Santos

Environment Management Plan: McArthur Basin 2019 - 2020 Hydraulic Fracturing Program

NT Exploration Permit (EP) 161

Date	Rev	Reason for Issue	Author	Checked	Approved
16/07/2019	0	For Review	MB	PW	DC
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14/10/2019	4	For Approval	MB	PW	DC

Executive Summary

Introduction and Scope

Santos QNT Pty Ltd (Santos) is the operator of Exploration Permit (EP) 161 which is located approximately 350 km south-east of Katherine in the Northern Territory (NT) (Figure ES-1). Santos has undertaken exploration activities in EP 161 since 2013, including acquiring 2D seismic, the drilling of two exploration wells Tanumbirini-1 and Marmbulligan-1, and the development of a water bore drilling and monitoring program in 2018. Santos has also sought approval to undertake civils, seismic, and drilling activity in 2019 under separate environmental management plans.

Under the Petroleum (Environment) Regulations (the Regulations), interest holders in petroleum titles must prepare and submit an Environment Management Plan (EMP) for all proposed exploration activities.

Santos has prepared and submitted this EMP for the proposed Hydraulic Fracture Stimulation (HFS) to be conducted through 2019-2020 at the Tanumbirini 1, Tanumbirini 2H and Inacumba 1/1H well locations.

Description of the Activity

Following the completion of the 2019 well drilling operations, the operator is seeking approval to conduct a program of hydraulic fracture stimulations and appraisal (production) tests of the Velkerri Formation in the Tanumbirini 1, Tanumbirini 2H and Inacumba 1H wells. The Hydraulic Fracturing Program will commence only after a successful drilling and well integrity assessment is complete for each individual well. The Drilling and Civil works required to prepare for the Hydraulic Fracturing Program, including the upgrading of access tracks and creation of infrastructure at the leasepad, are covered in separate EMPs which have been submitted to the Department of Environment and Natural Resources (DENR). The only additional surface disturbance required for this EMP will be drilling of approximately 50 shallow holes for surface tiltmeter installation around each wellsite and surface site preparation for installation of passive seismic monitoring equipment.

The HFS program is anticipated to commence in approximately October 2019 and conclude in approximately November 2019. The HFS program will be followed by production testing, for which we are seeking approval for 365 days (post commencement of production testing) and anticipate that the testing program will run between 90 and 365 days.

HFS is not part of the drilling process but is a completion technique applied after the well is drilled. The intent of HFS is to place a highly conductive channel (sand size proppant) into the reservoir to increase the flow capacity of the well and increase the production of gas. The process involves the injection of a water based fluid system at high pressure into a cased wellbore over a number of intervals or stages along the reservoir interval(s) intersected by a well. This technique is typically used in low permeability reservoirs that cannot sustain economic production, such as shale. It is a process that has been used in the oil and gas industry since 1947 and has been successfully used on wells in the Cooper Basin for nearly 50 years and is currently performed in many basins around Australia, including the Amadeus Basin in the Northern Territory.

On completion of production testing, the wells will either be suspended for future re-entry, suspended on build-up, or decommissioned with permanent cement plugs. For suspended wells, wellbore barriers will be put in place and will be monitored through a Well Integrity Monitoring Plan; and the well and well-pad will be monitored and maintained. At the completion of operations all surface infrastructure will be removed (excluding the well head).

Hydraulic Fracture Stimulation (HFS)

The stimulation process involves pumping water, contain a minor volume of a specific blend of chemical additives and a propping agent such as sand or ceramic beads, down the well at sufficient pressure to create a fracture in the target formation. Proppant keeps the fractures open once the pump pressure is released which thereby improves the productive potential of the well.

A number of steps are involved to inform, support or perform the hydraulic stimulation process:

1. Diagnostic Fracture Injection Test (DFIT) is conducted to validate and update the proposed stimulation design. This involves injecting a small volume of water, shutting down the surface pumps and monitoring pressure. This stage is optional and typically only performed in the exploratory or appraisal stages of development, or until localised fracture characteristics are defined.
2. Main stimulation treatment consisting of injecting a pre-determined volume of stimulation fluid (pad volume), followed by injection of proppant at monitored concentrations and other additives to achieve fluid mobility (slurry stages). Finally a flush stage displaces the last slurry stage through the perforations and into the fracture.
3. Isolation of the completed fracture stimulation stage using a mechanical plug installed at a pre-designed depth.
4. Perforation of the next stage to be hydraulically stimulated and repetition of the process in steps 2 to 4 above until the final fracture stimulation stage is completed.
5. Removal of all mechanical isolation devices by milling out the mechanical isolations.
6. Flowback well to clean up fracture stimulation fluids and monitor hydrocarbon production. This step may also be combined with an Extended Production Test (EPT) to help define the field reserves and expected production life. The flowback of stimulation fluid is conducted through a separator, which separates and captures liquids, and flares produced gas through a vertical 'flare stack'.

The above method describes the "plug and perf" technique for fracture stimulation. Another technique is to use coiled tubing assisted annular stimulation which is used to provide a conduit for "pin-point fracturing". Coiled tubing is run into the well to the deepest target. The bottom-hole assembly run on the end of the coiled tubing incorporates a jetting assembly that allows low concentration sand slurry to cut holes or slots into the casing and cement. The hydraulic stimulation treatment is then pumped into the coiled tubing / casing annulus to initiate and propagate the fracture.

Both of these techniques for fracture stimulation can take up approximately 15-40 days per well.

Chemical Risk Assessment

A chemical risk assessment has been completed for all chemical additives proposed to be used during the Hydraulic Fracturing program. A tier based assessment was conducted on two hydraulic fracturing fluid systems using a screening of the potential human health and ecological hazards that should be considered for potential exposure to chemical additives during transportation, hydraulic fracturing activities (including storage), and subsequent treatment and disposal of flowback.

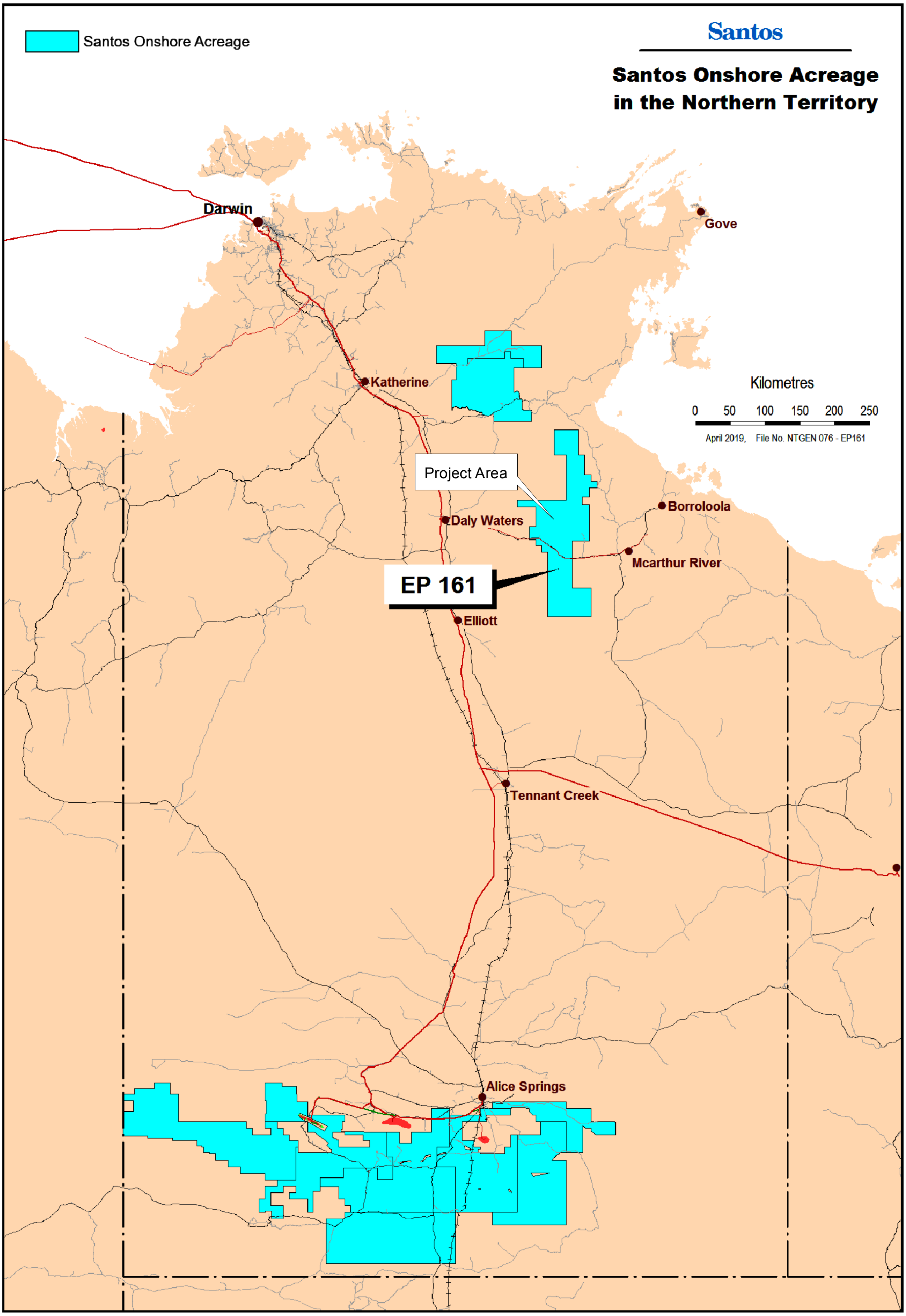
The outcome of the Tier 1 assessment identified the chemicals of low human health and environmental concern. Based on this outcome, no further management or mitigation are considered necessary for the majority of the chemicals and therefore these chemicals are not subject to the Tier 2 assessment. Five chemicals were identified that could potentially pose significant hazards or risks. These were evaluated in the Tier 2 Assessment.

