
- overpressure
- external interference
- pipeline material defects or construction faults.

As discussed in Section 3.6, pipeline operation is approached in a systematic manner over the life of the assets and is carried out in accordance with relevant standards, in particular AS 2885, the PIMP and PMS. The Safety Management Study process under AS 2885.1 is used to identify threats to the pipeline and identify controls to reduce the risk of a pipeline failure to As Low as Reasonably Practicable, and is regularly reviewed in accordance with AS 2885 requirements.

Regular inspection of pipelines and monitoring of the performance of cathodic protection devices on buried steel pipelines is undertaken, to ensure that protection levels are adequate. Cathodic protection systems are compliant to AS 2832.1.

Corrosion protection on composite pipelines is typically only required for any metal connectors or components, but may also be required for buried end connectors when connecting to an external non-metallic piping system. In addition, connectors are coated to reduce the likelihood of external corrosion. Composite pipelines may also have a HDPE inner layer which provides corrosion resistance that is suitable for the normal chemical and temperature ranges encountered in oil and gas applications. Regular inspection of the corrosion protection devices is undertaken to ensure adequate protection.

Composite pipe is a stress / time dependent material and degradation can occur over time. Testing of material coupons is used to provide data on changes in material properties which may affect remaining life. Degradation of composite pipe can also occur with long term exposure to UV. External protection is provided in areas of exposure to UV and regularly inspected.

Major pipelines in the Cooper Basin are also regularly pigged to remove water and sludge that accumulates at low points within pipelines. Sludge often supports sulphide reducing bacteria that are a significant cause of internal corrosion of pipelines in the Cooper Basin and testing is routinely carried out to detect potential for sulphide reducing bacteria.

Above ground pipelines are regularly inspected to ensure that contact between soil and steel pipe and fittings is minimised. Where contact occurs (e.g. as a result of failure of pipe supports) ‘long line corrosion cells’ can potentially form and result in rapid pitting of the pipe and possible pipeline rupture.

Damage to pipelines as a result of external interference by Beach or third parties has the potential to result in a leak or rupture. The likelihood of such damage occurring is relatively low due to the remoteness of the Cooper Basin, the nature of the pastoral activities that occur and the processes in place (communication, Notice of Entry) to manage petroleum industry activities. Marker signage is installed for all pipelines, and external interference protection measures, including physical and procedural controls (such as increased depth of burial and increased use of marker signs) are used to mitigate threats identified in the AS 2885 Safety Management Study.

A gas or oil leak from a flowline may result in the release of gas to the atmosphere or contamination of soil or groundwater respectively. The potential exists for oil and condensate to be spilt at any point between an oil well and production facility. Many of the consequences associated with oil spills and leaks, such as vegetation loss, soil disturbance and drainage alteration can be minimised if spills or leaks do occur. However, this largely depends on the land system involved.

In dry environments, such as dunefields and gibber, the consequences associated with an oil spill or leak are mainly localised, as oil is easier to contain and recover in dry conditions. Where shallow groundwater is present in these environments it is often saline, which means that if a spill reaches shallow groundwater, the risk of impacts to groundwater dependent ecosystems or groundwater users is reduced. However, the environmental consequences of oil spills in more sensitive wet environments, like the Cooper and Strzelecki Creeks and surrounding floodplains and wetlands, are potentially significant. Of primary concern are flood conditions that can potentially spread oil over large distances and throughout highly sensitive ecosystems. Additional pipeline protection measures are implemented in these areas in accordance with AS 2885 (e.g. increased wall thickness, increased depth of burial, monitoring and leak detection systems). Emergency response plans will be in place and will deal with the response to a spill or leak to surface water.

Fire and explosion are also possible hazards associated with pipeline operation. A fire or explosion along a pipeline can pose a danger to personnel, contractors and possibly the public and can potentially produce significant amounts of atmospheric emissions. The risk is reduced to ALARP by management measures. The potential for explosion or fire associated with oil pipelines is considered low due to the low volatility and flammability of oil and therefore the potential severity of the consequence minor. The potential for explosion or fire associated with gas pipelines are considered low as all gas pipelines are designed, installed and operated in compliance with AS 2885 (i.e. with appropriate design features and management measures including wall thickness, depth of burial, pipeline marker signs, cathodic protection, shutdown valves and monitoring, testing, maintenance and inspection procedures).

Table 24: Pipeline construction risk assessment

Activity / Event	Potential Consequences	SEO Obj	Management Strategy	Consequence	Likelihood	Residual Risk
Earthworks (e.g. clearing of construction easement, grading, trenching and backfilling)	Injury or death of fauna / stock in construction zone Long term disturbance to natural drainage patterns Significant damage to infrastructure Soil erosion and siltation of watercourses Diversion or blockage of overland flow or gibber creek channels Inversion of soil profile Dust generation Soil compaction of the easement Temporary disruption to land use (e.g. grazing and recreation) Impeded fauna movement through construction zone Damage to native vegetation Temporary loss of visual amenity Disruption to land use (e.g. grazing and recreation)	1, 2, 3, 5, 8, 10	Minimise environmental impact by appropriate route selection to minimise or avoid sensitive land systems, vegetation and cultural heritage sites Use existing easements where possible Liaise with landowners regarding notification and management of works and site issues including livestock management Stockpile topsoil separately from trench spoil (subsoil) for use in reinstatement Design and manage construction activities to avoid impeding or altering of surface water flows Undertake watercourse crossings in dry conditions where possible and complete within the shortest period practicable If crossing flowing watercourses, locate stockpiles (e.g. excavated bank material) and HDD sites (if HDD used) in bunded areas away from watercourse banks Implement erosion and sediment control measures where required Implement dust control measures where required, using water efficient or waterless techniques where feasible Observe procedures and guidelines for the identification, management and protection of cultural heritage sites, including obtaining heritage clearances by Native Title groups Minimise vegetation disturbance, and plan construction to avoid vegetated areas Avoid significant or priority[19] vegetation and ensure proposed routes have been scouted for significant vegetation and wildlife habitats by appropriately trained and experienced personnel Where possible trim vegetation rather than clearing Undertake vehicle and equipment washdown before entering Cooper Basin or after operating in areas of known weed infestations Minimise hazard to fauna by leaving trenched areas open for as little time as possible Utilise trench plugs and fauna ladders to facilitate movement of fauna out of and across trench Regularly inspect open trenches and excavations to detect and release trapped fauna Backfill trenches or excavations using excavated subsoil (i.e. leave topsoil stockpiles undisturbed for reinstatement) Reinstate construction areas including construction easement as soon as possible Rip areas of compacted soil (except on gibber plains and tableland environments) Respread topsoil Manage and rehabilitate borrow pits in accordance with SEO requirements Restore natural contours to minimise consequences to natural drainage patterns Stockpile cleared vegetation and respread following construction to facilitate revegetation Remove waste to minimise visual impact	Minor	Unlikely	Low
	Disturbance to cultural heritage sites Introduction and / or spread of weeds	4, 9		Moderate	Unlikely	Medium
Movement of heavy machinery and vehicles along construction easement and access tracks	Dust generation Soil compaction Soil erosion Damage to native vegetation Injury or death of native fauna Disturbance to cultural heritage sites Introduction and / or spread of weeds Damage to infrastructure Disruption to land use (e.g. grazing and recreation) Increased public access to remote areas	1, 2, 3, 4, 8, 9	Use existing cleared areas for laydowns and turn-arounds Liaise with landowners regarding notification and management of works and site issues including livestock management Implement dust control measures where required, using water efficient or waterless techniques where feasible Undertake vehicle and equipment washdown before entering Cooper Basin or after operating in areas of known weed infestations Drive only on access tracks and construction easement Rip areas of compacted soil (not on gibber plains and tablelands)	Minor	Unlikely	Low

[19]Refer to Appendix 4: Beach Energy Priority Plant List.

Activity / Event	Potential Consequences	SEO Obj	Management Strategy	Consequence	Likelihood	Residual Risk
Spills or leaks associated with chemical and fuel storage and handling	Contamination of soil, shallow groundwater and / or surface water Access to contaminants by stock and wildlife Loss of beef production certification Loss of vegetation and fauna habitat	3, 6	See *Completions and Workovers* section in Table 18 for general controls related to spills or leaks	Minor	Unlikely	Low
Ignition of fire along construction easement	Disturbance to cultural heritage sites Loss of vegetation and fauna habitat Release of particulate emissions to the atmosphere Disruption to land use (e.g. grazing and recreation)	3, 7, 8, 9	Smoking only permitted in designated safe areas away from equipment or activity Personnel are trained to supervise and instruct individuals entering area to conduct work Safe work permits must be obtained to ensure only individuals with proper clearance can conduct works Appropriate fire fighting equipment on-site Petrol vehicles to be excluded from construction sites Emergency response procedures should contain bushfire scenario Safety, testing, maintenance and inspection procedures are implemented Immediate clean-up and remediation to minimise contamination to soil / water Maintenance of firebreaks surrounding key infrastructure	Moderate	Remote	Low
Disposal of hydrotest water	Contamination of soil, shallow groundwater and / or surface water Access to contaminants by stock and wildlife Loss of or damage to vegetation and fauna habitat as a result of soil or water contamination Soil erosion / scouring	2, 3, 6	Use of biocides and toxic chemicals are kept to a minimum and if biocides are necessary UV-degradable or biodegradable biocides (e.g. THPS) shall be used where practicable Disposal of hydrostatic test water which contains biocide and other chemicals may be into existing lined and fenced ponds, or to specifically constructed pits sited to prevent the contamination or surface or near surface waters Assessment of hydrotest water prior to disposal to land to ensure that its quality is consistent with relevant guidelines (e.g. ANZECC (2000) / ANZG (2018) and EPA) for the disposal site. Discharged water not allowed to flow beyond the intended receiving area or into any watercourses or areas where it may enter surface water Use of aerators / spray bars, geotextile etc. to prevent soil erosion at discharge point where uncontaminated hydrotest water is released to land	Minor	Unlikely	Low

Table 25: Pipeline operation risk assessment

Activity / Event	Potential Consequences	SEO Obj	Management Strategy	Consequence	Likelihood	Residual Risk
Explosion or fire along a pipeline	Contamination of soil, shallow groundwater and / or surface water Atmospheric pollution Loss of vegetation and fauna habitat Disruption to land use (e.g. grazing) Danger to health and safety of personnel, contractors and possibly the public	3, 6, 7, 8	All pipelines are designed, constructed, operated and maintained in accordance with relevant standards[20] including installation of appropriate warning signage and appropriate external interference protection measures Composite pipelines are buried with increased depth of cover however transitions will be located above ground and protected by steel bollards Separation distances and exclusion zones are maintained Pipeline proximity fire breaks are cleared and maintained Safety, testing, maintenance and inspection procedures are implemented Establishment of appropriate emergency / spill response procedures for explosion or fire Personnel are trained to supervise and instruct individuals entering area to conduct work Safe smoking areas away from equipment or activity	Major	Remote	Medium
Spill or leak associated with pipeline failure to land	Contamination of soil, shallow groundwater and / or surface water Damage to vegetation and habitat Disruption to land use (e.g. grazing) Access to contaminants by stock and wildlife	3, 6	All pipelines are designed, constructed, operated and maintained in accordance with relevant standards[20] including installation of appropriate warning signage and appropriate external interference protection measures Safety, testing, maintenance and inspection procedures are implemented Export lines and high pressure flowlines associated with jet pumps have pressure monitoring / shutdown in case of leak Establishment of appropriate emergency / spill response procedures for spills or leaks to soil and water Spill response equipment maintained on-site Immediate clean-up and remediation of spills to minimise contamination to soil / water Fencing of contaminated areas if threat is posed to stock or wildlife Maintain a register of spills and / or leaks and implement corrective actions based on analysis of spill events Periodic review and exercise of response equipment and procedures to ensure preparedness	Moderate	Unlikely	Medium
Spill associated with pipeline failure in a watercourse	Contamination of groundwater, surface water and soil at spill site and potentially downstream Damage to vegetation and habitat at spill site and potentially downstream Access to contaminants by stock and wildlife Injury or death of native fauna Danger to health and safety of personnel, contractors and possibly the public	3, 6, 7	All pipelines are designed, constructed, operated and maintained in accordance with relevant standards[20] Flowlines in floodplain areas designed to maintain integrity during inundation Management strategies implemented for spills associated with pipeline failure including: • monitoring of process parameters on SCADA • surveillance patrols • leak detection with remote shutdown on major pipelines and control systems to automate shutdown and isolation Additional protection provided for pipelines traversing floodplains and ephemeral creeks including avoidance of connections, increased burial depth, casing and weighting to overcome buoyancy where appropriate Safety, testing, maintenance and inspection procedures are implemented Establishment of appropriate emergency / spill response procedures for spills or leaks to soil and water Spill response equipment maintained on-site Installation of marker posts near major water courses (e.g. main Cooper Creek Channel) to gauge any pipe movement during times of flooding Immediate clean-up and remediation of spills to minimise contamination to soil / water Fencing of contaminated areas if threat is posed to stock or wildlife Maintain a register of spills and / or leaks and implement corrective actions based on analysis of spill events Periodic review and exercise of response equipment and procedures to ensure preparedness	Major	Unlikely	Medium

[20] Relevant standards include AS 2885, AS 2832.1 and associated documentation/processes including Safety Management Study, Pipeline Integrity Management Plan, Pipeline Management System and Remaining Life Review

5.8 Road Construction and Maintenance

The major hazards associated with road construction are earthworks, vegetation clearance, chemical and fuel storage and waste disposal. Earthworks and vegetation clearance can potentially result in soil erosion, interruption of natural drainage patterns, disturbance to cultural heritage sites, introduction and spread of weeds and loss of vegetation. Waste disposal and chemical and fuel storage associated with road construction activities and mobile earthworks camps can lead to localised soil or water contamination. As indicated in Section 5.7 the type and severity of potential consequences of earthworks is dependent, to a certain extent, on the land system in which the activities are being carried out.

Hazards associated with road maintenance and operation include earthworks (i.e. grading), road watering and introduction of construction material (e.g. fill). Earthworks, including the construction of borrow pits, can potentially disturb natural drainage patterns, introduce or spread weeds, lead to soil erosion and result in the alteration of drainage lines or lead to the capture of water which in turn may attract animals and lead to an alteration in grazing patterns. A recent review of borrow pits in the Cooper Basin (Jacobs SKM 2014) highlighted water retention in borrow pits and the associated indirect impacts of increased grazing and predator pressure as an issue of particular concern. As discussed in Section 5.5, the Native Vegetation Act and Pastoral Land Management and Conservation Act place some approval requirements on pastoral landholders regarding approval of new waterpoints which may be relevant for borrow pits that retain water for long periods.

Introduction of fill material can also result in alteration of drainage patterns and possibly introduction and / or spread of weeds. The presence of roads can also increase the ease of access by third parties to previously inaccessible sites, which has been observed to increase impacts from grazing and tourism visitation (Gillen and Reid 2013).

Public roads will be maintained where impacted by Beach activities to minimise consequences on other public road users.

There are few hazards associated with road abandonment. Hazards include earthworks (i.e. ripping) and removal of road construction material (e.g. clay). Ripping can lead to soil erosion and alteration of drainage patterns. Disposal of road construction material may potentially spread weeds or alter drainage patterns and vegetation cover at the disposal site.

Table 26: Road construction and maintenance risk assessment

Activity / Event	Potential Consequences	SEO Obj	Management Strategy	Consequence	Likelihood	Residual Risk
Earthworks and physical presence of road	Injury or death of fauna / stock in construction zone Long term disturbance to natural drainage patterns Significant damage to third party infrastructure Soil erosion and siltation of watercourses Inversion of soil profile Dust generation Soil compaction Impeded fauna movement through construction zone Damage to native vegetation during construction Temporary loss of visual amenity Temporary disruption to land use (e.g. grazing and recreation) Damage to vegetation and habitats from increased access by third parties (grazing, visitor impact)	1, 2, 3, 4, 5, 8, 9	Use existing roads and tracks where possible Minimise impact on the environment by appropriate route selection to minimise or avoid sensitive land systems, vegetation and cultural heritage sites or areas of high biological significance Observe procedures and guidelines for the identification, management and protection of cultural heritage sites including heritage clearances by Native Title groups Design and construct road with drainage features (e.g. culverts and offtakes) that avoid disturbance to natural drainage and minimise erosion and sedimentation Undertake appropriate planning and construction for roads in floodplains and watercourses to avoid disturbance to natural drainage patterns. This may include: • construction of roads at (or not significantly above) the natural surface level as a minimum standard • hydrological assessment of proposed roads and drainage features to ensure potential impacts are identified and addressed in the design • installation of culverts or bridges across channels or flow paths to ensure flows are maintained • installation of 'fish passages' to enable passage of fish and other aquatic fauna where required • consultation with relevant agencies (e.g. DEM, DEW, SAAL Landscape Board) where appropriate Liaise with landowners regarding notification and management of works and site issues including livestock management Implement dust control measures where required, using water efficient or waterless techniques where feasible Minimise vegetation disturbance, and plan construction to avoid vegetated areas Avoid significant or priority[21] vegetation and ensure proposed routes have been scouted for significant vegetation and wildlife habitats by appropriately trained and experienced personnel Where possible trim vegetation rather than clearing Undertake environmental assessment and consultation with landowners and DEM where new road construction / stabilisation techniques or materials are proposed Undertake vehicle and equipment washdown before entering Cooper Basin or after operating in areas of known weed infestations	Moderate	Unlikely	Medium
	Introduction and / or spread of weeds Disturbance to cultural heritage sites		Remove waste to minimise visual impact Install appropriate signage to deter unauthorised third party access	Serious	Unlikely	Medium
Movement of heavy machinery and vehicles along road and access tracks	Dust generation Soil compaction Soil erosion Damage to native vegetation Injury or death of native fauna Disturbance to cultural heritage sites Introduction and / or spread of weeds Damage to third party infrastructure Disruption to land use (e.g. grazing and recreation)	1, 2, 3, 4, 7, 8, 9	Use existing cleared areas for laydowns and turn-arounds Liaise with landowners regarding notification and management of works and site issues including livestock management Implement dust control measures where required, using water efficient or waterless techniques where feasible Undertake vehicle and equipment washdown before entering Cooper Basin or after operating in areas of known weed infestations Drive only on access tracks and road formation Rip areas of compacted soil (not on gibber plains and tablelands) Implement traffic management measures / signage where appropriate for significant transportation movements	Minor	Unlikely	Low
Ignition of fire	Disturbance to cultural heritage sites Loss of vegetation and fauna habitat Release of particulate emissions to the atmosphere Disruption to land use (e.g. grazing and recreation) Danger to health and safety of personnel, contractors and possibly the public	1, 3, 7, 8, 9	Smoking only in safe areas away from equipment or activity Personnel are trained to supervise and instruct individuals entering area to conduct work Safe work permits must be obtained to ensure only individuals with proper clearance can conduct works Petrol vehicles to be excluded from construction sites Emergency response procedures should contain a bushfire scenario Safety, testing, maintenance and inspection procedures are implemented	Moderate	Remote	Low
Spills or leaks associated with	Contamination of soil, shallow groundwater and / or surface water	3, 6	See *Completions and Workovers* section in Table 18 for general controls related to spills or leaks	Minor	Unlikely	Low

[21] Refer to Appendix 4: Beach Energy Priority Plant List.