The results of the Tier 2 assessment indicate that all the relevant chemicals are of low health concern for workers and that no unacceptable risks remain based on the proposed management controls. The results also confirm there are no unacceptable risk associated with potential exposures to avian species. Based on the outcomes of this assessment, no further management controls are considered necessary.

A Wastewater Management Plan (WWMP) has been compiled and details the management of flowback fluids as a result of the Hydraulic Fracturing Program (Appendix G). A Spill Management Plan (SMP) has been compiled and details to manage the risk of potential spills during the Hydraulic Fracturing Program (Appendix H).

The Activity Location

The proposed activity will be undertaken in EP 161, which is located approximately 350 km south-east of Katherine in the Northern Territory (NT), as shown in Figure ES-1 below. The Project Area for the program is located on Tanumbirini Station, a 5000 km^2 cattle grazing property within NT Portion 701 of Arnold. The location and layout of the proposed project infrastructure is shown on Figure ES-2.



Not to scale

N

Santos
McArthur Basin
Environmental Management Plan

Santos's acreage in the NT

Project No. 43-22812
Revision No. A
Date 05/02/2019

FIGURE ES-1

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Print date: 02 May 2019 - 13:46

Data source: Santos: Base map (2014). Created by: cmacgregor

Legend
- Water Bores
- Existing Access Road
- Proposed Access Road
- Major Waterways
- Principal Road
- Inacumba Lease
- Tanumbirini Lease

1:220,000 @ A4

0 2.5 5 7.5 10

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

N

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Proposed Infrastructure

Project No. **43-22812**
Revision No. **B**
Date **2/04/2019**

FIGURE ES-2

S:\GIS\Projects\4322812\GIS\Maps\432281200_022_ProposedInfrastructure_RevB.mxd
Print date: 02 Apr 2019 - 10:20

Data source: Google Earth: imagery (Jun 2016, captured Mar 2017 . GA: Roads, Waterways (2015) Santos: Proposed Access Roads, Existing Access Roads, Inacumba and Tanumbirini Lease Pads, Borrow Pit, Seimic Line (2019)
Created by: cmacgregor

Existing Environment

The proposed project area is located within two bioregions, the Sturt Plateau and Gulf Fall and Upland Bioregions. Plateaus, sandstone outcrops and undulating plains outline the landscape. The vegetation is comprised of tussock grasslands, eucalypt and acacia forests and woodlands. The climate is semi-arid and subtropical, and is influenced by the monsoonal weather in the north. The soils in this area are comprised of kandosols and rudosols, and the major water system in the vicinity is the Roper River Catchment. The main ground water resource is the Cambrian Limestone Aquifer (CLA). The Project Area is located in the Limmen Bight River catchment which drains towards the Gulf of Carpentaria.

There are 12 threatened species listed as potentially occurring within the vicinity of the project area. This includes a range of birds, mammals and reptiles. Eleven migratory species are known to inhabit parts of this region, and two weeds and nine invasive fauna species have been identified as potentially occurring within the region. No protected areas or places with historical or cultural significance were found to be within a 10 km radius of the Project Area.

The environmental values and/or sensitivities with the potential to occur in the vicinity of the Project Area are provided in Table ES-1.

Table ES-1: Summary of Environmental Values and Sensitivities

Environmental Factors	Environmental Values and Sensitivities	Summary
Terrestrial Flora and Fauna	Sensitive or significant vegetation	Ecoz (2019) recorded riparian vegetation (a sensitive vegetation type) along the watercourses and drainage lines within the Project Area.
	Groundwater dependent ecosystems	There is a low potential for terrestrial GDEs and aquatic GDEs in the Project Area (BoM 2018b).
	Threatened fauna species and their habitat	The PMST and NT database searches identified 12 listed, threatened species have the potential to occur in the Project Area. Of these, the Gouldian Finch, Grey Falcon and Crested Shrike-tit have a medium likelihood of occurrence.
	Listed Migratory Species	The PMST search identified 13 EPBC listed migratory species that were potentially occurring in the Project Area. Of these, the Fork-tailed Swift had a medium likelihood of occurrence.
	Listed threatened flora species and ecological communities	There are no Threatened Ecological Communities (TECs) or threatened flora listed under the EPBC Act and/or TPWC Act known to occur within 10 km of the Project Area.
Terrestrial Environmental Quality	Soils	The Project Area has intact soils within ephemeral creeks and drainage lines maintain the stability of watercourse and reduce sedimentation when rainfall events occur.
Inland water environmental quality	Groundwater	The Cambrian Limestone Aquifer is a regional scale aquifer that provides groundwater resources for pastoral enterprises, domestic bores at homesteads and town water supplies at a number of small communities across the region. The groundwater resource in this area is understood to connect to the Roper River, where groundwater discharge supports aquatic, riparian and floodplain ecosystem function.

Environmental Factors	Environmental Values and Sensitivities	Summary
	Surface water	There are ephemeral creeks and drainage lines present in the Project Area. In significant rainfall events, these drain into larger rivers eventually in to the Gulf of Carpentaria. Eighty km downstream of the works area the rivers traverse the Limmen Bight NP.
Hydrological processes	Supply and quantity of water	Ephemeral creeks adjacent to the Project Areas are located in the headwaters of the Limmen Bight river catchment and feed into the Limmen Bight River during significant rainfall events
Social, economic and cultural surroundings	Cultural heritage, sacred sites	An application for an AAPA Authority Certificate was submitted to AAPA in January 2019 (reference 201900379). During a meeting on 1 April 2019 between Santos and the Authority, it was recommended that the proponent seek a variation for C2014/053 to address additional planned works as part of its 2019 work program. Additional works included works associated with hydraulic fracturing. Certificate 2019/043 was subsequently issued on 13 May 2019 and supersedes C2014/053.
Human health	People and communities	There are a number of pastoral properties with livestock and infrastructure in the vicinity of the Project Area. The nearest dwelling is Tanumbirini Homestead, located approximately 8.5 km southwest of Tanumbirini-2 Well.

Environmental Impacts and Environmental Risks of the activity

An environmental risk assessment was undertaken. A summary of the Environmental Factors and key risks are given below in Table ES-2.

Table ES-2 Summary of risk assessment

Environmental Value	Risk Sources
Terrestrial Flora and Fauna	• Vehicle and plant movements (day and night) • entrapment in open pits or excavations • Plant and vehicles carrying weeds from outside the project area. • Ignition sources from plant and machinery and inappropriate cigarette disposal • Appraisal testing (production testing), flaring (light) • Waste stored inappropriately attracting native or feral fauna • Lighting from camp • Spread of weeds in project area through vehicle movements
Terrestrial Environmental Quality	• Vehicles leave the previously constructed roads or work areas • Inappropriate storage or handling of hazardous substances, stimulation chemical additives or wastes. • Transport vehicle accident due to weather • Overflow of fluid storage tanks • Poor refuelling or fuel transfer practices • Transport vehicle stuck due to mechanical or weather events • Release from storage tanks • Flowline failure
Inland water environmental quality	• Inappropriate storage or handling of hazardous substances, including stimulation fluid and flowback fluid wastewater. • Cross-flow during hydraulic fracture stimulation, • Transport vehicle accident due to weather • Overflow of fluid storage tanks • Poor refuelling or fuel transfer practices • Faults or major structures enables cross-flow • Transport vehicle stuck due to mechanical or weather events

Environmental Value	Risk Sources
	• Release from storage tanks • Flowline failure
Hydrological processes	• Use of groundwater for project activities
Air quality and greenhouse gases	• Vehicle and plant movements • Fugitive emissions • Production Testing flaring
Social, economic and cultural surroundings	• Vehicle and plant movements • Vehicle movements and hydraulic fracture activities • Vehicle movements and hydraulic fracture activities at night, • Plant and vehicles carrying weeds from outside the project area. • Ignition sources from plant and machinery and well control events (flaring) • Production testing, flaring • Vehicle and plant movements throughout the project area • Lighting from camp • Spread of weeds in project area through vehicle movements • Inappropriate disposal of cigarettes
Human health	• Vehicle and plant movements

Environmental Outcomes in Relation to the Activity

Through implementation of control measures, the residual risk ranking for most risks or impacts have been reduced to two (low) (risk is acceptable provided ALARP has been achieved and demonstrated) or one (very low) (risk is acceptable and it is assumed that ALARP has been achieved).

Control measures have been identified using the NT Government Code of Practice and Santos hierarchy of controls; a process that moves from risk elimination through to protection, in descending order of effectiveness, until a control measure can be identified.

Stakeholder Engagement

Santos seeks to establish and maintain enduring and mutually beneficial relationships with the communities of which it is a part; ensuring that Santos' activities generate positive economic and social benefits for and in partnership with these communities.

Stakeholder identification was undertaken prior to commencing drilling works at Tanumbirini 1 in 2014. The relevant stakeholder groups were identified and engaged such that they could be informed of the proposed activities and the associated risks, build an understanding as to why and how Santos operations and have any objections or claims considered and addressed. The key stakeholders identified and engaged include:

- Station Managers for Tanumbirini, Beetaloo / O.T Downs and Broadmere
- Northern Land Council (NLC)
- Northern Territory Government
- Aboriginal Affairs Protection Authority (AAPA)

Santos has continued to engage with these key stakeholders on an ongoing basis since initial identification, specifically with regard to this project and development in the Northern Territory generally. This includes providing detailed information, presentations and mapping to key stakeholders. Government and industry stakeholders are updated through regularly scheduled industry and governmental joint meetings and one off conferences.

Other stakeholder engagement primarily involves engagement with landholders/managers. Landholders have been consulted with regard to the proposed activities on a number of occasions and have been directly involved in an on-ground inspection of proposed infrastructure locations. Land Access and Compensation Agreements (LACA) have been progressed and all LACAs will be in place prior to the Hydraulic Fracturing Program commencing.

Stakeholder engagement records detailing who, when, type of engagement, method of delivery and maters raised, have been provided within Table G-2 Stakeholder Engagement Records.

Approvals Process

The key processes and approvals required in addition to this EMP are provided in Table ES-3.

Table ES-3 Summary of Key Approval Processes

Process or activity	Approval process summary	Hydraulic Fracturing Program EMP status
Northern Land Council (NLC) and Traditional Owner Consultation	• Santos and the NLC (on behalf of Traditional Owners over the permit areas) are parties to a "Co-operation and Exploration Agreement". This agreement details the steps, and related terms and conditions, necessary for exploration activities to be undertaken. • The key steps facilitated by the NLC include community consultations to ensure free, prior and informed consent of proposed work program activities and sacred site avoidance surveys (i.e. field surveying activity by appropriately identified Traditional Owners) • The NLC complete an Anthropological Report, which summarises the outcomes of the consultation and surveying processes and is provided as an input to the Aboriginal Area Protection Authority certification process	• Multiple consultations and/or sacred site avoidance surveys completed in 2013, 2014, 2018 and 2019 • Consultation specific to the proposed 2019 program has been ongoing with NLC since Q4 2018 and included sacred site avoidance surveys in October 2018 and an On-Country consultation with Traditional Owners in March 2019
Aboriginal Area Protection Authority (AAPA)	• AAPA are the only authority upon which a proponent can be indemnified for works in relation to sacred sites. AAPA are able to issue Authority Certificates that provide this indemnity. Proponents can apply for written advice specifying the constraints (if any) to a particular activity imposed by the existence of sacred sites. • A formal application for an Authority Certificate is made to AAPA • Applications made by exploration proponents are typically activity and location specific • If AAPA are satisfied with the Anthropological Report provided by the NLC and any other independent consultation or register searches that they consider necessary, then they can issue an Authority Certificate to a proponent	• Application for an Authority Certificate or Authority Certificate Variation to cover all of the locations and activities in the 2019 proposed program submitted in January 2019. Subsequently Authority Certificate C2019/043 was granted to cover these activities. • A valid Authority Certificate or Authority Certificate Variation must be provided to support an EMP prior to consideration for approval by the Minister

Process or activity	Approval process summary	Hydraulic Fracturing Program EMP status
Archaeological surveying	• Surveying of proposed work locations completed to determine if there are any Aboriginal and/or non-Indigenous sites or artefacts of archaeological significance in the project area	• Archaeological surveying completed by independent consultant in March 2019
Land Access and Compensation Agreement (LACA)	• A LACA, or equivalent, is required for approval to undertake exploration activities in the NT • The LACA includes terms and conditions regarding the scope and location of activity and what compensation is appropriate based on the scope, location and interaction with the pastoral lessee's operations, business and/or other amenity • We engage with impacted pastoral lessees to ensure minimal impacts to their operations, business and/or other amenity	• Existing LACAs in place for ongoing work at Tanumbirini 1 location and water monitoring bore construction and sampling • Detailed, collaborative engagement continuing regarding 2019 program
Groundwater monitoring	• Under the Code of Practice a compliant groundwater monitoring plan must be developed • The Code of Practice sets out mandatory requirements; which include compliance with the guideline for Groundwater Monitoring Bores for Exploration Petroleum Wells in the Beetaloo Sub-basin (Section B.4.17of the code) • This guideline sets out explicitly the timing, scope and location of groundwater monitoring required to establish baseline data	• Water monitoring bores installed at both proposed 2019 drilling locations in November/December 2018 • A Groundwater Monitoring Plan has been developed in accordance with the Guideline which includes the timing and scope of monitoring
Weeds surveying	• Under the Code of Practice a project specific weed management plan must be developed which meets the requirements of the NT Weed Management Planning Guide: Onshore Petroleum Projects (section A.3.6 of the code)	• A Weed Management Plan has been in place since Q4 2018 for the project area and baseline surveying was completed prior to the installation of water monitoring bores in 2018. Above it states for the project area • In accordance with the Weed Management Plan, monitoring surveys will follow the 2018-19 wet season
Well Operations Management Plan (WOMP)	• Under the Code of Practice a Well Operations Management Plan (WOMP) must be approved by the regulator for regulated well activities (such as drilling)	• No Hydraulic Fracturing activity will commence until a relevant WOMP has been approved • The WOMP will set out all key information required to ensure safe operation and well integrity is maintained throughout the well life-cycle, for example it will detail: well design considerations for all phases of the well life-cycle, risk management, control measures, measurement criteria, and any other relevant information

Process or activity	Approval process summary	Hydraulic Fracturing Program EMP status
Water Extraction Licence	• Under the *Water Legislation Amendment Act 2018*, gas companies are required to obtain a water extraction licence to extract groundwater to support exploration activities	• Santos has a ground water extract licence (GRF10280). This license covers the water requirements of the HFS program and the activities covered in this EMP.

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Tables

Figures

Appendices

Abbreviations and Units

Acronym / Abbreviation	Description
ALARP	As low as reasonably practicable
ALRA	Aboriginal Land Rights Act
AAPA	Aboriginal Areas Protection Authority
APPEA	Australian Petroleum Production and Exploration Association
CLA	Cambrian Limestone Aquifer
Code	Code of Practice
CPESC	Certified Professional in Erosion and Sediment Control
DENR	Department of Environment and Natural Resources
DoEE	Department of Environment and Energy
DFIT	Diagnostic Fracture Injection Test
DPIR	Department of Primary Industry and Resources
D&C	Drilling and Completions
EC	Electrical Conductivity
EMP	Environmental Management Plan
EP	Exploration Permit
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999
EPS	Environmental Performance Standards
ERA	Environmental Risk Assessment
ESD	Ecologically Sustainable Development
ha	Hectares
HFS	Hydraulic Fracture Stimulation
GISERA	Gas Industry Social and Environmental Research Alliance
km	Kilometre
LACA	Land Access Compensation Agreement
LWD	Logging While Drilling
NLC	Northern Land Council
m	Metres
MD	Measured Depth
MoC	Management of Change
NRM	Natural Resource Management
ML	Megaliters
NT	Northern Territory
NT EPA	Northern Territory Environmental Protection Authority
NVIS	National Vegetation Information System
Panel	Independent Scientific Panel
PL	Petroleum Lease

Acronym / Abbreviation	Description
PMST	Commonwealth Protected Matters Search Tool
PPL	Petroleum Pipeline Licence
SEAAOC	South East Asia Australia Onshore Conference
SMS	Santos Management System
SSCC	Sacred Site Clearance Certificate
TOC	Total Organic Content
TPWC Act	Territory Parks and Wildlife Conservation Act 2014
TVD	True Vertical Depth
TVDSS	True Vertical Depth referenced to sea-level (Australian Height Datum)
WOMP	Well Operations Management Plan
WoNS	Weed of National Significance

1.0 Introduction

1.1 Background and Purpose

Santos QNT Pty Ltd (Santos) is the operator of Exploration Permit (EP) 161 which is located approximately 350 km south-east of Katherine in the Northern Territory (NT) (Figure 1-1). Santos has undertaken exploration activities in EP 161 since 2013, including acquiring 2D seismic, the drilling of two exploration wells Tanumbirini 1 and Marmbulligan 1 and most recently the development of a water bore drilling and monitoring program in 2018 and preparation for an exploration drilling program in 2019.

Santos is proposing a program of work for 2019-2020 that is covered by this EMP. Santos may request approval to undertake additional exploration activities following the completion of the activities covered under this EMP (which would require a further EMP and other regulatory approvals and are not covered by this EMP).