Activity / Event	Potential Consequences	SEO Obj	Management Strategy	Consequence	Likelihood	Residual Risk
chemical and fuel storage and handling	Access to contaminants by stock and wildlife Loss of beef production certification Loss of vegetation and fauna habitat					
Presence of borrow pits	Injury or death of stock and wildlife Soil erosion	1, 2, 3, 10	Procedures for operation and restoration of borrow pits are followed Existing unrestored borrow pits are used in preference to establishing new pits, and planning is undertaken to rationalise borrow pit establishment Reworking of pits, or construction of new pits occurs a suitable distance from existing facilities, including stock yards Pits are not to be established in locations which pose an unacceptable hazard to stock or wildlife Where required bunds are installed to divert overland flow and prevent water ingress Borrow pits are restored to a standard consistent with the surrounding land use, in accordance with SEO requirements Reuse of borrow pits as PFW evaporation or water storage ponds where appropriate Restored pits have topsoil / overburden replaced and pit re-profiled where necessary to prevent erosion and minimise the capture of water Liaise with landholder regarding grazing management near borrow pits	Minor	Possible	Medium
	Dispersal of watering points and redistribution of stock / wildlife movements resulting in inadvertent damage to vegetation and habitats			Moderate	Possible	Medium
Movement of road construction material	Introduction and / or spread of weeds	4	Inspect / monitor for weeds during standard inspections of facilities and infrastructure Undertake control measures for weed outbreaks Do not import material from areas of weed / disease infestation Washdown of equipment bought in from high risk areas for weed infestation	Moderate	Unlikely	Medium
Use of roads	Dust generation Injury or death of stock and wildlife Increased public access to remote areas	1, 3, 4, 7, 8	Training, speed restrictions and appropriate signage to reduce speed and increase awareness of hazards Implementation of in-vehicle monitoring system to track and improve driving safety Radio communication between road users and designated radio call points to notify other road users of presence on road Restrictions on night driving Inspect / monitor for weeds during standard inspections Signage to prevent unauthorised access Implement dust control measures where required, using water efficient or waterless techniques where feasible	Minor	Unlikely	Low
	Introduction and / or spread of weeds			Serious	Remote	Low
	Danger to health and safety of personnel, contractors and possibly the public			Major	Unlikely	Medium

5.9 Aircraft Landing Area

The principal hazards associated with construction of an aircraft landing area are earthworks, vegetation clearance, chemical and fuel storage and waste disposal, as discussed for road construction in Section 5.8.

The major hazards associated with operation of an aircraft landing area are the storage of fuels and the potential disruption or injury to stock or wildlife, particularly birds. Permanent airstrips are fenced to exclude stock or large fauna species.

Table 27: Aircraft landing area risk assessment

Activity / Event	Potential Consequences	SEO Obj	Management Strategy	Consequence	Likelihood	Residual Risk
Earthworks	See Road Construction and Maintenance above		See Road Construction and Maintenance above.			
Take-off / landing of aircraft	Disturbance to landowners and the public Disturbance to stock and wildlife Injury or death of birds, stock or other wildlife	1, 3	Airstrip located to minimise disturbance to landowners and the public Gates and signage installed to restrict vehicle and personnel movement through the landing strip area Permanent airstrips fenced to exclude cattle and large fauna species Protocols implemented to ensure landing area is clear of stock or wildlife (e.g. pre-landing inspection) Bird numbers monitored and scare methods used if large numbers become established on-site	Minor	Unlikely	Low
Leaks and / or spills associated with chemical and fuel storage and handling	Contamination of soil, shallow groundwater and / or surface water Access to contaminants by stock and wildlife Loss of beef production certification Loss of vegetation and fauna habitat	3, 6	If refuelling facilities are required, implementation of appropriate chemical and fuel storage and handling procedures (e.g. bunding and signage) in accordance with relevant standards and guidelines, including AS 1940, EPA guideline 080/16 Bunding and Spill Management and the ADG Code See *Completions and Workovers* section in Table 18 for general controls related to spills or leaks	Minor	Unlikely	Low

5.10 Oil Transport (by Road)

The major hazard associated with the transport of oil on road networks is a leak or spill of oil or fuel (e.g. as a result of a collision or truck rollover). Many of the consequences associated with oil spills and leaks, such as vegetation loss, soil disturbance and drainage alteration, can be minimised by effective emergency response and remediation. However, this largely depends on the land system involved.

Transport personnel will comply with road rules and drive to road conditions to minimise impact on other road users.

In dry environments, such as dunefields and gibber, the consequences associated with an oil spill are mainly localised, as oil is easier to contain and recover in dry conditions. However, the environmental consequences of oil spills in more sensitive wet environments, like the Cooper and Strzelecki Creeks and surrounding floodplains and wetlands, are potentially significant. Flood conditions that can potentially spread oil over large distances and throughout highly sensitive ecosystems are of primary concern and management measures need to minimise the environmental risk in these conditions.

Other hazards associated with oil transport include potential fire hazard and encountering stock or fauna on the roads. Consequences, such as stock or fauna death and vehicle damage or accidents, can be minimised by measures such as reducing the occurrence of night travelling and speed restrictions.

Table 28: Oil transport risk assessment

Activity / Event	Potential Consequences	SEO Obj	Management Strategy	Consequence	Likelihood	Residual Risk
Use of roads	See *Use of Roads* in Table 26 in Section 5.8	1, 3, 4, 7, 8	See *Use of Roads* in Table 26 in Section 5.8			
Spill associated with transport of oil / condensate (via truck) to land	Contamination of soil, shallow groundwater and / or surface water Access to contaminants by stock and wildlife Loss of beef production certification Damage to vegetation and fauna habitat	3, 6	Transportation of chemicals, fuels and oils in accordance with ADG Code Suitably trained, experienced and licensed contractors used to transport oil Ensure roads and causeways are designed to minimise risk of vehicle accident Training and speed restrictions to reduce speed and increase awareness of hazards Vehicles maintained and serviced in accordance with manufacturer's specifications Avoid transportation movements in wet conditions and use caution when crossing causeways (e.g. Innamincka causeway) during wet conditions Appropriate communication between trucks, other vehicles and facilities to plan safe transport movements Appropriate signage installed (e.g. at access to public roads) See *Completions and Workovers* section in Table 18 for general controls related to spills or leaks	Minor	Unlikely	Low
Spill associated with transport of oil / condensate (via truck) to watercourse / wetland	Contamination of soil, surface water and shallow groundwater Damage to vegetation and habitats Access to contaminants by stock and wildlife	3, 6	As above, plus: Install signage at creek crossings where appropriate No fording of flowing streams Removal of contaminated soil from spills in watercourses as appropriate Call signs for traffic management at and along creek crossings and roads	Major	Unlikely	Medium

5.11 Waste Management

Waste at Beach production facilities is currently transported off-site to a licensed facility for recycling or disposal. Sewage and grey water is treated in approved wastewater treatment systems on-site and treated effluent irrigated to land or to a wastewater evaporation pond. Untreated sewage may also be stored before being pumped out and trucked off-site by a licensed contractor. Concentrates from reverse osmosis (RO) or desalination are disposed to ponds (e.g. produced water ponds if volumes are suitably low relative to PFW volumes or dedicated lined ponds). There is a potential for localised contamination or salinisation of soil and groundwater as a result of leaks from the sewage treatment system or inappropriate disposal of treated effluent or RO concentrates.

Fracture stimulation flowback solids (e.g. proppant) remaining in ponds are disposed of at an appropriately licensed facility (e.g. soil remediation area or waste disposal facility) or may be disposed on site during pond rehabilitation if testing demonstrates that they meet appropriate criteria (e.g. waste fill guidelines).

Beach does not currently operate landfill sites for disposal of domestic waste in South Australia. If landfill sites were required to be developed in the future, they would be sited in a suitable, stable area, distant from watercourses or floodplain areas and approved and operated in accordance with EPA requirements, as discussed in Section 3.10.1.

Beach has a land treatment area at Bauer for the bioremediation and treatment of hydrocarbon contaminated soils, as discussed in Section 3.10.3. The land treatment site consists of an impermeable, bunded and fenced area, which is managed in accordance with relevant EPA guidelines, including the EPA *Guidelines for the assessment and remediation of site contamination (EPA 2019)* and subject to ongoing and monitoring.

Beach does not currently have a sludge treatment plant, but may construct one in the future, subject to DEM and EPA approval, as discussed in Section 3.10.5. The plant would typically involve physical and chemical processes to separate hydrocarbons, water and solids for reuse or disposal.

Potential consequences of these waste management practices include contamination or salinisation of soil or groundwater and the introduction and / or spread of weeds. In the case of a landfill site consequences also include outbreaks of pests and scavenging by wildlife.

Table 29: Waste management risk assessment

Activity / Event	Potential Consequences	SEO Obj	Management Strategy	Consequence	Likelihood	Residual Risk
Storage of waste at camps or facilities and transport to landfill	Localised contamination of soil and / or groundwater Scavenging by native and pest species Pest outbreaks Loss of visual amenity Odorous emissions	1, 3, 6, 10	EPA's Waste Hierarchy model (avoid, reduce, reuse, recycle, recover, treat, dispose) complied with and waste management undertaken with regard to *the Environment Protection (Waste to Resources) Policy 2010* Covered bins provided for the collection and storage of wastes. All loads of rubbish are covered during transport to an approved waste facility Waste streams segregated on-site and transported to appropriately licensed facilities to maximise waste recovery, reuse and recycling Production of waste minimised by purchasing reusable, biodegradable or recyclable materials where practical Hazardous wastes handled in accordance with relevant legislation and standards Licensed contractors used for waste transport Operational sites are kept free of litter and rubbish	Minor	Unlikely	Low
Disposal and treatment of sewage	Contamination of soil, shallow groundwater and / or surface water Danger to health and safety of personnel, contractors and possibly the public Access to contaminants by stock and wildlife	3, 6, 7	Containment of all untreated sewage wastes within septic tank or treatment system Treated effluent irrigated or disposed to land or ponds in area with appropriate fencing / signage, in a location where it will not enter surface waters All wastewater disposed in accordance with the *South Australian Public Health (Wastewater) Regulations 2013* or to the satisfaction of the Department of Health) and in accordance with the *Environment Protection (Water Quality) Policy 2015*	Minor	Unlikely	Low
Disposal of reverse osmosis concentrates	Salinisation of soil, shallow groundwater and / or surface water	6	Disposal of RO concentrate to PFW pond system, provided that volumes are suitably low relative to PFW volumes and will not result in unacceptable salinity impacts in free form areas Use of lined ponds (e.g. HDPE) for disposal where appropriate	Minor	Unlikely	Low
Disposal of fracture stimulation flowback solids	Contamination of soil, shallow groundwater and / or surface water	6	Fracture stimulation flowback solids (e.g. proppant) remaining in ponds are disposed of at an appropriately licensed facility (e.g. soil remediation area or waste disposal facility) or may be disposed on site during pond rehabilitation if testing demonstrates that they meet appropriate criteria (e.g. waste fill guidelines).	Minor	Unlikely	Low
Disposal of washdown water	Contamination of soil, shallow groundwater and / or surface water	6	Vehicle and equipment wash-down water disposed to existing ponds or to land (away from watercourses surface waters or environmentally sensitive areas) provided that water quality is consistent with relevant guidelines for the disposal site (e.g. ANZECC (2000) / ANZG (2018) or EPA guidelines.	Minor	Unlikely	Low
Domestic waste disposal facility*	Contamination of soil, shallow groundwater and / or surface water Scavenging by native animals and pest species Pest outbreaks Loss of visual amenity Odorous emissions	1, 3, 6	Sited in a suitable, stable area, distant from watercourses or floodplain areas Design and operation in accordance with EPA approval requirements Undertake soil and groundwater monitoring Cover and fence site with an appropriate material to prevent the spread of rubbish from the site by wind and prevent access by stock and wildlife Bury rubbish immediately to facilitate degradation and reduce offensive odours and aesthetic consequences Fill in waste pits if flood inundation is imminent	Minor	Unlikely	Low
Storage, treatment and disposal of contaminated soil	Contamination of soil, shallow groundwater and / or surface water Access to contaminants by stock and wildlife	3, 6	Temporary storage of contaminated soil at Beach production facility in designated lined, bunded area prior to treatment or removal off-site by licensed regulated waste contractor to appropriately licensed facility for treatment or disposal Appropriate siting of land treatment site in a suitable, stable area, distant from watercourses or floodplain areas Design and operation of land treatment area in accordance with DEM / EPA requirements and relevant EPA guidelines, including the EPA *Guidelines for the assessment of and remediation of site contamination* (EPA 2019) Ultimate reuse or disposal of treated soil consistent with the principles of the National Environment Protection Measure for contaminated sites and relevant EPA guidelines Monitoring of surrounding soil and groundwater for contaminants at least annually Fence off contaminated areas Development of remediation plans for land treatment area	Minor	Unlikely	Low
Sludge treatment*	Contamination of soil, shallow groundwater and / or surface water Access to contaminants by stock and wildlife Loss of vegetation and fauna habitat	3, 6	Plant and equipment designed, constructed, operated and maintained in accordance with DEM / EPA requirements and relevant standards and guidelines Appropriate areas are bunded and lined to contain spills See *Completions and Workovers* section in Table 18 for general controls related to spills or leaks	Minor	Unlikely	Low

* Landfill and sludge treatment activities do not currently occur but may in the future

5.12 Decommissioning / Rehabilitation

The major hazards associated with decommissioning are earthworks, movements of heavy vehicles, spills and leaks, chemical and fuel storage and waste disposal. Earthworks and vegetation clearance can potentially result in soil erosion, interruption of natural drainage patterns, disturbance to cultural heritage sites, introduction and spread of weeds and damage to vegetation, however the impacts are generally limited as earthworks are generally confined to disturbed infrastructure sites. Spills and leaks during decommissioning, waste disposal and chemical and fuel storage can lead to localised soil or water contamination.

Table 30: Decommissioning / rehabilitation risk assessment

Activity / Event	Potential Consequences	SEO Obj	Management Strategy	Consequence	Likelihood	Residual Risk
Earthworks e.g. grading, ripping and backfilling	Injury or death of fauna in a construction zone Loss of visual amenity Damage to native vegetation Introduction and / or spread of weeds Disturbance to natural drainage patterns Damage to third party infrastructure Soil erosion and siltation of watercourses Inversion of soil profile Dust generation Soil compaction Disturbance to cultural heritage sites	1, 2, 3, 4, 5, 8, 9, 10	Earthworks restricted to the minimum area necessary (typically on existing, disturbed infrastructure sites) Observe procedures for location of services and infrastructure Obtain excavation permits where required Observe procedures and guidelines for the identification, management and protection of cultural heritage sites Rip areas of compacted soil (except on gibber plains and tableland environments) Respread topsoil and stockpiled vegetation Restore natural contours to minimise impacts to natural drainage patterns Minimise vegetation disturbance, and plan works to avoid vegetated areas and significant or priority[22] vegetation Stockpile any cleared vegetation and respread following works to facilitate revegetation Minimise impacts to fauna by leaving excavations open for as little time as possible Undertake vehicle and equipment washdown when operations have been undertaken in areas of known weed infestations Liaise with landowners regarding notification and management of works and site issues including livestock management	Minor	Unlikely	Low
Movement of machinery and vehicles along ROW and access tracks during rehabilitation	Dust generation Soil compaction Soil erosion Damage to native vegetation Injury or death of native fauna Disturbance to cultural heritage sites Introduction and / or spread of weeds Damage to third party infrastructure Disruption to land use (e.g. grazing and recreation)	1, 2, 3, 4, 8, 9, 10	Undertake vehicle and equipment washdown when operations have been undertaken in areas of known weed infestations Drive only on access tracks and pipeline easement Rip areas of compacted soil (not on gibber plains and tablelands)	Minor	Unlikely	Low
Spills and leaks associated with chemical and fuel storage and handling	Contamination of soil, shallow groundwater and / or surface water Access to contaminants by stock and wildlife Loss of beef production certification Loss of vegetation and fauna habitat	3, 6	See *Completions and Workovers* section in Table 18 for general controls related to spills or leaks	Moderate	Highly Unlikely	Low
Loss of containment of gas or oil (pipeline failure / pigging during decommissioning or leaks from facility equipment)	Contamination of soil, shallow groundwater and / or surface water Disruption to land use (e.g. grazing) Danger to health and safety of personnel, contractors and possibly the public Atmospheric pollution Access to contaminants by stock and wildlife Loss of vegetation and fauna habitat	3, 6, 7, 8	Abandonment programs planned to avoid or minimise hazardous situations, with controls in place to address risks Pipeline decommissioning programs planned to take into account pipeline condition and location and minimise risk of rupture or leak Establish appropriate emergency / spill response procedures for spills or leaks to soil and water Implementation of appropriate emergency / spill response procedures Periodic review and exercise of response equipment and procedures to ensure preparedness Appropriate spill containment and clean-up equipment located on-site Personnel are trained in the use of spill response equipment Immediate clean-up and remediation to minimise contamination to soil / water Fence contaminated areas if threat is posed to stock or wildlife Maintain a register of spills and / or leaks and implement corrective actions based on analysis of spill events	Moderate	Highly Unlikely	Low

[22] Refer to Appendix 4: Beach Energy Priority Plant List.

Activity / Event	Potential Consequences	SEO Obj	Management Strategy	Consequence	Likelihood	Residual Risk
Disposal of hydrotest water or water used for flushing pipelines	Contamination of soil, shallow groundwater and / or surface water Access to contaminants by stock and wildlife Loss of vegetation and fauna habitat as a result of soil or water contamination	3, 6	See *Disposal of hydrotest water* in Table 24.	Minor	Unlikely	Low
Explosion or fire at the facility or along the ROW	Danger to health and safety of personnel, contractors and possibly the public Contamination of soil, shallow groundwater and / or surface water Atmospheric pollution (gas) Loss of vegetation and fauna habitat Disruption to land use (e.g. grazing and recreation)	3, 6, 7, 8	Abandonment programs planned to avoid or minimise hazardous situations, with controls in place to address risks Risk assessments undertaken in line with industry best practice Hazardous area assessment and compliance with AS 3000 Earthing maintained as appropriate to prevent static charges where residual hydrocarbons may be present No smoking or safe smoking areas away from equipment or activity Operation under fire permit requirements where relevant Safe work permits must be obtained to ensure only individuals with proper clearance can conduct works Immediate clean-up and remediation to minimise contamination to soil / water Petrol vehicles to be excluded from gas well / pipeline sites Establish appropriate emergency / spill response procedures for explosion or fire Safety, testing, maintenance and inspection procedures are implemented	Major	Remote	Medium
Storage of waste and disposal to licensed landfill	Scavenging by native and pest species Pest outbreaks Localised contamination of soil and / or groundwater Loss of visual amenity Odorous emissions	1, 6, 10	Refer to Table 29	Minor	Unlikely	Low
Water well abandonment	Cross flow between aquifers	5	Undertaking water well abandonment, including installation of cement plugs, as per Regulatory requirements for groundwater bore abandonment (e.g. Far North WAP and DEW water Licencing information)	Minor	Remote	Low

6 Environmental Management Framework

Production activities will be undertaken in accordance with Beach Energy's Operations Excellence Management System (OEMS) and Production Operations Safety Manual.

Operations Excellence Management System

The OEMS is a key tool in the management of Beach and associated contractors' environmental responsibilities, issues and risks. The OEMS also provides a framework for the coordinated and consistent management of environmental issues by ensuring the:

- establishment of an environmental policy (see http://www.beachenergy.com.au/)
- 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.

Production Operations Manual

The Production Operations Manual (POM) is the reference manual for Beach Site Supervisors and Production Operators controlling well production operations of land wells. The POM does not replace sound production practices and should reflect industry best practice.

The purpose of the POM is to:

- illustrate the guidelines, procedures and controls required during production of oil wells
- provide sufficient information to ensure that production operations are conducted with environmentally and safety orientated procedures
- provide a guide for relevant personnel on the procedures to be followed to ensure that a consistent, thorough and uniform approach is adopted to facilitate delivery of hydrocarbon product to point of sale
- provide sufficient information to allow a Production Supervisor to supervise and monitor production operation control standards and reporting
- provide sufficient information to allow the Production operator to operate, monitor and report on production operations.

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

6.1 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.

6.2 Responsibilities

Environmental management and compliance will be the responsibility of all personnel and contractors. The indicative organisation and responsibilities for personnel overseeing environmental management are detailed in Table 31. The exact nature and title of these roles may vary and positions may be amalgamated or the responsibilities shared under a modified arrangement.

Responsibility for control of all activities is delegated from the Chief Operating Officer to the General Manager Operations for each asset. The Facilities Manager and/or Operations Superintendent for each asset has the responsibility for ensuring that all work carried out is undertaken in accordance with all relevant procedures, systems and standards. The training of all personnel will ensure that each individual is aware of their environmental responsibility.

Table 31: Indicative roles and responsibilities

Role	Responsibility
Managing Director	• HSE performance of all activities across Beach Energy • Appropriate HSE policies are in place and HSE management system in place to deliver these policies in practice • Appropriate resources are in place to implement the OEMS.
Chief Operating Officer	• HSE performance of all activities across Beach Energy • Ensuring a system is in place for the ongoing identification and control of HSE risks • Developing HSE Improvement Action Plan and ensuring all sites/activities have one • Ensuring systems are in place to define requirements for personnel (including contractors) HSE competencies to carry out their work • Ensuring managers and supervisors understand, accept and carry out their responsibilities in safety and health matters and that they are trained and instructed to undertake these responsibilities • Ensuring processes are in place for interpreting and communicating relevant legislative requirements and industry standards and any changes thereto, and compliance with these obligations i.e. Annual Safety Report, • Safety Case/Safety Management Plans, Environmental Management Plans where these documents exist due to regulatory requirements • Monitor safety performance through review of lead and lag Key Performance Indicators (KPIs) and actions are taken to improve safety performance and correct any identified deficiencies.
Group Executive HSE & Risk	• Providing technical support to the Managing Director and the General Managers for each asset on OEMS and HSE issues • Ensuring a system is in place for the ongoing identification and control of HSE risks • Ensuring systems are in place to define requirements for personnel (including contractors) HSE competencies to carry out their work • Ensuring managers and supervisors understand, accept and carry out their responsibilities in safety and health matters and that they are trained and instructed to undertake these responsibilities • Development and update of the OEMS and supporting documentation within • Monitors safety performance through review of lead and lag Key Performance Indicators (KPIs) and actions are taken to improve safety performance and correct any identified deficiencies.

Role	Responsibility
Head of Technical Assurance	• Providing assurance that the onshore and offshore facilities have been designed and constructed to meet the requirements of the relevant OEMS applicable performance standards • Delivery of Safety Case/Safety Management Plans and regulatory reports where these documents exist due to regulatory requirements • Oversight of verification of safety critical controls within site Safety Cases/ EMPs via the Integrity Verification program. • Developing, monitoring, periodic review and update of the relevant Asset Integrity Management Plans • Ensuring assurance activities are undertaken in accordance with performance standards for safety critical elements
Head of Environment	• Emissions monitoring, reporting and reduction opportunity identification • Waste Management – liquid and solid management strategies including recycling • Rehabilitation – strategy development, on-ground implementation and monitoring • Energy Efficiency – facility monitoring, reporting and opportunity identification • Native title – stakeholder management strategies • Regulatory Compliance – monitoring, reporting (internal and external) and advocacy with regulators • Water Management – modelling, monitoring, strategy development and advocacy with regulators • Climate Change – policy and strategy development, carbon emissions reduction project identification
Head of Health & Safety	• Providing technical support to the Chief Operating Officer and the General Managers for each asset on OEMS and HSE issues • Supporting the identification and management of HSE risks across production operations • Assisting to uniformly implement the OEMS across Beach Energy facilities
Head of Corporate Risk	• Developing assurance plan and implementation of assurance activities that monitor overall compliance with the OEMS elements
General Manager - Engineering and Technical Services	• Managing implementation of Asset Integrity Management Plans • Managing inspections, maintenance and testing programs for plant, equipment and associated control systems to ensure continued reporting • Ensuring systems are in-place to maintain plant and equipment operations strictly within their designed operating envelope • Ensuring personnel inspecting, maintaining and testing equipment are competent to do so • Maintaining systems to control the quality and suitability of maintenance consumables and replacement parts • Maintaining systems to retain records of all scheduled programs for maintenance, inspection, testing and calibration of facilities, plant, equipment and machinery • Ensuring all engineering and maintenance contracts are in accordance with the relevant OEMS standards • Ensuring appropriate HSE reviews are undertaken for any new equipment or any planned modifications or changes in the design or operation of existing plant and equipment • Maintaining as built drawings and documentation of the facilities, plant and equipment. • Implementation and verification of safety critical controls within site Safety Cases/EMPs. • Execution of stay-in-business projects and planned modifications to the design or operation of existing plant and equipment, ensuring appropriate HSE reviews are undertaken in accordance with Management of Change processes

Role	Responsibility

General Manager Operations for each asset	• HSE performance of all activities across their asset
	• Responsible Person on behalf of the Person Conducting Business Undertaking (PCBU) for the development, implementation and compliance with the asset's Safety Cases/ EMPs.
	• Ensuring the Facilities Manager and Operations Superintendent has the required skills and can fulfil their duties as the "Accountable Person" for managing HSE performance at each site
	• Ensuring that, for every site and activity in their area of responsibility:
	  ◦ appropriate systems exist for monitoring existing and identifying new HSE risks
	  ◦ key controls are identified
	  ◦ appropriate risk treatment plans are implemented
	• Ensuring that regional and site level emergency response plans are in place and regularly tested
	• Implementing and ensuring compliance with systems which define the HSE competencies for personnel (including contractors) to carry out their work
	• Ensuring assurance activities are undertaken in accordance with performance standards for safety critical elements
	• Maintaining relationship and reporting relevant requirements under the Safety Cases/ EMPs and HSE legislation.

Facilities Manager / Operations Superintendent for each asset	• Day to day management of the asset in line with the Safety Case/ /EMP and the OEMS • NZ - Compliance with all "Permitted Operations" as described in the Safety Case Performance Standards for each Safety Critical Element • Ensuring appropriate and effective OEMS procedures, work instructions and support documents exist for their site or activity • Providing supervision and processes to ensure that the OEMS is implemented correctly on site • Ensuring compliance with all relevant procedures, systems and standards; • Appointing competent personnel to manage day-to-day HSE matters and associated compliance risks • Ensuring appropriate risk management is undertaken for their site or activity in accordance with relevant procedures • Ensuring that appropriate reporting, verification, authorisation and escalation occurs within their area of responsibility for the review and actioning of all incidents, defects, hazards, inadequacies of procedures • Ensuring that processes are implemented to ensure that all employees and contractors (members of the workforce) in their area of responsibility are appropriately inducted, hold the required competencies and licences to undertake their assigned work.
Senior Environmental Advisor Senior HSE Advisor	• Providing technical support to the General Managers, Facilities Manager and Superintendent for each asset on OEMS and HSE issues • Assisting with the development, revision and effective implementation of HSE procedures and tools necessary for efficient functioning of the OEMS • Supporting the identification and management of HSE risks across production operations • Assisting to uniformly implement the OEMS across Beach Energy facilities • Managing HSE audits and other assurance activities for improving the effectiveness of the OEMS. • Managing and recording consultation of stakeholders on HSE management of production operations.

Role	Responsibility
First Nations Engagement Manager	• Providing technical support to the General Managers, Facilities Manager and Superintendent for each asset on OEMS and HSE issues • Assisting with the development, revision and effective implementation of HSE procedures and tools necessary for efficient functioning of the OEMS • Supporting the identification and management of HSE risks across production operations • Assisting to uniformly implement the OEMS across Beach Energy facilities • Managing cultural heritage policy and procedure reviews and other assurance activities for improving the effectiveness of the OEMS. • Managing and recording consultation of stakeholders on cultural heritage management of production operations.
Employees and Contractors (Members of the Workforce)	• Carrying out work safely and without harm to themselves, others, equipment or the environment and in accordance with their training, operating procedures and work instructions described within the OEMS • Only complete tasks/activities that they have been instructed to do, and ensure they have the required competency and/or licence and experience to undertake the activity/task • Identifying and assessing hazards/risks associated with their work and ensuring suitable controls are in place before and during completion of the work • Enacting the Authority to Stop Work in the case of an immediate threat to the health or safety of any person • Reporting any hazards, unsafe acts or incidents observed in the workplace or deficiencies observed in work practice or procedures to their Supervisor or Facilities Manager/Operations Superintendent • Participating in training and development activities and competency reviews as and when required

6.3 Environmental Management Standard

All Beach employees and contractors are responsible for ensuring compliance with the BSTD 10.1 - Beach Environmental Management Standard and associated environmental legislation. The Environmental Management Standard 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 Beach operates. The standard covers all activities undertaken by Beach in Australia including exploration, drilling, well operations, and production.

Beach conducts periodic environmental audits to assess the appropriateness of the Standard to meeting Beach's policies, legislative requirements and environmental objective commitments and whether the standard has been properly implemented and maintained.

6.4 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. Beach 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.

Beach operates a single use, multi-purpose Permit to Work (PTW) system covering all areas of operations. The purpose of this PTW procedure is to summarise the Beach safety control mechanism designed to identify hazards, assess risks and to prevent accidents associated with task specific activities requiring a Permit prior to the work commencing.

6.5 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. Beach field personnel and contractors receive periodic, in-field environmental training. Beach also utilises knowledge sharing bulletins to communicate specific environmental issues.

A record of induction and attendees will be maintained.

6.6 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 (e.g. every 2 years in accordance with regulations) to ensure that personnel are familiar with the plans and the types of emergencies to which they apply, and that there will be a rapid and effective response in the event of a real emergency occurring.

6.6.1 Oil Spill Response

Oil spill response procedures are captured under Beach's emergency response plan, which requires spills to be contained, reported, cleaned-up and the cause investigated and corrective and / or preventative action implemented.

Minor spills in lined bunded areas are generally treated in situ in accordance with EPA guidelines. Initial clean-up of spills outside of bunded areas usually involves removal of hydrocarbon contaminated soil to a Beach production facility for temporary storage in a designated bunded area, prior to treatment or disposal (see Section 3.10.3 for discussion).

Assessment of potentially contaminated sites where spills have occurred is undertaken in accordance with the National Environment Protection Measure for contaminated sites. Site remediation (where required) is undertaken in line with relevant EPA guidelines.

6.7 Environmental Monitoring and Audits

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

Monitoring programs are 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

- site revegetation following completion and any restoration
- potential future problems.

6.8 Incident Management, Recording and Corrective Actions

Beach 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 and associated regulations.

6.9 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 Beach.

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

The NPI is an internet based database on emissions and transfer of substances (see Section 5.4.2). Several of Beach's production facilities exceed NPI reporting thresholds and the resultant emissions are reported at http://www.npi.gov.au/.

Where applicable, incidents causing or threatening serious or material environmental harm under the *Environmental Protection Act 1993* must be reported to the EPA in accordance with Section 83 of the Act.

As noted in Section 2.2, the Environmental Protection Act and its reporting obligation do not apply to:

- petroleum exploration activity undertaken under the Petroleum and Geothermal Energy Act
- wastes produced in the course of an activity (not being a prescribed activity of environmental significance) authorised by a licence under the Petroleum and Geothermal Energy Act when produced and disposed of to land within the area of the licence.

7 Stakeholder Consultation

The Cooper Basin is a sparsely populated and remote arid region. The local community broadly includes pastoral leaseholders, Innamincka township residents, DEW personnel, tourists, petroleum explorers / producers, geothermal explorers and associated contractors.

It is a requirement under the PGE Regulations that information on consultation with relevant landowners, Aboriginal groups or representatives, government departments or agencies, or any other interested person or parties is outlined in an EIR.

Stakeholders in the Cooper Basin region include landholders and the local community, native title groups, regulatory agencies, industry groups and environmental organisations.

Beach is committed to maintaining effective communication and good relations with all stakeholders. Beach maintains ongoing contact with landholders and other directly affected parties in relation to all aspects of its operations in the Cooper Basin. Issues raised to date have been integrated into this report.

Beach aims to continue to engage stakeholders for the duration of its production activities to ensure that all potential concerns are identified and appropriately addressed.

7.1 Overview of Consultation

Petroleum production operations have been conducted in the Cooper Basin for over 40 years. Consequently, key stakeholders in the region, particularly landowners, are aware of and understand the relevant issues associated with petroleum production operations in the region.

Beach undertakes active ongoing liaison with landowners and native title groups in the Cooper Basin. This includes formal notification and direct discussions regarding specific proposed activities such as well drilling, fracture stimulation, pipeline and facility construction, road construction and maintenance and site rehabilitation, as well as less formal liaison regarding general operational and land management matters.

7.1.1 Stakeholder Consultation on the EIR and SEO (2003-2019)

The EIR and SEO for Beach production operations in the Cooper Basin were originally developed by Beach in 2003, and have been reviewed and updated in 2008-9, 2015-16, and in 2019.

Key stakeholders, including landholders directly affected by Beach's activities and relevant government agencies were consulted during development of the Beach production EIR and SEO in 2003 (Beach 2003a and 2003b). Extensive consultation had previously been undertaken with stakeholders by Santos and PIRSA (now DEM) during preparation and review of the SACBJV Production and Processing Operations EIR and SEO in 2002/03 (Santos 2003). Further extensive consultation with all stakeholders during the development of the Beach production EIR and SEO was not considered necessary at that time, due to the familiarity of key stakeholders with the issues associated with petroleum production in the Cooper Basin and the very similar nature (and much smaller scale) of Beach's operations to production activities outlined in the Santos EIR.

The EIR and SEO were reviewed and updated in 2008-9 (Beach 2009a and 2009b) to ensure currency of information in the EIR (e.g. legislative changes, additional licence areas and facilities) and address changes to incident reporting definitions.

During the 2015-16 review of the EIR and SEO (Beach 2016a and 2016b), extensive consultation was again undertaken with stakeholders directly and indirectly impacted by Beach's production operations in the Cooper Basin, including with pastoral landholders, government agencies, the Innamincka township, native title claimants, non-government organisations (NGOs) and other petroleum and geothermal companies. Stakeholders were provided with four weeks to comment on the draft documents and Beach invited landholders in the Cooper Basin to a public meeting at Innamincka to discuss the draft EIR and SEO, which was cancelled due to limited interest. Government agencies were formally consulted by DSD (now DEM) under the PGE Act process following formal submission of the EIR and draft SEO in December 2015. Following the receipt of agency comments, Beach undertook further liaison with Traditional Owners to clarify for DSD the approaches to Aboriginal heritage site definition and WAC boundaries and confirm wording in the SEO.

The production EIR and SEO were further updated in 2019 (Beach 2019a and 2019b) to incorporate coverage of Beach's fracture stimulation operations in the Cooper Basin (which had previously been undertaken under a separate SEO), rather than revising the fracture stimulation SEO (Beach 2012b). Extensive, structured consultation regarding Beach's fracture stimulation and production operations had previously been undertaken during in 2012 and 2015, as well as other industry consultation on very similar operations undertaken in recent years. Following submission of the updated EIR and SEO DPC (now DEM) classified the regulated activities as low impact and the EIR and SEO were referred to government agencies for formal comment.

The 2012, 2015 and 2019 EIRs present summaries of the stakeholders consulted on the fracture stimulation and production EIRs and SEOs, the key issues raised during stakeholder consultation and Beach responses.