The purpose of exploration and appraisal activity is to increase our understanding of the prospectivity or potential of the EP 161 permit area. Our objective whenever undertaking such activity is to minimise our impact on the environment, including any activities of Traditional Owners and pastoral lessees. To meet this purpose, exploration activities in 2019 -2020 include:

- Civil engineering activity – upgrading and creation of new access tracks, lease pads, water bore installation and water extraction as required
- 2D seismic acquisition
- Exploration drilling – both vertical and horizontal drilling
- Well evaluation – including wireline logging, logging while drilling formation testing, core acquisition, fluid sampling, open-hole formation integrity testing (i.e. Diagnostic Fracture Injection Testing (DFITs)) and other standard evaluation techniques as appropriate
- Cased hole DFIT
- Walk-away VSP
- Hydraulic fracture stimulation (with microseismic / passive monitoring)
- Flow-back and production testing
- Environmental monitoring
- Well suspension and/or well decommissioning
- Ongoing site and well maintenance and monitoring, work-over and re-entry, and evaluation as required

Not all activities listed above will be subject to this EMP and the Scope of this EMP is detailed in section 1.2 below.

1.2 Scope of this EMP

Under the Petroleum (Environment) Regulations (the Regulations), interest holders in petroleum titles must prepare and submit an Environment Management Plan (EMP). Approval of an EMP is necessary for all activities that have an environmental impact or risk and is only one of several approvals required for the activity to proceed. An approved EMP is a statutory document that is enforceable.

Santos proposes to undertake a Hydraulic Fracture Stimulation and Production Testing Program in 2019 and 2020 (appraisal (production) testing may carry into 2021) at the Tanumbirini 1, Tanumbirini

2H and Inacumba 1/1H locations. This EMP covers these new proposed works. A full description of the activities covered in this EMP is provided in Section 3.0.

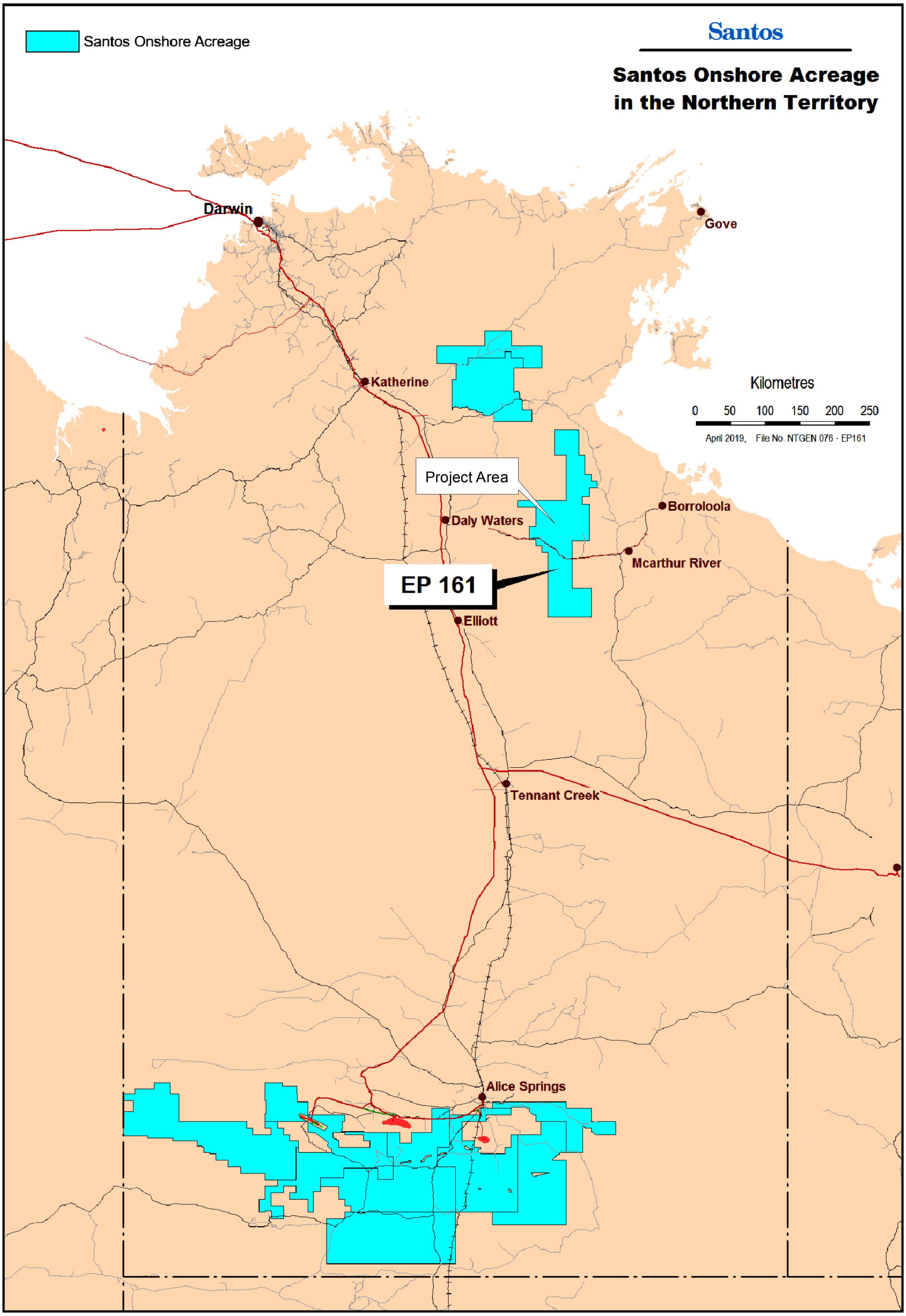
1.3 Titleholders Details

Table 1-1 provides details of the permit titleholder and titleholder nominated liaison person.

If there is a change in the titleholder, the titleholder's nominated liaison person or a change in the contact details for the titleholder or liaison person, Santos will notify and provide the updated details to the Department of Primary Industry and Resources (DPIR) and the Department of Environment and Natural Resources (DENR).

Table 1-1 Details of Titleholder and Nominated Liaison Person

Titleholder Details	Liaison Person Details
Name: Santos QNT Pty Ltd Address: 60 Flinders Street, Adelaide, SA 5000 Phone: 08 8116 5000 ACN: 083 077 196	Name: David Close Position: General Manager – Onshore New Ventures Company: Santos Ltd Address: 60 Flinders Street, Adelaide, SA 5000 Phone : 08 8116 7952 Email: david.close@santos.com



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Santos
McArthur Basin
Environmental Management Plan

Project No. 43-22812
Revision No. A
Date 05/02/2019

Santos's acreage in the NT

FIGURE 1-1

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Print date: 02 May 2019 - 13:47

Data source: Santos: Base map (2014). Created by: cmacgregor

2.0 Environmental Legislation and Other Requirements

2.1 The Petroleum Act 2016 (NT)

The *Petroleum Act 2016* (NT) is the governing legislation for onshore petroleum activities in the NT and the Petroleum (Environment) Regulations (the Regulations) govern environmental management. The objectives of the Regulations are to ensure that:

- Onshore oil and gas activities are carried out in a manner consistent with the principles of ecologically sustainable development (ESD); and
- Environmental impacts and risks associated with onshore oil and gas activities are reduced to a level that is as low as reasonably practicable (ALARP) and acceptable.

The Regulations achieve these objectives by requiring interest holders to have an approved EMP in place before a 'regulated activity' can be undertaken. An EMP will be approved when the Minister for Primary Industry and Resources (the Minister) is satisfied that approval criteria have been met.

The approval criteria for an environment management plan are provided in Section 9 of the Petroleum (Environment) Regulations:

9. Approval criteria for plan

(1) The approval criteria for an environment management plan are that the plan must:

(a) include all the information required by Schedule 1; and

(b) be appropriate for the nature and scale of the regulated activity to which the plan relates; and

(c) demonstrate that the activity will be carried out in a manner by which the environmental impacts and environmental risks of the activity will be reduced to a level that is:

(i) as low as reasonably practicable; and

(ii) acceptable.

(2) When considering whether an environment management plan meets the approval criterion mentioned in subregulation (1)(c), the Minister must take into account:

(a) the principles of ecologically sustainable development; and

(b) if an environmental report or statement has been prepared, or is required to be prepared, in relation to the regulated activity to which the plan relates – each environmental assessment recommendation in the assessment report made about the activity.

(3) In this regulation:

environmental report or statement means a public environmental report or environmental impact statement mentioned in section 7(2) of the Environmental Assessment Act.