7.2 EIR and SEO review (2022-23)

The production SEO and EIR were reviewed in 2022 to support the recent acquisition of licence areas across the Cooper Basin, formerly held and operated by Senex Energy. The updates to the SEO and EIR encompassed the new licence areas and facilities, updates to maps and photographs, review of risk assessment, and updates to legislative references and government departments. There were no changes to the scope or operational activities covered by the SEO and EIR.

Due to the minor amendments to the SEO and EIR, and following consultation with DEM, key Stakeholders were identified, notified via email and invited to provide feedback on the revised SEO and EIR, Feedback from Stakeholders has been incorporated into the SEO and EIR.

A list of stakeholders consulted during the 2022-23 review and a summary of stakeholder responses is provided in Appendix E.

7.3 EIR and SEO Assessment and Consultation (2023)

Revision 15 of the EIR and Revision xx of the SEO were submitted to DEM for assessment in April 2023. DEM undertook additional consultation on the SEO and EIR with the following government agencies:

- Department for Environment and Water (DEW)
- Aboriginal Affairs and Reconciliation (AAR)
- SAAL (South Australia Arid Lands) Landscapes board
- Environment Protection Authority (EPA)
- SA Health

A summary of consultation comments and responses is provided in Appendix E.

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9 Abbreviations and Glossary

Term	Definition
AAL	Associated Activities Licence
ADG Code	Australian Dangerous Goods Code
AGD-AAR	Attorney-General's Department - Aboriginal Affairs and Reconciliation
ALARP	As Low as Reasonably Practical
ANZECC	Australia and New Zealand Environment and Conservation Council (in reference to the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000*)
ANZG	Australian and New Zealand Governments (in reference to the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2018*)
Aquitard	A bed of low permeability adjacent to an aquifer
AS	Australian Standard
Basin-centred gas	Regionally pervasive gas accumulation in the centre of a hydrocarbon-rich basin that exhibits low permeability, abnormal pressure and gas saturation
bbls	barrels (1 barrel = 159 litres)
bpd	barrels per day
BDBSA	Biological Databases of South Australia
Biocide	Chemical compound that can kill living organisms (typically targeted at microorganisms)
BoM	Bureau of Meteorology
BTEX	Benzene, toluene, ethylbenzene, xylene
CAMBA	China-Australia Migratory Bird Agreement
CASA	Civil Aviation Safety Authority
Casing annulus	Space between the casing and any piping, tubing or casing surrounding it
Casing string	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
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
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
Conventional gas	Natural gas trapped in underground structures in highly permeable sandstones
CO_2	Carbon dioxide
D	Darcy
DEH	Department for Environment and Heritage (now DEW)
DEE	Department of the Environment and Energy (Commonwealth)
DEM	Department for Energy and Mining (regulator of the Petroleum and Geothermal Energy Act)
DMITRE	Department of Manufacturing, Innovation, Trade, Resources and Energy (now DEM)
DEW	Department for Environment and Water

Term	Definition
DEWNR	Department of Environment, Water and Natural Resources (now DEW)
DPC-ERD	Department of the Premier and Cabinet – Energy Resources Division (now DEM)
DPTI	Department of Planning, Transport and Infrastructure
DSD	Department of State Development (now DEM)
EIR	Environmental Impact Report prepared in accordance with Section 97 of the *Petroleum and Geothermal Energy Act 2000* and Regulation 10
EMS	Environmental Management System
EPA	Environment Protection Authority (South Australia)
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999
ESP	Electric submersible pump
EPT	Extended production testing
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
Fracturing fluids	The mixture of water and additives injected into a well during fracture stimulation
GAB	Great Artesian Basin
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.
GRE	glass reinforced epoxy
ha	hectare
H_2S	hydrogen sulphide
HDD	horizontal directional drilling
HDPE	high density polyethylene
Hydrotest	hydrostatic testing
ISO	International Standards Organisation
JAMBA	Japan-Australia Migratory Bird Agreement
JSA	Job Safety Analysis
kL	kilolitre (1,000 litres)
km	kilometre
km^2	square kilometres
L	litre
Lithology	Description of the physical characteristics of a rock such as colour, texture, grain size or composition
LTU	Land Treatment Unit
mD	millidarcy
mg/L	milligrams per litre

Term	Definition
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
ML	megalitre
MMSCFD	million standard cubic feet per day
NDT	non-destructive testing
NGER	National Greenhouse and Energy Reporting Act 2007 (Cth)
NPI	National Pollutant Inventory
NORM	Naturally Occurring Radioactive Materials
NPWS	National Parks and Wildlife Service
PAH	polycyclic aromatic hydrocarbon
PEL	Petroleum Exploration Licence
PFW	produced formation water
PIMP	Pipeline Integrity Management Plan
PGE Act	Petroleum and Geothermal Energy Act 2000
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
Pigging	Use of pipeline inspection gauges or 'pigs' to perform various maintenance operations on a pipeline, including cleaning and inspecting the pipeline
PIRSA	Primary Industries and Resources, South Australia (now DEM)
PMS	Pipeline Management System
PPL	Petroleum Production Licence
PRL	Petroleum Retention Licence
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
psi	pounds per square inch (a unit of pressure)
PSV	pressure safety valve
PTW	Permit to Work
QA/QC	Quality Assurance / Quality Control
Ramsar wetland	A Wetland of International Importance listed under the Ramsar Convention (held in Ramsar, Iran 1971).
RFDS	Royal Flying Doctor Service
Ripping	The use of machinery to rake or plough soil to relieve compaction and aerate soil.
ROW	Right of way
SACBJV	South Australian Cooper Basin Joint Venture
SCADA	Supervisory control and data acquisition

Term	Definition
SDS	Safety Data Sheet
SEB	Significant environmental benefit
SEO	Statement of Environmental Objectives prepared in accordance with the *Petroleum and Geothermal Energy Act 2000*
SFL	Special Facilities Licence
Slugcatcher	the unit in which slugs (a quantity of gas or liquid) at the outlet of pipelines are collected or caught
SMS	Safety Management Study
Stimulation	Fracture stimulation of a well, which involves pumping fluid, largely water, at high pressure 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
THPS	TetrakisHydroxymethylPhosphonium Sulfate (a biocide)
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
TPH	Total petroleum hydrocarbons
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"
Waterflood	injection of water back into the formation to maintain the pressure in the formation and improve the sweep efficiency, thus improving oil recovery
Wellhead	The part of an oil or gas well which terminates at the surface, where oil or gas can be withdrawn.
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

10 Document information and history

Rev	Date	Changes made in document	Reviewer/s	Consolidator	Approver
A	04 Dec 2014	Draft	SM/CS	BW/SM	-
0	02 Mar 2015	First review by Beach	BW	BW/SM	SM
1	19 Mar 2015	Beach / JBS&G edits for discussion	Beach	SM	SM
2	19 Mar 2015	Revised following discussions with DSD	SM/TF	BW/SM	SM
3	21 Apr2015	Priority plants added. Minor updates following Beach review	BW	SM	SM
4	10 Jun 2015	Revised to address stakeholder comments	BW	SM	SM/TF
5	17 Jun 2015	Issued for submission to DSD	SM	BW	SM/TF
6	6 Oct 2015	Revised to address DSD comments	TF/ZB/SM	BW	SM/TF
7	10 Dec 2015	Revised following discussions with DSD	TF/AM	SM/TF	SM/TF
8	12 May 2016	Formal consultation comments included for Beach review	SM	BW	SM
9	11 Nov 2016	Updated following Beach review and further consultation on cultural heritage	SM	BW	SM
10	11 Nov 2016	Issued for submission to DSD	SM	BW	TF
11	14 Dec 2017	Integration of fracture stimulation sections	Stephen Milne	Bronny White	Stephen Milne
12	19 Dec 2017	Final Beach edits incorporated. Issued for submission to DPC-ERD	Stephen Milne	Tim Flowers	Stephen Milne Tim Flowers
13	25 Jun 2019	Updated following consultation	Bronny White Stephen Milne	Stephen Milne	Tim Flowers
14	26 Oct 2022	Updated to incorporate Senex permits Issued for Stakeholder review	Stephen Milne Zoë Bowen Mika Porter Michael Henson Tim Flowers	Bronny White Pearl Catford Zoë Bowen	Bill Best
15	31 March 2023	Update to incorporate Senex permits & stakeholder consultation	Candice Nayda Tim Flowers	Zoë Bowen	Bill Best
16	31 October 2023	Update to incorporate DEM consultation	Andrew Fernie Tom Chapman Dave Spence	Zoë Bowen	Bill Best

			Milt Gillies Tim Flowers Mika Porter		
17	10 January 2024	Update to incorporate additional comments from DEM on PFW management	Tim Flowers Mika Porter	Zoë Bowen	Bill Best

Appendix A Additional Information on Fracturing Activities

A. 1. Introduction

This appendix provides additional information on additives used in fracture stimulation operations, based on additives that the main fracture stimulation service providers may use for their fluid systems.

It is expected that the type and purpose of additives that may be used by different providers in the future are likely to be similar to those outlined in this document. Detail on additives proposed for use in specific fracture stimulation operations is provided to DEM as part of the activity notification process.

A. 2. Additives

The following table lists typical fracturing fluid additives and examples of products that may be used by different fracture stimulation service providers.

Table 32: Fracturing fluid additives and examples of products used by different service providers (after Senex 2015)

Additive	Purpose	Halliburton	Baker Hughes	Schlumberger
Acid	Removes scale and cleans wellbore prior to fracturing treatment.	HCl		
Acid Inhibitor	Protects wellbore components and treatment equipment from corrosive action of acid.	DCA-17001, DCA-17004		
Biocide / Bactericide	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. Limits gel destruction due to bacterial action.	BE-9, BE-6, Tolcide, BE-7	Magnacide 575	M275 Microbiocide
Breaker	Reduces fluid viscosity after the treatment to aid quick clean up in flowback	CLBEAU196, CLBXTAU121, CLBCREAU81, DCA-13003, DCA-13002, DCA-1100	Enzyme G-I, High Perm CRB	J218, J479
Clay control	Prevents clays from swelling which can stop fluid flow post treatment.	DCA-16001, KCl, NaCl	ClayCare 2C	L071
Crosslinker	Increases fluid viscosity to help activate and carry proppant.	DCA-19002, DCA19001, BC-140C, CLLAU301	XLW-30G	J610
Foamer	Used to transport and place proppant into fractures.	HC-2A		
Friction reducer	Allows fracture fluid to move down the wellbore with the least amount of resistance.	DCA-23001	FRW-16	J568
Gelling agent / viscosifier	Adds viscosity to the fluid to help carry proppant.	CLWGAU421, DCA-25005, DCA-25003, DCA-25007	GLFC-5B	J580 Guar Polymer
Iron Chelating Agent	Helps prevent the precipitation of hydrated iron oxides from spent acid following an acidising treatment.	FE-2		

Additive	Purpose	Halliburton	Baker Hughes	Schlumberger
Neutralising agent	Counteracts the corrosive effect of acids or acidic treatment fluids on equipment.	DCA-14003, DCA-14004		
Non-emulsifier	Prevents emulsions forming and keeps oil separate from the fracturing / formation fluids during flowback		NE-118	
pH Buffer	Used to adjust the pH of the fluid and promotes hydration of gel.	Caustic 50%, Acetic acid 60%	BF-7L	HCL
Scale inhibitor	Prevents build-up of certain materials (i.e. scale) on sides of well casing and surface equipment	DCA-30001		
Surfactant	Assists in recovery of fluid from the well	Lo-surf 300, DCA-32002, CLSAU352, DCA32009	GasFloG	F112

A. 3. Constituents

An example of the chemical constituents that may be included in a fracturing fluid formulation are listed in the following table. This listing is based on the Halliburton formulation for an unconventional gas target.

Table 33: Example of constituents in fracturing fluid additives based on Halliburton unconventional gas formulation (after Beach 2012a)

Constituent Name	Generic Name	CAS Number	Common Use	Hazardous as Appears on SDS
1-(Benzyl) quinolinium Chloride	Quaternary Ammonium Salt	15619-48-4	Industrial and Commercial Disinfectant	Yes
2-Bromo-2-nitro-1,3-propanediol	Bronopol	52-51-7	Anti-Bacterial Soap, Skin Cleansing (Wipes), Hand Wash and Body Shampoo	Yes
Acetic Acid	Organic Acid	64-19-7	Processed Fruit, Cheese, Meat and Poultry	Yes
Acid Red 1	Red Dye	3734-67-6	Aloe and Olive Oil Cream, Stainless Steel Polish, FDA Approved Colorant, Industrial Buffer Solution	No
Acid Red 27	Red Dye	915-67-3	Laboratory Dye, Industrial Buffer Solution	No
Acid Violet 12	Violet Dye	6625-46-3	Air Freshener, Commercial pH Indicator Solution	No
Acrylate Polymer	Acrylate Polymer	*	No Common Product Uses Identified	No
Alcohol	Alcohol	*	Commercial Defoamer	No
Alcohols, C12-C16, Ethoxylated	Alcohols, Ethoxylated	68551-12-2	Car Wash Liquid, Laundry Stain Remover, Air Freshener	No
Aldehyde	Aldehyde	*	Non-Alcoholic Beverages, Ice Cream, Candy, Baked Goods, Chewing Gum	Yes

Constituent Name	Generic Name	CAS Number	Common Use	Hazardous as Appears on SDS
Alkylphenols	Alkylphenols	*	Metal Soldering Flux, Commercial/Industrial Cleaners and Degreasers	No
Amines, Coco Alkyl, Ethoxylated	Ethoxylated Amine	61791-14-8	Commercial Bathroom Cleaner, Medical Rinsing Solution, Photography Printer Ink	No
Ammonium Phosphate	Inorganic salt	7722-76-1	Milk Products	No
Ammonium Sulfate	Inorganic Salt	7783-20-2	Lawn Insecticide, Fertilizer, Fire Extinguishing Agent, Insulation, Body Wash, Caramel Food Coloring Agent	Yes
Borate Salt	Borate Salt	*	Agricultural Plant Food/Fertilizer, Industrial Glass Manufacturing Additive	Yes
Chlorous Acid, Sodium Salt	Inorganic Salt	7758-19-2	Food Additive	Yes
Citric Acid	Organic Acid	77-92-9	Fruit Juice, Dishwasher Cleaner, All Purpose Cleaner, Hand Soap	Yes
Crystalline Silica, Quartz	Silica	14808-60-7	Cat Litter, Tile Mortar, Arts & Crafts Ceramic Glaze	Yes
Disodium Octaborate Tetrahydrate	Inorganic Salt	12008-41-2	Wood Preservative, Agricultural Pesticide	Yes
Ether Compound	Ether Compound	*	Air Freshener, Food Flavoring Agents	No
Ethylene Glycol Monobutyl Ether	Glycol Ether	111-76-2	Paint Removal Gel, Citrus Household Cleaner, Sterilizing Wipes, Commercial Lubricating Oil	Yes
Fatty Acids, Tall Oil	Fatty Acids, Tall Oil	61790-12-3	Car Polish, Industrial Hand Cleaner	No
Glycerine	Glycerine	56-81-5	Laundry Stain Remover, Antimicrobial Soap, Toothpaste, Lipstick	No
Guar Gum Derivative	Guar Gum Derivative	*	Fabric Softener, Hair Straightening Aid, Shampoo, Body Lotion, Shaving Cream	Yes
Hydrochloric Acid	Inorganic Acid	7647-01-0	Table Olives, Unripened Cheese, Cottage Cheese	Yes
Isopropanol	Alcohol	67-63-0	Tape Head Cleaner, Hops Extract used for Beer, Air Freshener	Yes
Methanol	Alcohol	67-56-1	Furniture Refinisher, Liquid Hand Soap, Windshield Washer Concentrate, Hops Extract	Yes
Naphthenic Acid Ethoxylated	Cyclo Alkyl Acid Ethoxylate	68410-62-8	No Common Product Uses Identified	No
Polyacrylamide Copolymer	Polyacrylamide Copolymer	*	Mulch Binder/Dust Control Agent, Moisture Control Agent for Gardens, Emulsion Agent in Industrial Water Treatment	No

Constituent Name	Generic Name	CAS Number	Common Use	Hazardous as Appears on SDS
Polyacrylate	Polyacrylate	*	Laundry Detergent, Glass Cleaning Solution, Dishwashing Detergent	Yes
Polyacrylate	Polyacrylate	*	Paint Hardener, Detergent, Children's Bathwater Additive, Food Defoaming Agent	No
Polyethoxylated Fatty Amine Salt	Ethoxylated Amine	61791-26-2	Toilet Bowl Cleaner, Car Glass Polish	No
Proprietary	Proprietary	*	Hair Colorant, After Shave, Fabric Softener, Deodorant, Air Freshener	No
Proprietary	Proprietary	*	Floor Soap, Shampoo, Car Shampoo, Nail Polish Remover, Insect Repellent	No
Proprietary	Proprietary	*	Air Freshener, Fragrance, Scent for Soap and Household Cleaning Products	No
Proprietary	Proprietary	*	Medical Disinfectant, Automotive Rust Remover, Commercial Floor Cleaner	No
Proprietary	Proprietary	*	All-Purpose Household Cleaner, Fabric Softener, Pool Algae Control, Disinfecting First Aid Wipes	No
Proprietary	Proprietary	*	Laundry Detergent, Dishwashing Liquid, Toothpaste, Pool pH Adjustment Liquid	No
Proprietary	Proprietary	*	Air Freshener, Perfume Oil, Flea Repellant, Insect Repelling Candle	No
Proprietary	Proprietary	*	Deodorant, Body Hair Bleach, Leather Cleaner, First Aid Burn Treatment	No
Proprietary	Proprietary	*	Hydraulic Clutch Fluid, Brake Fluid	No
Quaternary Ammonium Salt	Quaternary Ammonium Salt	*	Industrial and Commercial Water Acidity Neutralizing Solution	Yes
Silicate	Silicate	*	Industrial Joint Compound, Industrial Construction Thickening Agent	No
Silica Gel	Silica	112926-00-8	Mouthwash, Toothpaste, Powdered Sugars	No
Sodium Carbonate	Carbonate	497-19-8	Laundry Detergent, Dishwashing Liquid, Toothpaste, Pool pH Additive	No
Sodium Chloride	Inorganic Salt	7647-14-5	Concentrations greater than 1%: Food Grade Salt, Laundry Detergent, Aquarium Fish Medication, Ice Melting Product	Yes
Sodium Hydroxide	Caustic Soda	1310-73-2	Laundry Detergent, Toothpaste, Cocoa, Milk Products, Chocolate	Yes
Sodium Iodide	Inorganic Salt	7681-82-5	Light Bulbs, Infant Food	No
Sodium Sulfate	Sulfate	7757-82-6	Dishwasher Detergent, Laundry Detergent, Liquid Hand Soap, Toothpaste	No

Constituent Name	Generic Name	CAS Number	Common Use	Hazardous as Appears on SDS
Terpene	Terpene	*	Laundry Soap, Furniture Oil, Thickened Stripper for Grease, Paint, Ink, and Gum Removal	Yes
Tributyltetradecylphos-phonium Chloride	Organic Phosphonium Salt	81741-28-8	Industrial Water Treatment Agent	Yes
Water	Water	7732-18-5	Water Present in Additives (Not Water Used as Carrier Fluid)	No

Notes:

*In certain cases, a small percentage of constituents may be protected under existing agreements between Halliburton and suppliers and customers. In these situations, CAS numbers are not provided by Halliburton – but the constituent's listing as hazardous on the MSDS is, as well as other common uses when identified.

**Items identified in the "common uses" column were chosen in part because the constituents found in these products exist in roughly the same concentrations as would be found in fracturing materials at the wellhead. In some cases, however, concentrations present in consumer products are either not publicly available or in higher percentages than would be found at the well site.

A. 4. Additional Details and Safety Data Sheets

Additional details and Safety Data Sheets for the fracturing fluid additives listed above are available at the following websites:

Fracture stimulation providers:	
Halliburton	https://www.halliburton.com
Schlumberger	https://www.slb.com/completions/stimulation
Baker Hughes	https://www.bakerhughes.com/completions/stimulation-and-fracturing

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

Government web sites:	
DEM	https://www.energymining.sa.gov.au/industry/energy-resources
DEHP	https://environment.des.qld.gov.au/management/activities/non-mining/fraccing
Industry bodies:	
APPEA	https://www.appea.com.au
API	https://www.api.org

Appendix B Land Systems of North East South Australia

Land System	Land form	Description
Blanche	Salt lakes	Saltlake country often with pale dunes on lake margins. Lake margins of Bladder Saltbush and Samphire; Cobbler Desert with Nitrebush, Samphire, Native Myrtle and Canegrass.
Bloodwood	Dunefields Gibber	Scattered dunes and sand plains interspersed with gibber gravel flats typical of south eastern Cordillo Downs. Red irregular shaped sand dunes with Sandhill Spider-flower, Sandhill Wattle and Sandhill Canegrass; sandplains with Bloodwood and Lobed Spinifex, plains with fine gibber gravel, Mitchell grass, Neverfail and herbs.
Collina	Dunefields Salt Lakes	Highly eroded and saline dunefield, of truncated parabolic dunes adjacent and north of the Lake Callabonna, Blanche, Gregory complex with predominantly Nitrebush dunes with broad saline flats and small plains and many small saline depressions.
Cooper	Floodplains Wetlands Dunefields	Channels, lakes, swamps and crabhole flats of Cooper Creek floodplain. Main channels with Coolibah, River Red Gum (upstream channels), Beantree, River Cooba, River Emubush, Broughton Willow and Lignum; swamps with Queensland Bluebush, Canegrass, Old Man Saltbush, Samphire and Lignum; lakes lined with Coolibah, River Couch and rushes; crabhole flats with Copperburrs and herbs; pale dunes and sandplains with Whitewood / Sandhill Wattle and Sandhill Canegrass; red longitudinal dunes with Sandhill Wattle and Sandhill Canegrass; interdune flats with variable soils and vegetation.
Diamantina	Floodplains Wetlands Dunefields	Channels and floodplains of Diamantina River. Land units as for Cooper land system; includes the intricately braided channels of Goyder Lagoon with Lignum / Broughton Willow / Queensland Bluebush and Canegrass.
Eulpa	Dunefields	Dunefield in the north east corner of the district on Cordillo Downs. Sand dunes with Sandhill Canegrass and scattered Sandhill Wattle; interdune flats with Copperburrs, Neverfail and annual grasses.
Hope (formerly Strzelecki)	Dunefields	Dunefields of Strzelecki Desert in the south east of the district. Red dunes with Whitewood, Mulga, Sandhill Wattle, Sandhill Canegrass and Lobed Spinifex; sandy interdune flats with Colony Wattle, Straggly Corkbark over Copperburrs and annual grasses; clay swales with Mitchell Grass, Neverfail and Plate Grass.
Jeljendi	Dunefield	Long high dunes of the eastern Simpson Desert with Sandhill Wattle and Waxy Wattle over Sandhill Canegrass and Lobed Spinifex. Alluvial floodouts with Coolibah, Queensland Bluebush, Lignum and Old Man Saltbush; main channels with Coolibah, Broughton Willow and River Cooba.
Kachumba	Floodplains	Alluvial outwash plains and channels of Kachumba and Rainbow Plains on Cordillo Downs. Alluvial plains with Canegrass, Queensland Bluebush and Lignum with Native Millet and Copperburrs; creeklines with River Red Gum
Ketietoonga	Dunefields	Dunefields, swamps and lakes of Pandie Pandie, western Cordillo Downs and northern Innamincka. Long red dunes with Lobed Spinifex, Sandhill Canegrass and scattered Sandhill Wattle and Narrowleaf Hopbush; variable interdune flats with Blackbush, Starbush and Neverfail on clay flats and Lobed Spinifex on sandy flats; swamps with Canegrass and Lignum; lakes fringed with Samphire and Copperburrs on lake beds.
Koonchera	Gibber Dunefields	Gently undulating gibber plains with Mitchell grass, Katoora and Bladder Saltbush. Run on depressions and swamps with Queensland Bluebush, Cottonbush, Canegrass and Neverfail; scattered long red sand dunes with Sandhill Canegrass and Desert Cynanchum; drainage lines with Coolibah, Plumbush, River Emubush and River Cooba.
Lamamour	Tablelands Gibber	Gibber low hills and tableland of Lamamour Plateau on Cordillo Downs. Low hills and undulating plains with Barley and Curly Mitchell Grass, Neverfail and Common Bottlewashers; creeks with River Red Gum and Red Mulga; rocky hills and mesas with Deadfinish and Silvertails.

Land System	Land form	Description
Marqualpie	Dunefields	Jumbled dunes, sandplains, channels and swampy flats abutting tableland country on Cordillo Downs and Innamincka. Red dunes with Sandhill Wattle, Sandhill Spider flower and Rattlepods over dense Spinifex; a variety of flats with Lignum, Canegrass, Queensland Bluebush, Neverfail, Mitchell Grass and Coolibah on the channels and deeper depressions; sandplains with Mulga, Deadfinish and Bloodwood over Woolybutt, Spinifex and annual grasses.
Merninie	Tableland Gibber	Gibber tableland and mesas of eastern Innamincka. Tableland and low hills with Mitchell Grass, Neverfail and Copperburrs; mesas with Emubushes, Gidgee and Mulga over Bladder Saltbush; drainage lines with Red Mulga, Gidgee and River Red Gum; alluvial plains with Mitchell Grass, Copperburrs and forbs.
Mulligan	Floodplains Wetlands Dunefields	Floodplains of Mulligan River which enters South Australia from Queensland on Alton Downs and flows south to Goyder Lagoon on Clifton Hills. Channels with Coolibah, Broughton Willow, River Cooba, Beantree and Lignum; floodout flats with Old Man Saltbush, Cottonbush and Queensland Bluebush; red dunes with Lobed Spinifex, Sandhill Canegrass, Sandhill Wattle and Sandplain Wattle.
Mumpie	Tablelands	Undulating gibber tableland country. Tableland with gilgais supporting Barley and Curly Mitchell Grass, Cottonbush, Samphire, Bladder Saltbush, Neverfail and Bindyis; mesas with scattered Mulga and low Bluebush; larger creeks with River Red Gum, Coolibah, Broughton Willow and River Cooba; minor creeks with Deadfinish and Plumbush.
Simpson	Dunefield	Active longitudinal dunes running generally north south. Sandhills are dominated by Sandhill Canegrass with scattered Mulga, Horse Mulga, Marpoo, Needlebush, Hopbush and Cassias; dune swales support Spinifex with Sandhill Wattle, Sandplain Wattle and various shrubs.
Strzelecki	Dunefield	Dune fields of Strzelecki Desert in the south east of the district. Red dunes with Whitewood, Mulga, Sandhill Wattle, Sandhill Canegrass and Lobed Spinifex; sandy interdune flats with Colony Wattle, Straggly Corkbark over Copperburrs and annual grasses; clay swales with Mitchell Grass, Neverfail and Plate Grass.
Sturts	Gibber plains Tablelands	Southern parts of Sturts Stony Desert with gibber downs and scattered red dunes. Lake Howitt and other saline lakes; the mesa jump ups around Mungerannie Gap; undulating gibber plains with gilgais with Neverfail, Mitchell Grass, Cottonbush, scattered Lignum and Canegrass swamps; sandplains with Bladder Saltbush, Mitchell Grass and Katoora; mesas with Deadfinish, low Bluebush, Blackbush and Shrubby Twinleaf; dunes with Sandhill Wattle overS and Sandhill Canegrass.
Tingana (formerly Della or Strzelecki)	Dunefield	Dune Fields of Strzelecki Desert in the south east of the district. Red dunes with Whitewood, Mulga, Sandhill Wattle, Sandhill Canegrass and Lobed Spinifex; sandy interdune flats with Colony Wattle, Straggly Corkbark over Copperburrs and annual grasses; clay swales with Mitchell Grass, Neverfail and Plate Grass.
Tirari	Dunefields Floodplains	Sandhills and flats of the Tirari Desert east of Lake Eyre often known as Peachawarinna country. Includes channels and floodplains of the lower Cooper, Warburton and Kalakoopah Creeks; dunes with Sandhill Canegrass, Desert Cynanchum and scattered Sandhill Wattle; variable flats with Starbush, low Bluebush and annual grasses; channels with Coolibah and scattered Nitrebush, Goosefoot swamps; saltlakes and claypans with Samphire.
Warburton	Floodplains Dunefields	Channels, floodplain and associated sand dunes of Warburton Creek. Channels with Coolibah, Broughton Willow, River Cooba and Lignum; swamps with Queensland Bluebush, Old Man Saltbush and Lignum; sand dunes with Canegrass, Desert Cynachium and Sandhill Wattle.
Wirringina	Dunefields Salt lakes	Red sandplains, dunes and sand accumulations on stony country. Salt lakes including Lake Harry; sand plains and dunes with Needlewood, Sandhill Wattle, Sandhill Canegrass and Starbush; saltlakes with samphire, Tangled Poverty Bush and Water Weed; kopi lunettes with Blackbush, Bladder Saltbush and Tates Bindyi; creeks with Coolibah, River Cooba and Old Man Saltbush.

Appendix C Threatened Species Recorded in the Region

Listed plant species recorded or predicted in the area[1]

Species	Common Name	Conservation Status[2]	
		AUS	SA
*Acacia carneorum**	Needle Wattle	V	V
Acacia confluens	Arkaroola Wattle		V
Acacia georginae	Georgina Gidgee		R
Acacia loderi	Nealie		R
*Acacia peuce**	Waddy, Waddi, Waddy-wood, Birdsville Wattle	V	
Acacia pickardii	Pickard's Wattle	V	R
Acacia tenuissima	Slender Wattle		R
Atriplex eichleri	Eichler's Saltbush		R
Atriplex kochiana	Koch's Saltbush		V
Bergia occultipetala			V
Bulbostylis turbinata			R
Calandrinia stagnensis			R
Callitriche sonderi	Matted Water Starwort		R
Codonocarpus pyramidalis	Slender Bell-fruit, Camel Poison	V	E
Cyperus bifax	Downs Flat-sedge		R
Cyperus concinnus			R
Cyperus dactylotes			V
Cyperus nervulosus			R
Elacholoma prostrata	Small Monkey-flower		R
Eleocharis papillosa	Dwarf Desert Spike-rush	V	R
Eleocharis plana	Flat Spike-rush		R
Eragrostis lacunaria	Purple Love-grass		R
Eremophila polyclada	Twiggy Emubush		R
Eremophila subfloccosa ssp. *glandulosa*	Green-flower Emubush		R
Eriocaulon carsonii ssp. *carsonii*	Salt Pipewort, Button Grass	E	E
Eryngium vesiculosum	Prostrate Blue Devil		R
Frankenia cupularis			R
Frankenia plicata		E	V
Frankenia subteres			R
Gilesia biniflora	Western Tar-vine		R
Gratwickia monochaeta			R

Species	Common Name	Conservation Status[2]	
		AUS	SA
Gymnoschoenus sphaerocephalus	Button Grass		E
Iotasperma sessilifolium			R
Neurachne lanigera	Woolly Mulga-grass		R
Nymphoides crenata	Wavy Marshwort		R
Ophioglossum polyphyllum	Large Adder's-tongue		R
Orobanche cernua var. *australiana*	Australian Broomrape		R
Osteocarpum acropterum var. *deminutum*	Wingless Bonefruit		R
Osteocarpum pentapterum	Five-wing Bonefruit		E
Phlegmatospermum eremaeum	Spreading Cress		R
Pimelea penicillaris	Sandhill Riceflower		R
Podolepis muelleri	Button Podolepis		V
*Pterostylis xerophila**	Desert Greenhood	V	V
Roepera humillima	Small-fruit Twinleaf		R
Sclerolaena blackiana	Black's Bindyi		R
*Sclerolaena walkeri**		V	
Senecio gypsicola	Gypsum Groundsel		R
Senecio laceratus	Cut-leaf Groundsel		R
Stylidium desertorum			V
Swainsona behriana	Behr's Swainson-pea		V
Swainsona fuscoviridis	Dark Green Swainson-pea		R
Swainsona leeana	Lee's Swainson-pea		R
Swainsona microcalyx	Wild Violet		R
Swainsona oligophylla			R
Synostemon ramosissimus			R
Tecticornia cupuliformis			V
Utricularia violacea	Violet Bladderwort		R
Wurmbea deserticola	Desert Nancy		R

[1]Search area is 26°S-30°S, 138°E-141°E. Database records and species ratings were current at the time of searching (May 2022) (see NatureMaps 2022, DAWE 2022b).

[2]Conservation status under the SA *National Parks and Wildlife Act 1972* & Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*: R – Rare, V – Vulnerable, E – Endangered, EX – Extinct

* Indicates the species has been predicted to occur by the protected matters search tool (DAWE 2022b) but has not been recorded in the BDBSA (NatureMaps 2022).

Listed fauna species recorded or predicted in the area[1]

Species	Common Name	Conservation Status[2]	
		AUS	SA
Birds			
Actitis hypoleucos	Common Sandpiper		R
*Amytornis barbatus barbatus**	Bulloo Grey Grasswren, Grey Grasswren (Bulloo)	E	
Amytornis barbatus diamantina			R
*Amytornis merrotsyi merrotsyi**	Short-tailed Grasswren (Flinders Ranges)	V	V
Amytornis modestus	Thick-billed Grasswren	V	
Amytornis modestus cowarie	Thick-billed Grasswren (NE)	sp	
Amytornis modestus raglessi	Thick-billed Grasswren (northern FR)	sp	
Anhinga novaehollandiae novaehollandiae	Australasian Darter		R
Anseranas semipalmata	Magpie Goose		E
Antigone rubicunda	Brolga		V
Aphelocephala pectoralis	Chestnut-breasted Whiteface		R
Aprosmictus erythropterus erythropterus	Red-winged Parrot		R
Ardea intermedia plumifera	Plumed Egret		R
Ardeotis australis	Australian Bustard		V
Arenaria interpres interpres	Ruddy Turnstone		R
Biziura lobata menziesi	Musk Duck		R
Bubulcus ibis coromandus	Eastern Cattle Egret		R
Burhinus grallarius	Bush Stonecurlew		R
Calidris ferruginea	Curlew Sandpiper	CE	E
Calidris melanotos	Pectoral Sandpiper		R
Calidris subminuta	Long-toed Stint		R
Charadrius mongolus mongolus	Lesser Sand Plover		R
Chlamydera maculata	Spotted Bowerbird		E
Cladorhynchus leucocephalus	Banded Stilt		V
Conopophila whitei	Grey Honeyeater		R
Dromaius novaehollandiae	Emu		ssp[3]
Egretta garzetta nigripes	Little Egret		R
Elanus scriptus	Letter-winged Kite		V
Emblema pictum	Painted Finch		R
Epthianura crocea crocea	Yellow Chat		E
Falco hypoleucos	Grey Falcon	V	R

Species	Common Name	Conservation Status[2]	
		AUS	SA
Falco peregrinus macropus	Peregrine Falcon		R
Falco subniger	Black Falcon		R
Gallinago hardwickii	Latham's Snipe		R
Geophaps plumifera leucogaster	Spinifex Pigeon		R
Grantiella picta	Painted Honeyeater	V	R
Haliaeetus leucogaster	White-bellied Sea Eagle		E
Hamirostra melanosternon	Black-breasted Buzzard		R
Hieraaetus morphnoides	Little Eagle		V
*Limosa lapponica baueri**	Nunivak Bar-tailed Godwit, Western Alaskan Bar-tailed Godwit	V	R
Limosa limosa melanuroides	Black-tailed Godwit		R
Lophochroa leadbeateri	Major Mitchell's Cockatoo		R
Lophoictinia isura	Square-tailed Kite		E
Melanodryas cucullata	Hooded Robin		ssp[3]
Melithreptus gularis laetior	Golden-backed Honeyeater		R
Microeca fascinans	Jacky Winter		ssp[3]
Myiagra inquieta	Restless Flycatcher		R
Neophema chrysostoma	Blue-winged Parrot		V
Neophema elegans elegans	Elegant Parrot		R
Ninox connivens connivens	Barking Owl		R
Northiella haematogaster (NC)	Bluebonnet (Eastern and Naretha)		ssp[3]
Oriolus sagittatus sagittatus	Olive-backed Oriole		ssp[3]
Oxyura australis	Blue-billed Duck		R
*Pedionomus torquatus**	Plains-wanderer	CE	E
Pezoporus occidentalis	Night Parrot	E	E
Phaps histrionica	Flock Bronzewing		R
Plegadis falcinellus	Glossy Ibis		R
Pluvialis fulva	Pacific Golden Plover		R
Podiceps cristatus australis	Great Crested Grebe		R
Rostratula australis	Australian Painted Snipe	E	V
Spatula rhynchotis	Australasian Shoveler		R
Stictonetta naevosa	Freckled Duck		V
Thinornis cucullatus cucullatus	Hooded Plover	V	V
Tringa glareola	Wood Sandpiper		R

Species	Common Name	Conservation Status[2]	
		AUS	SA
Tyto longimembris longimembris	Eastern Grass Owl		R
Tyto novaehollandiae novaehollandiae	Australian Masked Owl		E
Zapornia tabuensis	Spotless Crake		R
Fish			
Mogurnda clivicola	Flinders Ranges Mogurnda, Flinders Ranges Purple-spotted Gudgeon	V	CE
Mammals			
Dasyuroides byrnei	Kowari	V	E
Leporillus conditor	Greater Stick-nest Rat	V	V
Macrotis lagotis	Greater Bilby (Bilby)	V	V
Mormopterus eleryi	Bristle-faced Free-tailed Bat		V
Notomys cervinus	Fawn Hopping-mouse		V
Notomys fuscus	Dusky Hopping-mouse	V	V
Petrogale xanthopus xanthopus	Yellow-footed Rock-wallaby	V	V
Pseudomys australis	Plains mouse, Palyoora	V	V
Saccolaimus flaviventris	Yellow-bellied Sheath-tailed Bat		R
Tachyglossus aculeatus	Short-beaked Echidna	ssp[3]	ssp[3]
Trichosurus vulpecula	Common Brushtail Possum		R
Reptiles			
Aspidites ramsayi	Woma		R
Austroblepharus kinghorni	Blacksoil Skink		R
Ctenotus astarte	Ashy Downs Ctenotus		R
Ctenotus joanae	Blacksoil Ctenotus		R
Emydura macquarii	Macquarie Tortoise		V
Morelia spilota	Carpet Python		R
Pseudonaja guttata	Speckled Brown Snake		R
Frogs			
Cyclorana cultripes	Knife-footed Frog		R

[1]Search area is 26°S-30°S, 138°E-140°E. Database records and species ratings were current at the time of searching (May 2022) (see NatureMaps 2022, DAWE 2022b).