The requirements of Schedule 1 of the Petroleum (Environment) Regulations are listed in Table 2-1

Table 2-1 Requirements of this EMP

Part	Section	Requirement	Section in this Plan
1.1	Description of a regulated activity	A plan must give a comprehensive description of the regulated activity to which it relates and include: (a) the location (or locations) of the activity; and (b) general details of the construction and layout of any facility associated with the activity; and (c) an outline of, and proposed timetable for, the operational details of the activity.	Section 3.0
1.2	Description of existing environment	A plan must include: (a) a description of the existing environment that may be affected by the regulated activity described in the plan; and (b) details of any particular values and sensitivities of that environment relevant to the activity; and (c) details of any uncertainties or lack of understanding in relation to that environment	Section 4.0
1.3	Assessment of environmental impacts and environmental risks	(1) A plan must include: (a) details of all environmental impacts and environmental risks of the regulated activity described in the plan and an assessment of those impacts and risks; and (b) details of all environmental impacts and environmental risks of the regulated activity described in the plan and an assessment of those impacts and risks; and (c) a description of the process used to assess the environmental impacts and environmental risks. (2) The assessment mentioned in subclause (1)(a) must be of: (a) all the environmental impacts and environmental risks arising directly or indirectly from: (i) all aspects of the regulated activity; and (ii) potential emergency conditions, whether resulting from an incident or any other reason; and (b) the cumulative effects of those impacts and risks when considered with each other and in conjunction with any other activities or events that occurred or may occur in or near the permit area for the regulated activity. Example for clause 3(2)(b) of other activities or events Activities or events associated with: (a) other exploration for, or production of, petroleum; or (b) the exploration for, or extraction of, minerals or extractive minerals.	Section 5.0
1.4	Environmental outcomes and Environmental Performance Standards	A plan must specify: (a) the Environmental Outcomes in relation to the regulated activity described in the plan; and (b) the Environmental Performance Standards against which the performance of the interest holder in achieving the Environmental Outcomes can be measured; and (c) the measurement criteria to be used to ensure the Environmental Outcomes and Environmental Performance Standards are met.	Section 6.0

Part	Section	Requirement	Section in this Plan
2.5	Requirement for implementation strategy	A plan must include an implementation strategy, in accordance with this Part, for the regulated activity described in the plan.	Section 8.0
2.6	Details of systems, monitoring, tests etc.	(1) An implementation strategy must provide for: (a) ongoing monitoring and review of the strategy; and (b) monitoring, recording, audit and management of non-conformance with the plan and review of the interest holder's environmental performance. (2) The implementation strategy must give details of: (a) the specific systems, practices and procedures to be used to ensure that the Environmental Outcomes and Environmental Performance Standards in the plans are met, and (b) the following, as relevant to the regulatory activity described in the plan: (i) the monitoring of its environmental impact, (ii) the monitoring of emissions and discharges (whether occurring during normal operations or otherwise) (iii) the carrying out and recording of the monitoring mentioned in this paragraph in a manner that is accurate and can be audited against the Environmental Performance Standards and measurement criteria specified in the plan, and the intervals at which each type of monitoring will be carried out; (iv) tests to be carried out to assess the performance and accuracy of the equipment used for the monitoring mentioned in this paragraph, and the intervals at which the tests are to be carried out.	Section 8.2 Section 8.9
2.7	Personnel	An implementation strategy must: (a) establish a clear chain of command, including during emergencies or potential emergencies; and (b) set out the roles and responsibilities of personnel in relation to the implementation, management and review of the plan; and (c) specify measures to ensure that each employee or contractor working on, or in connection with, the regulated activity described in the plan: (i) is aware of his or her responsibilities or potential emergencies, and (ii) has the appropriate competencies and training.	Section 8.2 Section 8.3
2.8	Emergency contingency plan	An implementation strategy must include: (a) a contingency plan that specifies arrangements for the response to emergencies or potential emergencies, and (b) provisions for the implementation and maintenance of the contingency plan.	Section 8.5
3 A	Reporting requirements of hydraulic fracturing	An interest holder in relation to an activity that includes hydraulic fracturing must give the Minister a report about flowback fluid within 6 months of the flowback occurring. The report must contain the following information:	Section 8.10

Part	Section	Requirement	Section in this Plan
		(a) the identity of any chemical or NORM found in the flowback fluid; (b) the concentration of any chemical or NORM found in the flowback fluid; (c) details regarding how any chemical or NORM has been or will be managed; (d) details regarding how any chemical or NORM has been or will be transported; (e) details regarding how any chemical or NORM has been or will be treated; (f) details regarding any action proposed to be taken to prevent any chemical or NORM spill; (g) details of the emergency contingency plan included in the environment management plan to which the activity relates; (h) the requirements in relation to the management of any chemical or NORM of the prescribed chemical legislation.	
3.9	Stakeholder engagement	(1) A plan must include information about the stakeholder engagement carried out by the interest holder that includes the following: (a) a list of the stakeholders and the stakeholder's contact details; (b) a copy of the information provided to the stakeholders by the interest holder; (c) if written responses have been received from stakeholders – a summary and copy of each response; (d) an assessment of the merits of any objection or claim made by a stakeholder about the anticipated environmental impact of the proposed regulated activity; (e) a statement of the interest holder's response, or proposed response, to each objection or claim made by a stakeholder; (f) a record of communications with stakeholders that is not mentioned in paragraph (b), (c) or (e), (for example, telephone discussions); (g) details of changes the interest holder made as a result of the stakeholder engagement. (2) A plan must also include information about future stakeholder engagement to be carried out by the interest holder.	Section 9.0
3.10	Legislative requirements	A plan must: (a) specify any legislative requirements applicable to the regulated activity described in the plan that are relevant to the practices and processes used to manage the environmental aspects of the activity; and (b) demonstrate how those requirements will be met.	Section 2.0
3.11	Recording, monitoring and reporting	(1) A plan must specify arrangements for: (a) recording, monitoring and reporting information about the regulated activity to which the plan relates in a manner that will enable the Minister to determine whether the Environmental Outcomes and Environmental Performance Standards in the plan are being met; and	Section 8.9 Section 8.10

Part	Section	Requirement	Section in this Plan
		(b) giving the Minister a report about the matters mentioned in paragraph (a), at approved intervals, but not less often than annually. (2) the information mentioned in subclause (1) includes information required to be recorded, monitored or reported under these Regulations or any other law in force in the Territory applying to the regulated activity.	
4A	Chemicals used in the application of hydraulic fracturing	If the activity is hydraulic fracturing, a plan must specify the following information in relation to any chemical or other substance that may be in, or added to, any treatment fluids to be used in the course of the activity: (a) the identity of the chemical or other substance; (b) the volume of the chemical or other substance; (c) the concentration of the chemical or other substance; (d) the purpose of the chemical or other substance; (e) details regarding how the chemical or other substance will be managed; (f) details regarding how the chemical or other substance will be transported on-site; (g) details regarding any action proposed to be taken to prevent a spill of the chemical or other substance; (h) the requirements in relation to the management of the chemical or other substance of the prescribed chemical legislation. Note for clause 4A(e) Managed includes handling, collecting and storing any chemical or other substance.	Section 3.4 Appendix A

Other legislation, agreements and codes of practice relevant to the project, which are detailed below.

2.2 Scientific Inquiry into Hydraulic Fracturing In the Northern Territory

On 14 September 2016, the Chief Minister of the Northern Territory, the Hon. Michael Gunner MLA, announced a moratorium on hydraulic fracturing of onshore unconventional shale gas reservoirs in the NT. The Chief Minister also announced that he would appoint an independent scientific panel (Panel) to investigate the impacts and risks associated with hydraulic fracturing.

The Terms of Reference are required the Panel to assess and determine:

- the nature and extent of the risks associated with hydraulic fracturing of onshore unconventional shale gas reservoirs and its associated activities on the environmental (aquatic, terrestrial and atmospheric), social, cultural and economic conditions of the NT;
- whether these risks can be mitigated to an acceptable level;
- if they can, by what methodology or methodologies can these risks be mitigated; and
- whether the existing regulatory framework is sufficient to implement these methodologies, and if not, what changes need to be made.

Results of the inquiry determined that, provided that all of the recommendations made in the Final Report are adopted and implemented in their entirety, not only should the risks associated with an onshore shale gas industry be minimised to an acceptable level, in some instances, they can be avoided altogether. In developing tools to ensure risks can be mitigated to an acceptable level, the panel recommended that codes of practice be developed for, among other things, well integrity and well abandonment.

2.3 Key Legislation Overview

Table 2-2 Key Relevant Commonwealth and Northern Territory Legislation

Act	Summary
Commonwealth	
Aboriginal and Torres Straights Heritage Protection Act 1984	Protects areas and objects in Australia that are of particular significance to Aboriginals in accordance with Aboriginal tradition. The Act allows the Commonwealth Environment Minister, on the application of an Aboriginal person or group of persons, to make a declaration to protect an area, object or class of objects from a threat of injury or desecration.
Aboriginal Land Rights (Northern Territory) Act 1976	This Act is the key mechanism for the creation of Aboriginal-owned freehold land in the NT. It also includes provisions for the establishment of Land Trusts (over which the Land Councils have oversight).
Australian Heritage Council Act 2003	Establishes the Australian Heritage Council that is the principal adviser to the Australian Government on heritage matters. The Council's main role is to assess the heritage values of places nominated for the National Heritage List and the Commonwealth Heritage List, and to advise the Minister on promotion, research, education, policies, grants, conservation and other matters.
Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)	Provides for the protection of the environment and the conservation of biodiversity. It regulates a development or activity if it is likely to have a significant environmental impact on matters of national environmental significance (MNES). This Act is administered by the Commonwealth Department of the Environment and Energy (DoEE). It is considered that the proposed activities will not adversely impact MNES therefore; the project has not been referred for assessment nor approval under the EPBC Act.
National Environment Protection Council Act 1994	Provides national standards for ambient air quality, movement of controlled wastes and contaminated sites. This Act is administered by DoEE.
National Greenhouse and Energy Reporting Act 2007	Titleholders are required to report emissions and energy use annually in accordance with this Act.
Native Title Act 1993	This Act provides statutory recognition and protection for the concept of native title, including provisions for reaching Indigenous land use agreements.
Northern Territory	
Biological Control Act 1984	Makes provision for the biological control of pests in the NT, and related purposes.
Bushfires Management Act 2016	Provides for the protection of life, property and the environment through the mitigation, management and suppression of bushfires, and for related purposes.
Control of Roads Act 1953	Provides for the administration and control of public or gazetted roads, including the maintenance of roads and opening and closing of roads.
Transport of Dangerous Goods by Road and Rail (National Uniform Legislation) Act 2010	Makes provision for safety in the transport of dangerous goods by road as part of the system of nationally consistent road transport laws and makes provision for safety in the transport of dangerous goods by rail. Establishes common guidelines so that dangerous goods can be transported between states and territories.
Energy Pipelines Act 1981	Makes provision for the construction, operation, maintenance and cessation of use or abandonment of pipelines for the conveyance of energy-producing hydrocarbons.