[2]Conservation status under the SA *National Parks and Wildlife Act 1972* & Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*: R – Rare, V – Vulnerable, E – Endangered, CE – Critically Endangered, EX – Extinct

[3]Subspecies is listed under the *National Parks and Wildlife Act 1972*, however subspecies information is not contained in BDBSA records.

* Indicates the species has been predicted to occur by the protected matters search tool (DAWE 2022b) but has not been recorded in the BDBSA (NatureMaps 2022).

Appendix D Beach Energy Priority Plant List

Common Name	Scientific Name	Perennial	Years to maturity	Regenerates readily from seed	Regenerates readily from root-stock	Conservation Priority*	Habitat / Occurrence
Trees							
Beefwood	*Grevillea striata*	✓	30-50			1	Acacia Woodlands (Q) / Mulga Woodlands (Q) / Dunefields (SA, Q)
Belah / Black Oak / Scrub She-oak	*Casuarina cristata*	✓				1	Acacia Woodlands (Q)
Bendee	*Acacia catenulata*	✓				2	Mulga Woodlands (Q)
Bloodwood	*Corymbia tumescens*	✓	30-50	✓		1	Dunefields (SA, Q)
Boonaree / Bullock Bush	*Alectryon oleifolius*	✓				1	Acacia Woodlands (Q) / Mulga Woodlands (Q)
Bowyakka	*Acacia microsperma*	✓				1	Acacia Woodlands (Q)
Brigalow	*Acacia harpophylla*	✓				1	Mulga Woodlands (Q) - Cooper Basin is on W limit of known occurrence
Broughton Willow	*Acacia salicina*	✓	30-50	✓	✓	2	Floodplains (SA,Q) / Drainage lines (SA,Q)
Bull Oak	*Hakea chordophylla*	✓	30-50			1	Dunefields (SA, Q)
Coolibah	*Eucalyptus coolabah*	✓	30-50	✓		1	Floodplains (SA,Q) / Drainage lines (SA,Q
Corkwood Oak / Bootlace Oak	*Hakea lorea*	✓				1	Acacia Woodlands (Q)- Cooper Basin is on W & S limit of known occurrence
Emu apple / Sour plum	*Owenia acidula*	✓	30-50	✓		2	Dunefields (SA,Q) Acacia Woodlands (Q) / Mulga Woodlands (Q)
Ghost Gum	*Corymbia blakei*	✓				1	Mulga Woodlands (Q)

Common Name	Scientific Name	Perennial	Years to maturity	Regenerates readily from seed	Regenerates readily from root-stock	Conservation Priority*	Habitat / Occurrence
Gidgee / Stinking Wattle	*Acacia cambagei*	✓	30-50			2	Floodplains (SA,Q) / Drainage lines (SA,Q) / Dunefields (SA, Q) / Tablelands (SA, Q)
Ironwood	*Acacia excelsa*					1	Acacia Woodlands (Q)- Cooper Basin is on W limit of known occurrence
Lime Bush / Desert Lime	*Citrus glauca*	✓				1	Acacia Woodlands (Q) / Mulga Woodlands (Q)
Long-fruited Bloodwood	*Corymbia terminalis*	✓				1	Mulga Woodlands (Q)
Mountain Yapunyah / Yapunyah, Thozet's Box	*Eucalyptus thozetiana*	✓				1	Acacia Woodlands (Q)
Mulga	*Acacia aneura*	✓	30-50			2	Dunefields, rocky hills and ranges (SA,Q) Acacia Woodlands (Q) / Mulga Woodlands (Q)
Narrow-leaf Bumble Tree	*Capparis loranthifolia*	✓				1	Acacia Woodlands (Q) / Mulga Woodlands (Q)
Native Apricot	*Pittosporum phylliraeoides*	✓	30-50			1	Dunefields (SA,Q) / Floodplain (SA,Q) / Gibber Plain (SA,Q)
Poplar Box	*Eucalyptus populnea*	✓				2	Acacia Woodlands (Q) / Mulga Woodlands (Q)
Queensland Bean Tree / Bauhinia	*Lysiphyllum gilvum*	✓	50-100			1	Watercourses (SA,Q) / Floodplains (SA,Q)
Queensland Peppermint	*Eucalyptus exserta*	✓				2	Acacia Woodlands (Q)- Cooper Basin is on W limit of known occurrence
Red Ash	*Alphitonia excelsa*	✓				2	Acacia Woodlands (Q)- Cooper Basin is on W & S limit of known occurrence

Common Name	Scientific Name	Perennial	Years to maturity	Regenerates readily from seed	Regenerates readily from root-stock	Conservation Priority*	Habitat / Occurrence
Red Mulga / Minni ritchi	*Acacia cyperophylla*	✓	30-50			2	Watercourses in Tablelands (SA,Q)
River Cooba	*Acacia stenophylla*	✓	30-50	✓		2	Watercourses, Floodplains (SA,Q)
River Paperbark	*Melaleuca trichostachya*	✓	30-50	✓	✓	1	Watercourses (SA,Q)
River Red Gum	*Eucalyptus camaldulensis (var.obtuse)*	✓	50-100	✓		1	Watercourses (SA,Q) / Floodplains (SA,Q)
Sandalwood / Plum Bush (root parasite)	*Santalum lanceolatum*	✓	30-50	✓		2	Dunefields (SA,Q) / Floodplain (SA,Q) / Gibber Plain (SA,Q) Acacia Woodlands (Q) / Mulga Woodlands (Q)
Silver-leaved Ironbark	*Eucalyptus melanophloia*	✓				1	Acacia Woodlands (Q) / Mulga Woodlands (Q) - Cooper Basin is on W limit of known occurrence
Straggly Corkbark	*Hakea eyreana*	✓	30-50			1	Dunefields (SA,Q) / Watercourses (SA,Q) / Gibber Plain (SA,Q)
Vine Tree / Supplejack/ Kumianna	*Ventilago viminalis*	✓				2	Acacia Woodlands (Q) / Mulga Woodlands (Q)
Whitewood	*Atalaya hemiglauca*	✓	30-50	✓		2	Dunefields (SA,Q) / Acacia Woodlands (Q) / Mulga Woodlands (Q
Wild Orange (SA) / Bumble Tree (Qld)	*Capparis mitchellii*	✓	30-50			1	Floodplains (SA,Q) / Acacia Woodlands (Q) / Mulga Woodlands (Q)
Wilga	*Geijera parviflora*	✓				2	Acacia Woodlands (Q) / Mulga Woodlands (Q)- Cooper Basin is on W limit of known occurrence
Yapunyah	*Eucalyptus ochrophloia*	✓	30-50			2	Floodplains (SA,Q) / Drainage lines (SA,Q)

Common Name	Scientific Name	Perennial	Years to maturity	Regenerates readily from seed	Regenerates readily from root-stock	Conservation Priority*	Habitat / Occurrence
Shrubs							
Bean Bush / Fire Bush / Native Senna	*Senna pleurocarpa*	✓				4	Acacia Woodlands (Q) / Mulga Woodlands (Q)
Bitter Bark	*Alstonia constricta*	✓				1	Acacia Woodlands (Q) / Mulga Woodlands (Q)- Cooper Basin is on W limit of known occurrence
Blackbush	*Maireana pyramidata*	✓		✓		3	Dunefields (SA,Q) / Floodplains (SA,Q) / Gibber Plains (SA,Q) /
Black-fruit Bluebush	*Maireana melanocarpa*					3	Mulga Woodlands (SA) – Cooper Basin is N & E limit of known occurrence
Bladder Saltbush	*Atriplex vesicaria*	✓	5-10	✓		3	Dunefields (SA,Q) / Floodplains (SA,Q) / Gibber Plains (SA,Q) / Salt lakes (SA)(
Bluebush Pea / Loose-flowered Rattlepod	*Crotalaria eremaea*	✓	3-5	✓		4	Dunefields (SA,Q)
Boobialla	*Myoporum montanum*	✓				2	Acacia Woodlands (Q) / Mulga Woodlands (Q)
Bristly Sea-heath	*Frankenia serpyllifolia*	✓	10-30			3	Dunefields (SA,Q) / Floodplains (SA,Q) / Gibber Plains (SA,Q)
Broom Bush / Warrior Bush / Currant Bush	*Apophyllum anomalum*	✓				1	Acacia Woodlands (Q) / Mulga Woodlands (Q)- Cooper Basin is on S & W limit of known occurrence
Buckbush / Roly poly	*Salsola australis*	✓	1-3			4	Dunefields (SA,Q) / Floodplains (SA,Q)
Butterfly Bush	*Petalostylis labicheoides*	✓				3	Acacia Woodlands (Q) / Mulga Woodlands (Q)- Cooper Basin is on W, S & N (SA) limit of known occurrence

Common Name	Scientific Name	Perennial	Years to maturity	Regenerates readily from seed	Regenerates readily from root-stock	Conservation Priority*	Habitat / Occurrence
Charleville Turkeybush	*Eremophila gilesii*					2-3	Mulga Woodlands (Q)
Cotton Bush	*Maireana aphylla*	✓				3	Floodplains (SA,Q) / Gibber Plains (SA,Q)
Crimson Turkeybush	*Eremophila latrobei*					3	Mulga Woodlands (Q)
Cunningham's Bird Flower / Parrot pea	*Crotolaria cunninghammii*					4	Dunefields (SA,Q)
Currant Bush / Native Currant	*Carissa ovata*	✓				3	Acacia Woodlands (Q)- Cooper Basin is on S limit of known occurrence
Dead Finish	*Acacia tetragonophylla*	✓	10-20	✓		2	Dunefields (SA,Q)
Deane's Wattle / Fern-leaf Wattle	*Acacia deanei*	✓				3	Acacia Woodlands (Q) / Mulga Woodlands (Q) - Cooper Basin is on W limit of known occurrence
Desert Fuchsia	*Eremophila dalyana*	✓	20-30			2	Gibber Plains (SA,Q)
Dwarf Needlewood	*Hakea collina*					2	Mulga Woodlands (Q)
Ellangowan Poison Bush / Turkey Bush	*Eremophila deserti*	✓				3	Acacia Woodlands (Q) / Mulga Woodlands (Q)- Cooper Basin is on W & N (SA) limit of known occurrence
Emu Bush	*Eremophila longifolia*	✓	20-30	✓	✓	3	Dunefields (SA,Q) Acacia Woodlands (Q) / Mulga Woodlands (Q)
Eurah / Bignonia emu bush	*Eremophila bignoniiflora*	✓	10-20			3	Floodplains (S)
False Sandalwood	*Eremophila mitchellii*					2-3	Acacia Woodlands (Q) / Mulga Woodlands (Q)
Fern-leaf Grevillea / Golden Parrot Tree	*Grevillea pteridifolia*	✓	20-30			1	Dunefields (SA,Q) / Floodplains (SA,Q)

Common Name	Scientific Name	Perennial	Years to maturity	Regenerates readily from seed	Regenerates readily from root-stock	Conservation Priority*	Habitat / Occurrence
Flowering Lignum	*Eremophila polyclada*	✓	20-30			1	Floodplains (SA,Q) / Gibber Plains (SA,Q)
Golden Goosefoot / Queensland Bluebush	*Chenopodium auricomum*	✓	5-10			3	Floodplains (SA) Yupunyah-Gidgee Woodlands (Q) / Floodplains (Q)
High Sida	*Sida trichopoda*					4	Yupunyah-Gidgee Woodlands (Q) / Floodplains (Q)
Honeysuckle Spider-flower	*Grevillea juncifolia*	✓	5-10			3	Dunefields (SA,Q)
Hop bush	*Dodonaea viscosa(ssp. angustissima)*	✓	10-15	✓		3	Dunefields (SA,Q)
Lignum	*Duma florulenta*	✓	20-30		✓	2	Floodplains (SA,Q)
Lifesaver Burr	*Sida platycalyx*					4	Mulga Woodlands (Q)
Low Bluebush	*Maireana astrotricha*	✓		✓		2-3	Dunefields (SA,Q)
Marpoo / Sandhill Wattle	*Acacia ligulata*	✓	10-15	✓		3	Dunefields (SA,Q)
Miles Mulga	*Acacia aprepta*	✓				2	Mulga Woodlands (Q)
Mimosa Bush / Sweet Acacia	*Acacia farnesiana*	✓	10-20	✓		2	Dunefields (SA,Q) / Drainage lines (SA,Q) Acacia Woodlands (Q) / Mulga Woodlands (Q)
Murray's Wattle / Sandplain Wattle	*Acacia murrayana*	✓	20-30			2	Dunefields (SA,Q) / Floodplains (SA,Q)
Native Currant	*Canthium latifolium*	✓	10-30			2	Gibber Plains & Tablelands (SA,Q) / Sandfields (SA, Q)
Needlewood	*Hakea leucoptera*	✓	20-50	✓		2	Dunefields (SA,Q)
Nitre Bush / Nitre Goosefoot	*Chenopodium nitrariaceum*	✓	5-10			3	Floodplains (SA,Q)

Common Name	Scientific Name	Perennial	Years to maturity	Regenerates readily from seed	Regenerates readily from root-stock	Conservation Priority*	Habitat / Occurrence
Old Man Saltbush	*Atriplex nummularia*	✓	30-50		very poor	2	Dunefields (SA,Q) / Floodplains (SA,Q) / Salt lakes (SA)
Pearl Bluebush	*Maireana sedifolia*	✓				2	Dunefields (SA,Q)
Prickly Wattle / Elegant Wattle	*Acacia victoriae*	✓	10-15	✓		3	Dunefields (SA,Q) / Floodplains (SA,Q)
Ruby Saltbush	*Enchylaena tomentosa*	✓	5-10			3	Dunefields (SA,Q) / Floodplains (SA,Q)
Samphire	*Halosarcia indica*	✓	20-30			3	Salt lakes (SA, Q) / clay flats (SA,Q) / Gibber Plain (SA,Q)
Sandhill Spider-flower	*Grevillea stenobotrya*	✓	20-30			2	Dunefields (SA,Q)
Sanity Bluebush	*Maireana georgi*	✓		✓		3	Dunefields (SA,Q) clay flats (SA,Q) / Gibber Plain (SA,Q)
Silver Cassia (SA) / Butter Bush (Qld)	*Senna artemisioides (ssp. artemisioides)*	✓	5-10			3	Dunefields (SA,Q) / Gibber Plain (SA,Q) Acacia Woodlands (Q) / Mulga Woodlands (Q)
Silver Turkeybush	*Eremophila bowmanii*	✓				3	Mulga Woodlands (Q)
Spiny Saltbush / Thorny Saltbush	*Rhagodia spinescens*	✓	5-10			3	Dunefields (SA,Q) / Floodplains (SA,Q)
Spotted emu bush	*Eremophila maculate (var. maculate)*	✓	20-30			2	Watercourses & Floodplain (SA, Q)
Sticky Hopbush	*Dodonaea viscosa*	✓				3	Acacia Woodlands (Q)
Sturt's Pigface	*Gunniopsis quadrifida*					2-3	Dunefields (SA,Q) / Floodplains (SA,Q) / Gibber Plain (SA,Q) / Salt lakes (SA)
Tangled Lechenaultia	*Lechenaultia divaricata*	✓	2-5			2	Dunefields (SA,Q)
Umbrella Wattle	*Acacia oswaldii*					2	Dunefields (SA,Q)

Common Name	Scientific Name	Perennial	Years to maturity	Regenerates readily from seed	Regenerates readily from root-stock	Conservation Priority*	Habitat / Occurrence
Wait-A-While / Split Jack / Bush Passionfruit	*Capparis lasiantha*	✓				3	Acacia Woodlands (Q) / Mulga Woodlands (Q)
White Fringe Myrtle	*Calytrix tetragona*	✓				3	Acacia Woodlands (Q) - Cooper Basin is on W limit of known occurrence
Bastard Mulga / Witchetty Bush	*Acacia stowardii*					1	Mulga Woodlands (Q) Yupunyah-Gidgee Woodlands (Q) / Floodplains (Q)
Herbs							
Barley Mitchell-grass	*Astrebla pectinata*	✓	2-3			4	Gibber Plain, Floodplain (SA,Q)
Cat-head	*Tribulus hystrix*		<1	✓		4	Dunefields (SA,Q)
Cattle bush	*Trichodesma zeylanicum*	✓	1-3			4	Dunefields (SA,Q) / Floodplains (SA,Q) / Gibber Plain (SA,Q)
Dark Wiregrass	*Aristida calycina*					4	Yupunyah-Gidgee Woodlands (Q) / Floodplains (Q)
Erect Kerosene grass	*Aristida holathera*					4	Dunefields (SA,Q)
Fleshy Groundsel / Yellow-tops	*Othonna gregorii*		<1	✓		4	Dunefields (SA,Q)
Leafy nine-awn	*Enneapogon polyphyllus*					4	Mulga Woodlands (Q)
Lobed Spinifex / Hard Spinifex	*Triodia basedowii*	✓	10-20	✓		2-3	Dunefields (SA,Q)
Long-tails / Pussy-tails	*Ptilotus polystachyus*	✓	1-2			4	Dunefields (SA,Q)
Mulga grass / Kerosene grass	*Aristida contorta*	✓	1-3			4	Dunefields (SA,Q)
Nardoo	*Marsilea drummondii*		<1		✓	4	Floodplain (SA,Q)
Pea flower	*Swainsona campylantha*	✓	1-3	✓		4	Dunefields, Floodplain, Gibber Plain (SA,Q)