Act	Summary
Environmental Assessment Act 1982	Establishes the framework for the assessment of potential or anticipated environmental impacts of developments, and provides for protection of the environment. The NT Environment Protection Authority (NT EPA) is responsible for administering the Act. The NT EPA also determines the appropriate level of assessment for new developments or material changes to existing operations, based on the sensitivity of the local environment, the scale of the proposal and its potential impact upon the environment.
Environmental Offences and Penalties Act 1996	Establishes a penalty structure for environmental offences based around four offence levels. Penalties are defined in a variety of environmental statutes such as the Waste Management and Pollution Control Act and the Water Act.
Heritage Act 2011	Establishes the Heritage Council and the NT Heritage Register. It sets the process by which places become heritage places, allows for interim protection of places and sets out the process for getting permission to do work to heritage places and allows for fines and imprisonment for offences against the Act.
Northern Territory Aboriginal Sacred Sites Act 1989	Establishes the Aboriginal Areas Protection Authority (AAPA) as the body responsible for overseeing the protection of sacred sites in the NT. The AAPA provides a process for avoidance of sacred sites and/or entry onto sacred sites and the issue of Authority Certificates, which indemnify the holder against prosecution under the Act for damage to sacred sites in the certificate area, provided works or use has occurred in accordance with the conditions of the Authority Certificate.
Pastoral Land Act 1992	The Pastoral The Pastoral Land Act 1992 (NT) is an 'Act to make provision for the conversion and granting of title to pastoral land and the administration, management and conservation of pastoral land, and for related purposes. In particular, the Act provides for (i) the monitoring of pastoral land so as to detect and assess any change in its condition; (ii) the prevention or minimisation of degradation of or other damage to the land and its indigenous plant and animal life; and (iii) the rehabilitation of the land in cases of degradation or other damage.
Petroleum Act 1984	The Petroleum Act is the principal legislation dealing with petroleum tenure, exploration and production activities onshore and in inland waters of the NT. The Act provides a legal framework to undertake exploration for petroleum and to develop petroleum production so that the optimum value of the resource is returned to the NT. The Act is supported by the Petroleum (Environment) Regulations (Regulations) and the Schedule of Onshore Petroleum Exploration and Production Requirements 2012 (Schedule). The rules governing access by an interest holder to Pastoral Leases (granted under the Pastoral Land Act 1992) are set out in the Petroleum Act Stakeholder Engagement Guidelines Land Access (Land Access Guidelines). The Act and Requirements are administered by the Northern Territory Petroleum Registry (Registry) which forms part of the DPIR. The Minister for Primary Industry and Resources (Minister) is the applicable Minister for the purposes of the Act. The Petroleum (Environment) Regulations aim to ensure that: a) onshore oil and gas activities are carried out in a manner consistent with the principles of ESD; and b) environmental impacts and risks associated with onshore oil and gas activities are reduced to a level that is ALARP and acceptable. The Regulations achieve these objectives by requiring interest holders to have an approved EMP in place before a ‘regulated activity’ can be undertaken. The

Act	Summary
	Regulations also provide that the EMP will also form the basis of a Notice of Intent under the *Environmental Assessment Act*. The Minister for Environment has responsibility for the administration of the Regulations.
Public and Environmental Health Act 2011	Makes provision to protect and promote the health of individuals and communities in the Territory, and to monitor, assess and control environmental conditions, factors and factors and agents, facilities and equipment and activities, services and products that impact on, or may impact on, public and environmental health. Other relevant regulations under the Act include Public and Environmental Health Regulations which call up the Code of Practice for On-site Wastewater Management.. Wastewater treatment systems are be subject to requirements of the Act. Sewerage plants need to meet the NT Code of Practice for Small On-site Sewage and Sullage Treatment Systems and the Disposal or Reuse of Sewage Effluent.
Soil Conservation and Land Utilisation Act 1969	Makes provisions for the prevention of soil erosion and soil conservation and reclamation. It makes provisions for restricting construction activities that may damage or further damage land that is not environmentally stable, such as areas suffering soil erosion or areas that have the potential to erode.
Territory Parks and Wildlife Conservation Act 1976 (TPWC Act)	Makes provision for the establishment of Territory Parks and other Parks and Reserves and the study, protection, conservation and sustainable utilisation of wildlife. It sets aside areas of the NT as parks and conservation areas that may not be developed. Flora and fauna can also be declared as threatened species under the Act.
Waste Management and Pollution Control Act 1998 (WMPC Act)	Aims to protect, and where practicable, restore and enhance the quality of the NT environment; encourage ecologically sustainable development; and facilitate the implementation of National Environmental Performance Measures established by the National Environment Protection Council. It is designed to prevent contamination of the surrounding environment, including soil, air, and water, and imposes a general duty on conducting an activity or action that causes or is likely to cause pollution resulting in environmental harm, or that generates or is likely to generate waste. The disposal of listed waste and discharge of water to the environmental requires a licence under the Act. The WMPC Act does not apply within the petroleum permit area however applies to project activities undertaken outside the petroleum permit area.
Water Act 1992	Provides for the investigation, allocation, control, protection, management and administration of water resources in the NT. The Act prohibits waste to come in contact with water or water to be polluted unless under authorisation. The Water Act requires gas companies to obtain a water extraction licence prior to the extraction of any groundwater.
Weeds Management Act 2001	Aims to prevent the spread of weeds throughout the NT, ensuring the management of weeds is an integral component of land management. It is designed to ensure there is community consultation in the creation of weed management plans and that the landholder or interest holder takes responsibility in implementing weed management plans. If a weed is declared, all landholders, land managers and land users must comply with the declaration classification. The following are the three classes of declared weeds in the NT: • Class A - to be eradicated • Class B - growth and spread to be controlled • Class C - not to be introduced into the NT.

Act	Summary
	All Class A and Class B weeds are also Class C weeds.
Work Health and Safety (National Uniform Legislation) Act 2011	The WHS Act is part of the nationally harmonised work health and safety laws, which aim to provide all workers in Australia with the same standard of health and safety protection regardless of the work they do or where they work.
International Agreements	
• Migratory species: • Japan-Australia Migratory Bird Agreement • China-Australia Migratory Bird Agreement • Republic of Korea-Australia Migratory Bird Agreement • Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention)	Australia is party to many international agreements to protect and conserve migratory species and their habitat. Migratory species listed on the annexes to these Agreements are placed on the migratory species list under the EPBC Act.
Ramsar Convention on Wetlands	The Ramsar Convention's broad aims are to halt the worldwide loss of wetlands and to conserve, through wise use and management, those that remain. Ramsar wetlands within Australia are listed as a MNES and protected under the EPBC Act.

2.3.1 Summary of Legislative Requirements

A summary of legislative requirements and associated project approvals relevant to environmental management, and Santos's actions and intent for each are provided in Table 2-4.

Table 2-3 Summary of Legislative Requirements

Legislative Requirement	Relevant Legislation	Administrator	Proposed Action
Commonwealth			
Exploration Permit	*Petroleum Act 2016* and Petroleum (Environment) Regulations	DPIR	Activities operated under Exploration Permit 161.
Approved Environmental Management Plan	Petroleum (Environment) Regulations	DENR	An EMP will be approved prior to commencement of the project activities
Minister's Approval	*Environment Protection and Biodiversity Conservation Act 1999*	DOEE	Santos does not consider the scope of the EMP likely to have any significant impacts on Matters of National Environmental Significance and will not be referring the activities for assessment at this stage. Refer to Section 6.2.1.

Legislative Requirement	Relevant Legislation	Administrator	Proposed Action
Notice of Intent and Formal Environmental Assessment	*Environmental Assessment Act 2013* and Administrative Procedures	NT EPA	This EMP does not constitute any material change of use. Santos therefore considers it unnecessary to refer the activity for assessment. Refer to Section 6.2.2.
Must not enter, damage or interfere with a Sacred Site (even if not registered) AAPA Authority Certificate	*Northern Territory Aboriginal Sacred Sites Act 2013*	AAPA	Santos and the Northern Land Council are parties to a Cooperation and Exploration Agreement. Multiple consultations and sacred site avoidance surveys completed 2013 – 2019. Refer to Section 4.3. All activities proposed in this EMP will only be conducted with an AAPA Authority Certificate. The Authority Certificate protects sacred sites on or in the vicinity of the subject land via the imposition of relevant conditions on the carrying out of the works. Application for an Authority Certificate Variation to cover all of the locations and activities in the 2019 proposed program was submitted in January 2019. Subsequently Authority Certificate C2019/043 was granted to cover these activities.
Work approval (for removal or damage of archaeological sites)	*Heritage Act 2011*	DENR	A survey has been completed and no archaeological sites were identified. As a result, Santos does not anticipate a work approval will be required.
Groundwater Extraction Licence	*Water Legislation Amendment Act 2018*	DENR	Application for a groundwater extraction licence associated with NT Portion 701 accepted in February 2019.
Reporting under National Greenhouse and Energy Reporting Scheme (NGERS)	*National Greenhouse and Energy Reporting Act*	Australian Government – Clean Energy Regulatory	Santos is obligated and registered to report under the scheme.
Dangerous Goods Vehicle Licence	*Transport of Dangerous Goods by Road* and *Rail (National Uniform Legislation) Act*	NT Worksafe	Santos will ensure licence is held by Santos or contractor if applicable.
Land Access and Compensation Agreement (LACA)	*Petroleum Act 2016 and* Petroleum Act Stakeholder Engagement Guidelines Land Access (Land Access Guidelines)	DPIR	Existing LACAs in place for ongoing work at Tanumbirini 1 location and water monitoring bore construction and sampling. Santos will ensure LACAs are in place for all activities proposed in this EMP prior to commencing activities.

Legislative Requirement	Relevant Legislation	Administrator	Proposed Action
All activities described in this EMP	*Work Health and Safety (National Uniform Legislation) Act 2011* and Regulations	NT WorkSafe	All activities described in this EMP are subject to *Work Health and Safety (National Uniform Legislation) Act 2011* and Regulations

2.4 Relevant Agreements and Operating Consents

Land access guidelines under the Petroleum Act require Santos to reach agreement with the Pastoralist prior to the commencement of exploration activities.

The Regulations sets out a process for stakeholder engagement when a company proposes to undertake a regulated activity. Stakeholder engagement undertaken for the project is discussed in Section 8.

Traditional owners under the *Native Title Act*, and Aboriginal owners under the *Aboriginal Land Rights Act* (ALRA) are given the opportunity to negotiate an agreement about how petroleum activities must occur in accordance with statutory processes described in each Act.

The agreement, Co-operation and Exploration Agreement - Exploration Permit Application EP (A) 161, Northern Territory, executed on 4 April 2012, is a legal agreement between Tamboran Resources Pty Ltd and the Northern Land Council (NLC) (the body corporate representing the Traditional Owners). The agreement is referred to by Santos as 'the NLC Agreement'.

Santos will ensure that prior to commencement of the new works proposed in this EMP, necessary consents and approvals have been identified, obtained and are in place and the work will be undertaken in accordance with the terms and conditions as detailed in the NLC Agreement.

2.5 Codes of Practice and Relevant Guidelines

The Code of Practice: Petroleum Activities in the Northern Territory ("The Code") (Northern Territory Government, 2019) applies to all activities involved in both conventional and unconventional oil and gas exploration, appraisal, development and production and ancillary activities in the Northern Territory. The Code covers all petroleum activities including all petroleum well types including exploration, appraisal, development, monitoring, injection and production wells.

Measures to ensure the proposed Hydraulic Fracturing Program are compliant with the Code have already commenced. In November and December 2018 two separate EMPs were approved for the construction of lease pads and installation of groundwater monitoring bores at the Tanumbirini 1/2H and Inacumba 1/1H locations. These control monitoring bores have been installed and baseline monitoring in compliance with the Guideline and the Code has commenced.

Well lease layouts for the Hydraulic Fracturing Program showing the location of the monitoring bores is provided in Figure 3-2 and Figure 3-3.

In addition to the Code, contractors undertaking activities will be required to comply with the following environmental standards, guidelines and codes of practice:

- Santos Management System (SMS).
- Australian Petroleum Production and Exploration Association (APPEA) *Code of Environmental Practice* (2008).
- Draft Guideline for the preparation of an Environmental Management Plan under the Petroleum (Environment) Regulations (draft Guidelines) (Northern Territory Government, 2019).

- NT EPA Environmental Factors and Objectives (NT EPA, 2018)
- Code of Practice: Petroleum Activities in the Northern Territory (expected 2019)
- NORSOK D-010, Rev 4 (2013)
- Code of Practice for the construction and abandoning Coal Seam Gas and petroleum wells and Associated Bores in Queensland Version 1, 1 (2018)

The following ISO/API standards have been adopted for the selection of materials for use in the EP161 for this project:

Table 2-4 ISO/API Standards for Material Selection

Component	Applicable Standard
Casing	ISO 11960: Steel pipes for use as casing or tubing for wells.
Couplings	ISO 13679 Procedures for testing casing and tubing connections.
Cement and Additives	API RP 10B-2 Recommended Practice for Testing Well Cements
Drilling Fluids	ISO 10414-1: Recommended Practice for Field Testing Water Based Drilling Fluids. API 13B-1 and 13B-2 Recommended Practices
Well Control Equipment	API STD 53: Blow-Out Prevention Equipment Systems for Drilling Wells. API 16A (ISO 13533): Specification for drill through equipment. API 16D: Specification for Control Systems for Drilling Well Control Equipment and Control Systems for Diverter Equipment.
Wellheads	API 6A: Specification for Wellhead and Christmas Tree Equipment. ISO 10423: Petroleum and Natural Gas Industries - Drilling and Production Equipment - Wellhead and Christmas Tree Equipment
Drill String	API Spec 5DP (ISO 11961) Specification for Drill Pipe DS-1 Fourth Edition

2.6 Referrals under NT and Commonwealth legislation

2.6.1 Referral under the Environment Protection and Biodiversity Conservation Act

The *Environment Protection and Biodiversity Conservation Act 1999* provides for the protection of the environment and conservation of biodiversity, particularly MNES. Referral of the project to the Department of Environment and Energy is required if the proposed action will have, or is likely to have a significant impact, which is discussed in section 6.2.1.

2.6.2 Referral under the Environmental Assessment Act

Petroleum activities that could reasonably be considered to be capable of having a significant effect on the environment are referred to the NT EPA, pursuant to Section 7 of the Environmental Assessment Act (EA Act). Using the guideline “Referring a proposal to the NT EPA: A guide for proponents and referral agencies” (NT EPA 2018), a detailed review of and assessment against each prescribed Environmental Objectives for each Environmental Factor was conducted in relation to the proposed Hydraulic Fracturing Program, which is discussed in section 6.2.2.

3.0 Project Description

Santos QNT Pty Ltd (Santos) is the operator of exploration permit (EP) 161 which is located approximately 350 km south-east of Katherine in the Northern Territory (NT). The Project Area for the program is located on Tanumbirini Station, a 5,000 km^2 cattle grazing property within NT Portion 701 of Arnold.

Santos has undertaken exploration activities in EP 161 since 2013, including acquiring 2D seismic data, drilling of one exploration well (Tanumbirini 1), one stratigraphic core hole (Marmbulligan-1), and the installation of water monitoring bores.

In support of the 2019 exploration program, the McArthur Basin Civil and Seismic Program EP161 EMP, covering all civils works associated with the construction of access tracks and the well lease, was submitted and approved on 6 June 2019. An additional EMP (McArthur Basin 2019 Drilling Program EP 161) covering drilling related actives leading up to (but not including) the hydraulic stimulation activities, was submitted on 8 April 2019 was reviewed for completeness and formally accepted on Tuesday 9 April 2019. The drilling EMP also includes, rehabilitation post well suspension and post-decommissioning of wells as well as post-rehabilitation monitoring.

Santos proposes to undertake a Hydraulic Fracture Stimulation (HFS) and Appraisal (Production) Testing Program in 2019 and 2020 at the Tanumbirini 1, Tanumbirini 2H and Inacumba 1/1H locations. This EMP covers these new proposed works. A full description of the activities covered in this EMP is provided below.

3.1 Timing

The HFS Program is expected to take between 15-40 days per well and will be undertaken Q3 2019 through to Q1 2020. Flow testing will following the HFS Program and will have a duration of up to 12 months. An indicative project schedule is provided in Table 3-1. The project will be carried out in 12-hour day shifts where possible.

Table 3-1 Indicative Project Schedule

Activity	Estimated duration	Estimated commencement
Drilling Tanumbirini 2	9 weeks	Aug-Oct 2019
Drilling Inacumba 1	14 weeks	Oct-Dec 2019
Hydraulic Fracture Stimulation	8 weeks	Nov-Dec 2019
Demobilisation of HFS equipment	2-4 weeks	Nov-Dec 2019
Well testing and flowback fluid management and testing	12 months	Dec 2019 - Dec 2020
Well Suspension and/or Plugging and Abandonment	4 weeks	To be determined

3.2 Workforce and Accommodation

All contractors will be drive in and drive out until April 2020 when the charter flight services commence.