Common Name	Scientific Name	Perennial	Years to maturity	Regenerates readily from seed	Regenerates readily from root-stock	Conservation Priority*	Habitat / Occurrence
Poached Egg Daisy	*Myriocephalus stuartii*		<1	✓		4	Dunefields (SA,Q)
Ray grass / Katoora	*Sporobolus actinocladus*					4	Yupunyah-Gidgee Woodlands (Q) / Floodplains (Q)
Sandhill Canegrass	*Zyglochloa paradoxa*	✓	5-10	✓		4	Dunefields (SA,Q)
Swamp Canegrass	*Eragrostis australasica*	✓	5-10	✓		4	Floodplain (SA,Q)
Variable Groundsel	*Senecio lautus*	✓	5-10			4	Dunefields (SA,Q)
Wanderrie grass	*Eriachne mucronata*					4	Yupunyah-Gidgee Woodlands (Q) / Floodplains (Q)

Appendix E Stakeholder Consultation on Production Operations EIR and SEO

E. 1. Stakeholders consulted during the 2022-23 review

Government

Department of Energy & Mining (DEM)

Environment Protection Authority (EPA)

Department of Environment and Water (DEW)

DEW Pastoral Unit

SA Arid Lands Landscape Board

Attorney General's Department – Aboriginal Affairs (AAR)

Department for Infrastructure and Transport (DIT)

Outback Communities Authority

Safe Work SA

Department of Health

Community / Non-Government

Innamincka Progress Association

Conservation Council of SA

Wilderness Society

Traditional Owners

Dieri Aboriginal Corporation RNTBC

Yandruwandha Yawarrawarrka Traditional Land Owners (Aboriginal Corporation)

Landholders

Bollards Lagoon

Clifton Hills (Crown Point)

Gidgealpa

Innamincka

Lindon

Merty Merty

Mungeranie

Mulka

Innamincka and Strzelecki Regional Reserves (DEW)

Environmental Impact Report

<u>Industry</u>

Santos Ltd

Cooper Energy Ltd

Epic Energy South Australia Pty Ltd

APA Ltd

E. 2. Comments and Responses on Production Operations EIR and SEO, 2022

Comments on the EIR, 2022

Agency	Document Section	Comment	Response
AAR	2.2 (Table 1)	Pg 13 Agency Column: • Change DPC to Attorney-General's Department. • Add (SA) after AHA 1988. Pg 13 Legislation column • Add Native Title Act 1993 (Cth) • Attorney-General's Department	Text amended.
	4.1.7 (Table 14)	Pg 95 Sand Dunes – site type. Add additional site types – Stone artefact scatters and claypans, often found at the base of dunes or on the flat ground between dunes.	Text amended
	4.7.1	Pg 95. Last sentence 'Work Area Clearances are carried out with the relevant Native Title group in advance of all activities to ensure that cultural heritage values and significant places are not impacted.' Replace with: Work Area Clearances and/or cultural heritage surveys are carried out with the relevant Traditional Owners in advance of all activities to ensure that Aboriginal cultural heritage is not impacted.	Text amended Work Area Clearances are carried out with the relevant Native Title group to ensure that culturally sensitive and significant places are excluded from operational areas in advance of all activities
	4.7.3	Pg 96 Use of term Native Title claims throughout section - Incorrect use of the term claims – all three are determined native title land and should be referred to as Native Title determinations or Native Title holders	The term claims/claimants has been amended to Native Title holders.
	5.3 (Table 19) 5.3 (Table 20)	Pg 121 & Pg 125 Disturbance to cultural heritage sites. Suggest all cultural sites are also mapped on GIS systems as exclusion zones as well as physical barriers. A Cultural Heritage Management Plan could be undertaken in addition to WAC survey to agree management strategies where Aboriginal heritage is discovered or damaged. Monitoring of ground works in areas identified as high risk in section 4.7.1 is recommended	Beach maintains a GIS for Cooper Basin operations which includes the locations of cultural heritage exclusion zones. Beach maintains a cultural heritage management system, including plans and procedures for Cooper Basin operations.
	6.2	Pgs 154-157. The person responsible for Aboriginal and non-Aboriginal cultural heritage oversight is unclear, as there is no reference to cultural heritage against any of the listed positions.	Table 31 has been amended to include the role and responsibilities of the Beach First Nations Engagement Manager

Agency	Document Section	Comment	Response
		It is important to make this explicit especially given the references to the management and protection of cultural heritage that appears in this report and in the risk assessment sections.	
	9	Abbreviations and glossary. Add AGD-AAR as above	Updated
EPA	General	EPA expects Beach, following their general environmental duty, to undertake all steps reasonable and practicable to minimise their impacts to groundwater including the application of the waste hierarchy and best available technology economically achievable (BATEA).	Noted.
	5.2, (Table 18) 5.5, (Table 21) 5.9. (Table 27)	Incorrect EPA guideline (EPA 080/12) was referenced. The correct reference is EPA 080/16	Text amended
	5.5 (Table 21)	Incorrect EPA guideline (EPA 509/14) was referenced. The correct reference is EPA 509/19	Text amended

Comments on the SEO, 2022

Agency	Document Section	Comment	Response
AAR	Table 1 Serious Incidents 3.a; Footnote 2	Add (SA) after each act listed to clarify this is state legislation. As this point relates to a potential breach of the AHA 1988, recommend adding to the footnote to contact Aboriginal Affairs (AGD-AAR).	'(SA)' added after legislative references. No change. This table relates to incidents reported under P&GA Act. In the event of an incident DEM will notify AAR.
	Objective 9 Footnote 7	Amend to clarify that NTA 93 and AHA 88 are two independent pieces of legislation and there is no formal regulatory connection. Beach personnel must always comply with the requirements of the AHA 1988, even where a Part 9B Agreement or ILUA sets out procedures for undertaking cultural heritage surveys or allows impacts in 'cleared' areas. Surveys and clearances, while not described in the AHA 1988, have no separate legal status other than as a contractual undertaking in the Agreement. Only the Minister for Aboriginal Affairs and Reconciliation or their delegate can ever authorise excavation, damage, disturbance or interference with a site, remains or objects under the Act.	No change. The wording does not imply any connection between "NTA 93 or AHA 88". Noted Noted

Agency	Document Section	Comment	Response
		Note s20 AHA 88 requires the discovery of all Aboriginal heritage to be reported to AAR.	Acknowledged
	Objective 9 Footnote 9	WAC is not defined under or referenced by the AHA 1988. Amend to make clear that WACs cannot ever authorise impacts to heritage under AHA 1988	Text amended to clarify that a Work Area Clearance (WAC) means an area identified by the relevant Native Title holders, pursuant to a process as required and described in an agreement established under the Native Title Act 1993 for the inspection or clearance of land for the purpose of protecting Aboriginal sites, objects or remains. The reference to the AHA 1988 has been removed
	Appendix B Goals - Protect sites of natural, scientific or heritage significance	Use of "significant sites" in terminology. Note the AHA 1988 does not distinguish between sites i.e. All sites are protected regardless of their level of significance. Suggest you drop its use in this context as it may be misleading for personnel in the field (i.e. if a site is not seen as 'significant' there may be a sense that it is not protected).	No change. Both an environmental and a cultural heritage assessment are undertaken prior to earthworks to assist in the identification and protection of any sites. The level of 'significance' of a site is assessed by the NT holder / isn't not specified and all sites are protected.
EPA	General	EPA expects Beach, following their general environmental duty, to undertake all steps reasonable and practicable to minimise their impacts to groundwater including the application of the waste hierarchy and best available technology economically achievable (BATEA).	Noted.
	Objective 6.6	Incorrect EPA guideline (EPA 509/14) was referenced. The correct reference is EPA 509/19	Text amended

E. 3. Comments and Responses on Production Operations EIR and SEO, 2023

Comments on the EIR, 2023

Agency	Document Section	Comment	Response
AAR	4.1.7 & Table 14	AAR notes that the section and table 14 on Aboriginal cultural heritage has been taken from a 2021 Santos Environmental Impact Report.	Correct, this table has been adapted from Santos as it describes the land systems found across all the Cooper Basin petroleum tenements.
	Appendix E.1	Remove Department of the Premier and Cabinet and add Attorney General's Department (AAR machinery of government to AGD was effective by 1 July 2022)	Text amended
	Appendix E.2	Change AARD to AAR (p197) Remove 'and Reconciliation' from the Minister's title in any current/future document. Kyam Maher is the Minister for Aboriginal Affairs.	Text amended
	General	Need to reference the Coroners Act 2003 as there is a defined process when human skeletal remains are discovered.	A reference to the *Coroners Act 2003* (SA) has been added to Table 1: Additional environmental legislation and approvals in the EIR.
DEW	Figure 1	The figure could be edited to aid clarity 1. The Operating oil field symbols on the map do not match the symbology on the legend. Further the symbols look like there was a syntax error 2. The PEL, PRL etc labels do not clearly indicate the areas to which they refer. Consider colour coding areas based on required groupings and then produce another legend using this colour coding to refer to the area groupings.	Figure 1 and Figure 2 have been updated to reflect current Beach operational areas.
	3.1.2 and 3.1.5 4.6.3	*A review of water bores in the region (Senex 2015) indicated that most groundwater wells in the area where oil and gas exploration and production is undertaken are completed in the shallow aquifers above the main GAB aquifer system. There were no mapped bores in the uppermost main GAB aquifer (Cadna-owie) and a small number of bores at a depth more consistent with the lower main GAB aquifer (Hutton) which were principally converted petroleum wells.* Note that one option in well integrity and abandonment management that does not appear to be mentioned in these sections, but may be worth adding some discussion, concerns conversion of wells to groundwater bores prior to handover to third parties (pastoralists). There are requirements within the Far North WAP (2021) concerning the limitations of such conversions and handovers, as	Noted. To date Beach have only converted oil wells to water supply bores for the sole purpose of providing a potable water supply for petroleum production activities. Beach don't have any plans to handover water bores to third parties. Table 1 has been updated to include a reference to WAP and WAA Policy. Section 3.1.5 has been updated to reflect that petroleum wells may, on occasion, be converted to water supply wells for petroleum production operations. In this instance Beach would

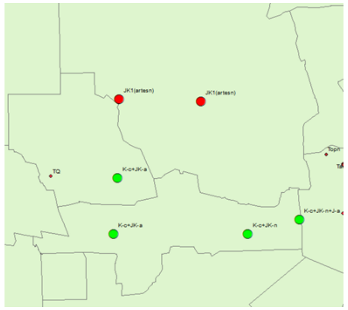
Agency	Document Section	Comment	Response
		well as considerations concerning liability. Whilst such handovers are generally considered on a case by case basis by DEM, DEW and the other parties involved, acknowledging the unique requirements and risk assessments involved should be considered here. Note the following from the current Far North PWA WAP (2021) are relent to this discussion Section 7.4 48 (d) *Subject to principle 50 and the transitional provisions in section 7.9 of this Plan, a water resource works approval, which permits the taking of water from a 'new well', will only be granted or varied where…the well, having previously been used for mining or petroleum production purposes, and being proposed to be used for an alternative purpose: i) has been converted from a mineral or petroleum well to a water well and meets the current edition of the Minimum Construction Requirements for Water Bores in Australia; and ii) a transfer of ownership has been sought through the Department and a deed of transfer has been signed by both parties and provided to the Department.* Section 7.4 49(c): *Subject to principle 50 and the transitional provisions in section 7.9 of this Plan, a water resource works approval will not be granted or varied:….for the taking of water from a well which has access to the water resources below the Eromanga Basin in the Cooper region, unless the applicant can demonstrate the capability to manage the take of water with high pressures and temperatures.*	obtain approvals from DEM and DEW prior to undertaking conversion.
	3.2.1.1 3.2.1.3	*Hydraulic fractures within the oil reservoir are typically designed to remain within tens of metres from the well bore and are contained within the natural top seals to each accumulation, such as the upper Murta horizon aquitard and the lower half of the overlying Cadna-owie Formation (which is classified as an aquitard unit) in the case of a Murta Formation target.* *The Nappamerri Group rocks which form a seal above the gas bearing formations of the Cooper Basin have their thickest development (up to 500 m) over the unconventional targets (in the Nappamerri Trough) and provide an effective barrier to fracture propagation between the unconventional targets and deep Great Artesian Basin (GAB) aquifers.* Whilst reviewers at DEW are aware of the stratigraphy referenced in this section. DEW also notes that none of these concepts have been introduced to this point in the document. A restructure or clear cross referencing to appropriate sections in the document where these terms are introduced would help readers who are unfamiliar.	Section 3 of the EIR provides a general description of activities undertaken within the scope of the EIR. Section 4.5 of the EIR provides general information on the geology of the region. Section 3.2.1 includes the following reference: *Details of the geology of the target formations are provided in Section 4.5.*

Agency	Document Section	Comment	Response
	Figure 7	*During the operation, if an unexpected response is seen, one or more variables may be altered. If a significantly different response is observed which could indicate height growth beyond design parameters (e.g. a slight dip in net pressure or large decrease in treatment pressure) the stimulation is typically stopped. Figure 7 shows a typical example of real-time monitoring output.* A little further explanation in text as to what the graph is and how it should be interpreted would add valuable context. For example, does the figure show an "unexpected response"?	Figure 7 shows a typical example of real-time pressure monitoring output. Section 3.2.4 has been amended to reflect this.
	3.2.8	*Fracture stimulation equipment for activities targeting the Eromanga Basin typically requires 5-10 truck loads. Fracture stimulation equipment in the Cooper Basin unconventional targets typically requires in the order of 20 truck loads.* It is unclear what a "truck-load" is referring to. Does a truck-load refer to equipment? Additives? Both? Further, if the idea is to provide an idea of volumetric scale, the term "truck-load" is overly ambiguous. How big is a "truck-load"?	A 'truck-load' refers to truck trailer loads of equipment. There are no units of measurement associated with this reference as the volume, size or weight of the load is dependant on the nature of the equipment and weight of the load. Section 3.2.8 has been amended to try and clarify the term.
	3.2.8	*For a 15-stage unconventional (shale gas) fracture stimulation in a horizontal well, approximately 50 trailers of proppant and 6 trailers of additives will be required.* Has the term "stage" been explained? Is it a single fracture stimulation treatment? Please add a definition or indicate where a definition can be found.	A 'stage' in the context of fracture stimulation represents a single fracture stimulation treatment over a discrete formation interval. Section 3.2.5 has been amended to include this definition.
	3.2.9.1	The clarity of this section will be improved if consistent units were used. ML and kL appear to be used interchangeably. Please choose one and edit accordingly.	All figures have been converted to ML
	3.2.9.1	*Where possible, water for fracture stimulation uses recycled water sources (e.g. from existing production ponds). Alternatively, water may be obtained from shallow water wells which are generally drilled within the lease area of each petroleum well. Water well productivity and water quality uncertainties may also make it necessary for Beach to seek landowner permission to obtain water from existing bores.* *Appropriate authorisations are obtained for water well drilling and extraction of groundwater (and Beach liaises with DEW where required). Beach will consult with landowners regarding any proposed water extraction and use to ensure use does not impact adversely on existing users of groundwater.* The wording here is ambiguous regarding the role of DEW with respect to the installation of groundwater bores. Note that all new groundwater bore installation in the Far North Prescribed Wells Area require a drilling permit and assessment against current water licences, or are subject to the provision of a new water licence. Consequently DEW are required to be involved in all	Wording has been amended to reflect appropriate authorisations required for water drilling activities.

Agency	Document Section	Comment	Response
		groundwater bore installations located in the Far North Prescribed Wells Area. Further permits are required for all groundwater bore decommissioning or alteration works. Groundwater bores require appropriate design and installation or decommissioning by an appropriately licenced driller. DEW recommend that the wording be changed to reflect these regulatory requirements.	
	3.3	*All but two of these production facilities (the Middleton gas facility and Vanessa Facility) produce oil.* Should Hornet be mentioned as well? Found in Table 3 as a gas only facility.	Hornet 1 is not a facility and has been removed from Table 3
	3.5.1.2	*Reinjection has not commonly been undertaken in the Cooper Basin because of the high cost associated with installation and ongoing operation of the infrastructure.* Does this refer only to the geological Cooper Basin or is this a reference to the Cooper Basin Region and is therefore inclusive of Eromanga Basin Strata? Please clarify.	This statement refers to the Cooper and Eromanga Basin Region. Section 3.5.12 has been amended to clarifyt this.
	3.11 5.12	*• abandonment of water bores (production or monitoring) including plugging* *5.12 Decommissioning / Rehabilitation* Although abandonment of water bores is specifically mentioned in section 3.11 as requiring specific consideration during decommissioning and rehabilitation activities, there are no details in the document concerning what is involved. Please note that the decommissioning and rehabilitation regulatory requirements for groundwater bores are different to that for petroleum wells. Please refer to the Far North WAP and DEW water Licencing information concerning requirements. Please add this detail where appropriate in Chapter 5.	Section 3.11 lists abandonment and rehabilitation activities. Information on associated regulatory approvals is referenced in Section 2.2. Table 30: Decommissioning / rehabilitation risk assessment in Section 5.12 has been amended to reflect environmental risks associated with water well abandonment
	Table 13	*Uppermost GAB or K aquifer. Known to be less than GAB J aquifer (Della 20 evidence)* *Part of main GAB J aquifer system, on a common water pressure system* The terms "K aquifer" and "J aquifer" have not been introduced or explained. They come from Habermehl (1980).	Table 13 has been amended to reflect that K refers to the Cretaceous aquifer and J refers to the Jurassic aquifer.
	4.6.3	*The salinity of the principal formations in the main GAB aquifer system are often in the range 600 – 2,000 mg/L in the eastern part of South Australia, which is acceptable for stock watering purposes (or potentially drinking water supply if salinity is below 1,200 mg/L), however they are generally too deep for widespread pastoral use.* *Due to the depth of the artesian aquifers in the centre of the basin, the majority of pastoral water use from these aquifers in South Australia occurs along the southern and western margins of the basin*	GABCC (1998) refers to Great Artesian Basin Consultative Council Great Artesian Basin Resource Study (eds. R Cox and A Barron). This reference has been added to Section 8. The references to information provided in Santos (2021a) have also been updated.

Agency	Document Section	Comment	Response
		where the majority of bores intersect minor / shallow artesian aquifers at less than 600 m (GABCC 1998). GABCC (1998) is not in the reference section. Further, it is uncertain how the information ascribed to the reference was estimated. If use is being judged by the number of bores present in an area, then this might be fallacious as one high flow artesian bore may support a large distribution system that could be the equivalent of a larger number of shallow, lower-flowing bores found elsewhere. If this is based on water use, then a review of water licence allocation per pastoral station and the completion depths of bores listed on the licence or another measured or estimation method is required before such an assertion can be made. Such details cannot be checked as the reference is not provided. Further, note that the current Far North WAP (2021) suggests that approximately 75% of total licenced water extraction comes from the GAB. Whilst the distribution of the remaining 25% of non-GAB licenced water take is not discussed, mining in the western portion of the FNPWA is expected to contribute the majority of this. It is recommended that interpretations concerning the viability of a given water source for pastoral use be removed unless they can be convincingly substantiated.	
	4.6.3	*The alluvium along some of the major streams is a frequent source of sub-artesian water across the broader region (Division of Land Utilisation, 1974)…* This reference is old given recent published works. Note that the Federal Government published a Stage 3 Bioregional Assessment covering the Cooper Basin Region that focussed on shallow, as well as deeper aquifers. This is not referenced in the EIR. Please acknowledge that the Cooper Basin region has been the subject of a Federal Government risk-assessment study as part of the Bioregional assessment program and provide citation as required. https://www.bioregionalassessments.gov.au/gba/cooper-gba-region-synthesis	A reference to the Federal Government Bioregional assessment program has been included in Section 4.6.3
	4.6.3	*The use of artesian water in the central portions of the Cooper Basin is generally limited to converted petroleum wells due to the expense associated with drilling bores to the depth required to intersect freshwater aquifers.* Clarity is required as to what is meant by "Cooper Basin". Does this mean the aquifers found within the Permo-carboniferous strata of the Cooper Basin, or the "Cooper Basin region" inclusive of the Eromanga Basin? Note that it is more likely that the latter is the correct interpretation. Note also the following from the current Far North PWA WAP (2021) Section 7.4 49(c): *Subject to principle 50 and the transitional provisions in section 7.9 of this Plan, a water resource works approval will not be granted or varied:….for the taking of water from a well which has access to the*	This statement refers to the Cooper Basin and Eromanga Basin Region. This statement has been amended to reflect this. Noted

<table>
<tr><th>Agency</th><th>Document Section</th><th>Comment</th><th>Response</th></tr>
<tr><td></td><td></td><td>water resources below the Eromanga Basin in the Cooper region, unless the applicant can demonstrate the capability to manage the take of water with high pressures and temperatures.</td><td></td></tr>
<tr><td></td><td>5.3.2.1</td><td>“…there have been sporadic hydrocarbon shows in the Cadna-owie (i.e. hydrocarbons are potentially present in the Cadna-owie in this area), and there are no known water bores completed in the Cadna-owie in the region.

Please check this statement. This may have been relevant for Senex only operations, however for the Cowarie, Clifton Hill and Mungeranie Pastoral Stations, of the 8 wells listed on water licences, 5 of the 8 wells are listed as being open to the Cadna owie Formation and a further two only have the J-K aquifer listed as the monitored aquifer, meaning they could be open to the Cadna owie Formation. Far North PWA existing users’ data file may be found at the Naturemaps web portal http://spatialwebapps.environment.sa.gov.au/naturemaps/?locale=en-us&viewer=naturemaps.
</td><td>The statement ‘there are no known water bores completed in the Cadna-owie in the region’ is taken from the Senex EIR (2105). While Beach is not aware of of any water bores completed in the Cadna-owie we can not verify the statement and it has been removed.</td></tr>
<tr><td></td><td>5.3.2.1</td><td>Senex (2015) also assessed the Birkhead Formation (which has had very few fracture stimulation treatments undertaken to date) as potential target. The assessment identified that there are underlying and overlying aquitard units providing hydraulic seal / isolation and it is expected that the level of risk for suitable targets in this formation (following detailed geomechanical analysis and fracture stimulation design) would be similar to the Murta formation (i.e. a low level of risk).

This statement requires further elaboration. Table 13 states that the Birkhead Formations is underlain by the Hutton Sandstone aquifer and overlain by the Adori Sandstone aquifer.</td><td>Section 5.3.2.1 has been amended to clarify that the underlying and overlying aquitard units are within the Birkhead Formation.</td></tr>
</table>

Agency	Document Section	Comment	Response
	5.3.5	*Where groundwater extraction for fracture stimulation is required, it will be undertaken within the regulatory framework of the Natural Resources Management Act. Appropriate authorisations will be in place for drilling and extraction of groundwater.* The Natural Resources Management Act (2004) has been superseded by the Landscapes South Australia Act (2019). Please update.	The reference to the NRM Act has been updated to the LSA Act.
	5.4.2	*Unconfined groundwater across much of the Cooper Basin has high salinity, which means that if a leak or spill reaches shallow groundwater, the risk of impacts to groundwater dependent ecosystems or groundwater users is reduced.* The statement appears to be an oversimplification in light of more recent published information from the Federal Government. Note that the Stage 2 Bioregional assessment for the Cooper GBA (https://www.bioregionalassessments.gov.au/sites/default/files/gba-coo-stage2-appendix_hydrogeology_final.pdf) stated the following: *• There are at least two groundwater systems in the Cenozoic (Section 3.3.3): a shallow local system with highly variable salinity above 60-80 m, and deeper, possibly fresher and regional scale groundwater system down to 300 m. The highly variable salinity in shallow system may relate to bores water quality been influenced by local recharge and discharge processes, with more saline water quality being intersected near areas of discharge. The deeper aquifer systems may be fresher and potentially relate (in part) to older palaeo-recharge. It should be noted that there could also be bias in available salinity data, as there may be no data from areas where deeper aquifers in the Lake Eyre Basin discharge. Only further sampling will clarify these issues.* *• There are many unknowns, including degree of compartmentalisation, the nature of the boundary between the shallow and deeper Cenozoic aquifer, recharge sources and amount of upward leakage from underlying Winton-Mackunda partial aquifer. Also, there is not a robust water balance estimate.* Please also refer to the Stage 3 Cooper GBA study for risk assessments concerning shallow aquifers in the region, noting risk level to shallow aquifers may be spatially controlled. Please update the statements to reflect recent studies.	This statement has been amended to clarify that this is referring to shallow unconfined groundwater. Noted A reference to the Federal Government Bioregional assessment program has been included in Section 4.6.3
	Table 21	Compliance with the Water Allocation Plan and water licence conditions (e.g. regarding the Southwest Springs Zone, GAB springs and state border) The Southwest Spring Zone has been superseded by Zone B, as described in the current Far North WAP and can be accessed via the Naturemaps web portal. Please update the text.	Text has been amended to reflect the change in names.

Agency	Document Section	Comment	Response
EPA	General	EPA expects Beach, following their general environmental duty, to undertake all steps reasonable and practicable to minimise their impacts to groundwater including the application of the waste hierarchy and best available technology economically achievable (BATEA).	Noted. Section 2.2 has been amended to reflect this general environmental duty.
	Table 1 'EPA'	Update the Radiation Protection and Control Act 1982 reference to Radiation Protection and Control Act 2021	Reference to RP&C Act amended
	3.2.9.2	The footnote 15 reference is incorrect and should read as footnote 5. Previous advice (GENI 227) stated 'dilution' is not an appropriate management strategy or remediation technique and also requested the reference to the ANZECC guidelines be removed and replaced with reference to the Environment Protection (Water Quality) Policy 2015. This advice has been captured correctly in Table 19 ('Disposal of flowback fluids in open systems'), however footnote 5 retains references to dilution and ANZECC guidelines. Footnote 5 should align with the Table 19 'Disposal of flowback fluids in open systems' management strategy wording	Footnote number has been amended to 5. Footnote 5 has been amended to reflect the wording in Table 19.
	3.4.1.3	Footnote 6: The list of analytes screened as part of the annual free form evaporation systems has changed since the 2019 EIR revision and does not reflect the analytes defined in the current Beach Production Operations Environmental Monitoring Plan HSE PL 10 (rev 7.). The following extract from page 23 of the monitoring plan is as follows. Annual FFE sampling is to be carried out in the summer months where chemical concentrations are higher due to higher evaporation rates. The FFE areas are sampled for a larger suite of parameters than the holding ponds due to their unlined nature and the presence of complete pathways between the water source and environmental receptors. FFE areas in the Western Flank are sampled for the following parameters as a minimum requirement: • TDS & pH (tested in-situ) • Total Recoverable Hydrocarbons (C6 -C40) • BETXN (Benzene, Ethylbenzene, Toluene, Xylene, Naphthalene) • Polycyclic Aromatic Hydrocarbons (PAH) • Phenols • National Environment Protection Measures (NEPM) suite of dissolved metals (Arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, lead, manganese, nickel, selenium, vanadium, zinc, mercury)	Footnote 6 has been amended to reflect the current suite of analytes

Agency	Document Section	Comment	Response
		• Cations (Calcium, Magnesium, Sodium, Potassium) • Anions (Chlorine, Sulfate, Alkalinity) • Ionic balance • Nutrients (Nitrate, Nitrite, Nitrogen, Fluoride, Reactive Phosphorus).	
	3.4.2	Paragraph 1 should consider the Environment Protection (Water Quality) Policy 2015 as part of the water quality assessment process for secondary use of Produced Formation Water (PFW). Recommend replacing the phrase 'consistent with relevant guidelines' to 'consistent with relevant legislation and guidelines	Compliance with the Environment Protection (Water Quality) Policy is referenced in Section 2.2, Table 1.
	5.3.9	Update the Radiation Protection and Control Act 1982 reference to Radiation Protection and Control Act 2021.	Reference to RP&C Act amended
	Table 24 'Disposal of hydrotest water'	Assessment of hydrotest water prior to disposal to land should have regard for the Environment Protection (Water Quality) Policy 2015 (Clause 3(2)(a)), and supporting guidelines such as ANZECC/ANZG and EPA publications. Recommend replacing the phrase 'consistent with relevant guidelines' to 'consistent with relevant legislation and guidelines'.	Noted. Compliance with the Environment Protection (Water Quality) Policy is referenced in Section 2.2, Table 1.
SAALLB	Page 41, Paragraph 5	The activities listed on this page, e.g. bunds and their effect on surface water drainage patterns, are examples of works that require a Water Affecting Activity (WAA) Permit	Noted
	Page 60, Paragraph 7	The activities listed on this section, e.g. trenching through watercourses, are examples of works that may require a Water Affecting Activity (WAA) Permit, in conjunction with activities listed in Section 3.6.4 (Page 61). Consult with SAAL Landscape Board before proposed works. Horizontal Directional Drilling (HDD) is the preferred method for pipe (and other infrastructure) installation through watercourses/water bodies. Why is HDD generally not used in the Cooper Basin?	Noted Noted HDD is can be used to cross watercourses when water is present to avoid impacting flows, however major water course crossings in the Cooper Basin can usually be scheduled to occur when there is little or no water present in the watercourse and as such open trenching is the preferred crossing method.
	Page 60	We note that hydrostatic test water is not disposed of into water sources or areas where it could damage water sources.	Noted

Agency	Document Section	Comment	Response
	Page 61-62	We note that activities on salt lakes are avoided (Table 5 and 23) but future road construction and associated works that occur on floodplains and wetlands will require a WAA permit. Consult with SAAL Landscape Board before proposed works.	Noted
	Page 133 and Table 23 (Pg 134)	It would be good if wetlands were always avoided when planning pipeline routes. If wetland disturbance is required for pipeline installation a WAA permit may be required.	Noted
SA Health	General	Confirmed that all SA Health requirements had been referenced appropriately in the document.	N/A

Comments on the SEO, 2023

Agency	Document Section	Comment	Response
AAR	Table 1 Serious Incidents 3.a;	Reference to 'clearance' or working area clearances (WACs). Please note that clearances or WACs are not defined under or referenced by the Aboriginal Heritage Act 1988 (Act). Amend or cross reference to another section to make clear that WACs cannot ever authorise impacts to Aboriginal heritage.	Noted. Work Area Clearances (WACs) are undertaken by relevant Native Title holder to avoid impacts to cultural heritage as a result of petroleum production activities. No change to Table 1. This table relates to incidents reported under P&GA Act. In the event of an incident DEM will notify AARD.
DEW	Appendix A, page 17	*If it is not possible to avoid extracting groundwater from these aquifers and there is potential for impact, a monitoring plan will be implemented."* Change to "a groundwater monitoring and management plan". Such plans typically discuss management options for when unacceptable impacts are indicated from monitoring. The wording change makes this clearer.	Text amended to clarify the development of a groundwater management and monitoring plan.
EPA	Appendix A: Objective & Assessment Criteria Goal 6.4 'To prevent impacts as a result of hydrotest water and washdown water disposal'	To include considerations for the Environment Protection (Water Quality) Policy 2015, recommend replacing the phrase 'consistent with relevant guidelines' to 'consistent with relevant legislation and guidelines'.	Text amended to include a reference to relevant legislation and guidelines.

Agency	Document Section	Comment	Response
	Appendix A: Objective & Assessment Criteria Goal 6.6 'To minimise impacts as a result of produced formation water treatment and disposal and restrict to defined areas'	The objective goal assessment criteria relies on an annual monitoring event for TRH. Recommend introducing a Goal Attainment Scaling (GAS) criteria for routine visual assessment of pond condition (inclusive of water quality), acknowledging that emulsions can present as a single phase requiring corrective action. While TRH values are key assessment criteria to PFW water quality, there are additional analytes tested as part of the monitoring program and may have an impact on meeting the objective. Recommend the assessment criteria for water monitoring results to include additional keys analytes as per the applicable guidelines.	The frequency of monitoring TRH in PFW at each operational facility is defined in the Cooper Basin Environmental Monitoring Plan (HSE-PL10). The minimum frequency for monitoring for TRH in ponds is annual, however ponds may be sampled more frequently (e.g. quarterly) if there are alterations to the facility or further analysis of trends is required.An environmental compliance inspection is undertaken at each operational facility once a fortnight. The checklist includes inspection of produced water ponds (including freeboard, evidence of erosion, presence of hydrocarbon and algae in holding ponds, state of pipework), chemical storage and bunds. A reference to the fortnightly inspection checklist has been added to 'Guide to How' under Goal 6.6 in the SEO. TRH is considered the key analyte of concern and is hence covered in the Assessment Criteria. The remaining analytes are addressed in the Guide to How (e.g. water assessed prior to secondary use consistent with relevant guidelines). Beach undertakes annual PFW monitoring in line with both the Assessment Criteria and the Guide to How and as set out in the Beach Cooper Basin Environmental Monitoring Plan. The current suite of analytes tested in PFW has been derived from an assessment of regulations, land uses, presence of sensitive receptors, risk assessment and a review of historical Beach monitoring data. TRH remains the only key analyte of concern and is not influenced by other analytes, consequently no other analytes are included in the Assessment Criteria.
	Appendix A: Objectives & Assessment Criteria Goal 6.9 'To minimise adverse impacts from water injection for waterflood or disposal'	Update the Radiation Protection and Control Act 1982 reference to Radiation Protection and Control Act 2021.	Text amended to reflect revision of Radiation Protection and Control Act.
SAALLB	Page 16	We note the reference to water affecting activities and permits required	Noted

Agency	Document Section	Comment	Response
	Page 16	Objective 5: Monitoring/regular patrols should also look for sedimentation, ponding of water and changes in landscape geomorphology. Include reference to SA Arid Lands Landscape board as the relevant authority of the Water Affecting Activities Control Policy. In Objective 5.2 state that the Water Allocation Plan has been developed by SAAL Landscape Board and administered by Department for Environment and Water.	Operational areas are regularly inspected after rainfall events to identify any areas of erosion or water ponding around infrastructure and roads. Where appropriate drainage controls are applied to minimise interruption of natural surface drainage. Table 1 in the EIR includes a list of relevant legislation and administering Agencies. This table has been amended to include a reference to WAA control policy and water allocation plan)
	General	Inspections for environmental objectives (e.g. weeds, surface water etc) should occasionally be undertaken by independent assessors so there is a balance of self-assessment and 3rd party 'audits'.	Environmental inspections are regularly undertaken by field operations personnel. Beach Environmental Advisors also undertake adhoc environmental compliance inspections of operational areas. Key regulators (DEM, EPA) also undertake periodic inspections of Beach production operations in the Cooper Basin.
	General	There is little reporting of pest fauna species. Given the large area held by Beach there is an opportunity for closing a knowledge gap that can assist in feral animal management. SAAL can potentially facilitate this and work in collaboration with Beach Environmental officers to improve reporting of camels, pigs, donkeys etc. using feral scan.	Noted
	General	The fencing out of livestock and large wildlife is ill defined. Kangaroos and emus tend to go straight through standard stock fences. Also, no other wildlife is prevented from accessing contaminated water. Claims that not many species are impacted should be backed up by research and field data.	The majority of fencing used in operational areas has been installed to exclude livestock. At some locations Emu proof fencing has been installed (e.g. airstrips). Due to the arid conditions and presence of Dingos, Kangaroos are rarely observed in Beach operational areas beyond the permanent and semi-permanent waterholes of the Cooper Creek. Evidence of native fauna accessing produced water ponds and drilling sumps is very rare. Fauna ladders have been installed in well cellars to facilitate the escape of any small fauna not excluded by cellar covers.
SA Health	General	Confirmed that all SA Health requirements had been referenced appropriately in the document.	N/A

beach