The majority of contractors working on the project to date have been Northern Territory based drive in and drive out personnel employed by NT based companies. These include:

- Rusca Group have been utilised for the civils;
- Silver City Drilling for the water bore drilling; and
- MS Contracting accommodation supplies.

The Drilling and Completions and hydraulic fracturing program will almost all be drive in and drive out interstate/international personnel until April 2020. All equipment will be driven in to site. Personnel will be driving down from Darwin for crew changes.

Once the charter flight services commence in April 2020, the rostered changes for the workforce will be full fly in and fly out interstate/international personnel. This is predominantly due to skill requirements and industry infancy in the McArthur Basin. Local providers will be used where suitable.

Accommodation will be provided for by MS Contracting (Darwin based). There will be a camp at each of the two well site locations and each camp can hold up to 116 people and support the full operation.

3.3 Well Description and Site Activities

The purpose of exploration and appraisal activities is to increase the understanding of the prospectivity or potential of the EP161 permit area by:

- Hydraulic fracture stimulation (including fracturing diagnostics)
- Flow-back and appraisal (production) testing

A location and infrastructure plan for the Hydraulic Fracturing Program is shown and well lease layouts for the Hydraulic Fracturing Program are shown in Figure 3-1, Figure 3-2 and Figure 3-3. In addition, an illustrative section showing proposed target intervals of the Tanumbirini 2H and Inacumba 1/1H wells is shown in Figure 3-4.

Key activities for the Hydraulic Fracturing Program includes:

- Fracture stimulation preparation activities including cement bond logging, drifting and pressure testing
- Fracture stimulation evaluation
- Pressure monitoring
- Placement of chemical tracers
- Installation of tiltmeters
- Installation of passive seismic monitoring surface array
- Walkaway VSP
- Microseismic / passive seismic monitoring
- Tiltmeter recovery and restoration
- Flowback fluid recovery and well testing
- Installing appraisal (production) testing tubing
- Suspension and build-up testing
- Well appraisal testing

Legend
- Water Bores
- Existing Access Road
- Proposed Access Road
- Major Waterways
- Principal Road
- Inacumba Lease
- Tanumbirini Lease

1:220,000 @ A4

0 2.5 5 7.5 10

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

N

Santos
McArthur Basin
Environmental Management Plan

Proposed Infrastructure

Project No. **43-22812**
Revision No. **B**
Date **2/04/2019**

FIGURE 3-1

S:\GIS\Projects\4322812\GIS\Maps\432281200_022_ProposedInfrastructure_RevB.mxd
Print date: 02 Apr 2019 - 10:20

Data source: Google Earth: imagery (Jun 2016, captured Mar 2017 . GA: Roads, Waterways (2015) Santos: Proposed Access Roads, Existing Access Roads, Inacumba and Tanumbirini Lease Pads, Borrow Pit, Seimic Line (2019)
Created by: cmacgregor

Legend

- Water Bore
- Existing Well
- Proposed Well
- Proposed Topsoil Area
- Proposed Access Road
- Existing Access Road
- 2D Seismic Line
- Waterline
- Fire Control Area
- Cuttings Pit
- Existing Topsoil Area
- Borrow Pit
- Proposed Facilities
- Tanumbirini 1 Lease
- Tanumbirini 2 Lease
- Water Tank
- Dam
- Proposed Irrigation Area

1:5000 @ A4

0 50 100 150 200

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

N

GHD

Santos
McArthur Basin
Environmental Management Plan

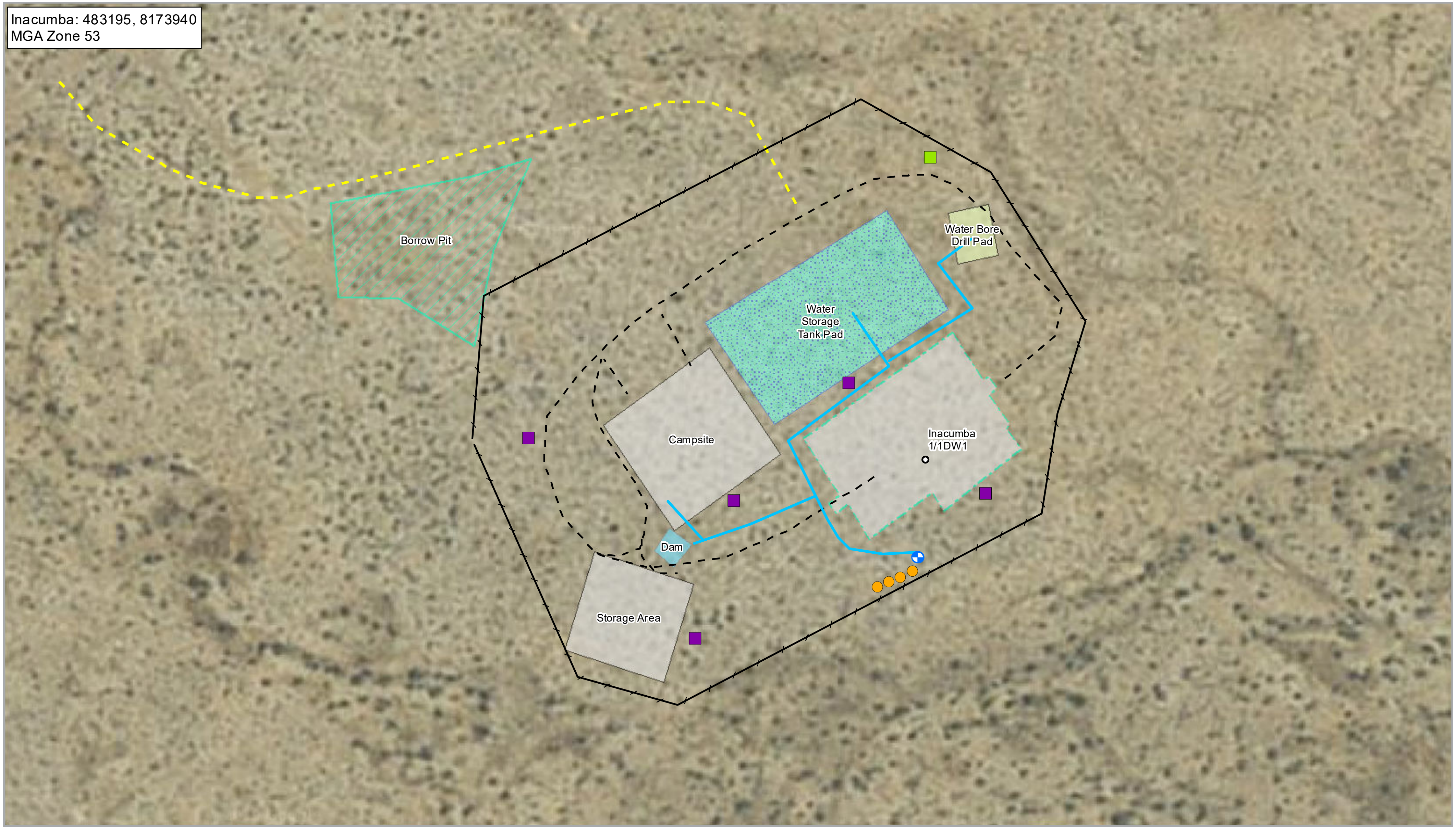
Tanumbirini Lease Pad

Project No. 43-22812
Revision No. B
Date 30/04/2019

FIGURE 3-2

\\ghdnet\ghd\AU\Brisbane\General\Services\GIS\Projects\43\22812\GIS\Maps\4322812 00_005_TanumbiriniLeasePad_RevB.mxd
Print date: 30 Apr 2019 - 14:31

Data source: Google Earth: imagery (Jun 2016, captured Mar 2017). Santos: Water Bores, Wells, Drilling Opportunities, Valves, Access Roads (existing and proposed), Waterline, Seismic Line, Fire control Area, Leases, Facilities, WaterTanks, Dam, Borrow Pit, Overburden (2019); GHD: Irrigation Area, Proposed Topsoil (2019). Created by: ACJackson



Legend

- Proposed Well
- 30,000L Tank
- Water Bores
- Soil Stockpile
- Vegetation Stockpile
- Loop Road Access
- Water Flowline
- New Access Road Option 1
- Fence
- Water Bore Drill Pad
- Inacumba Lease
- Borrow Pit
- Facilities
- Dam
- Water Tank Pad

1:5000 @ A4

0 25 50 75 100 125 150

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

N

GHD

Santos
McArthur Basin
Environmental Management Plan

Proposed Infrastructure for the Inacumba-1/1DW1 Location

Project No.	43-22812
Revision No.	C
Date	13/06/2019

FIGURE 3-3

N:\AU\Brisbane\General\Services\GIS\Projects\4322812\GIS\Maps\432281200_006_InacumbaLeasePad_RevC.mxd
Print date: 13 Jun 2019 - 16:51

Data source: . Google Earth: imagery (Jun 2016, captured Mar 2017). Santos: Water Bores, Wells, Drilling Opportunities, Valves, Access Roads (existing and proposed), Waterline, Leases, Facilities, WaterTanks, Dam, Borrow Pit (2019). GHD: Proposed Topsoil Area (2019). Created by: xlee

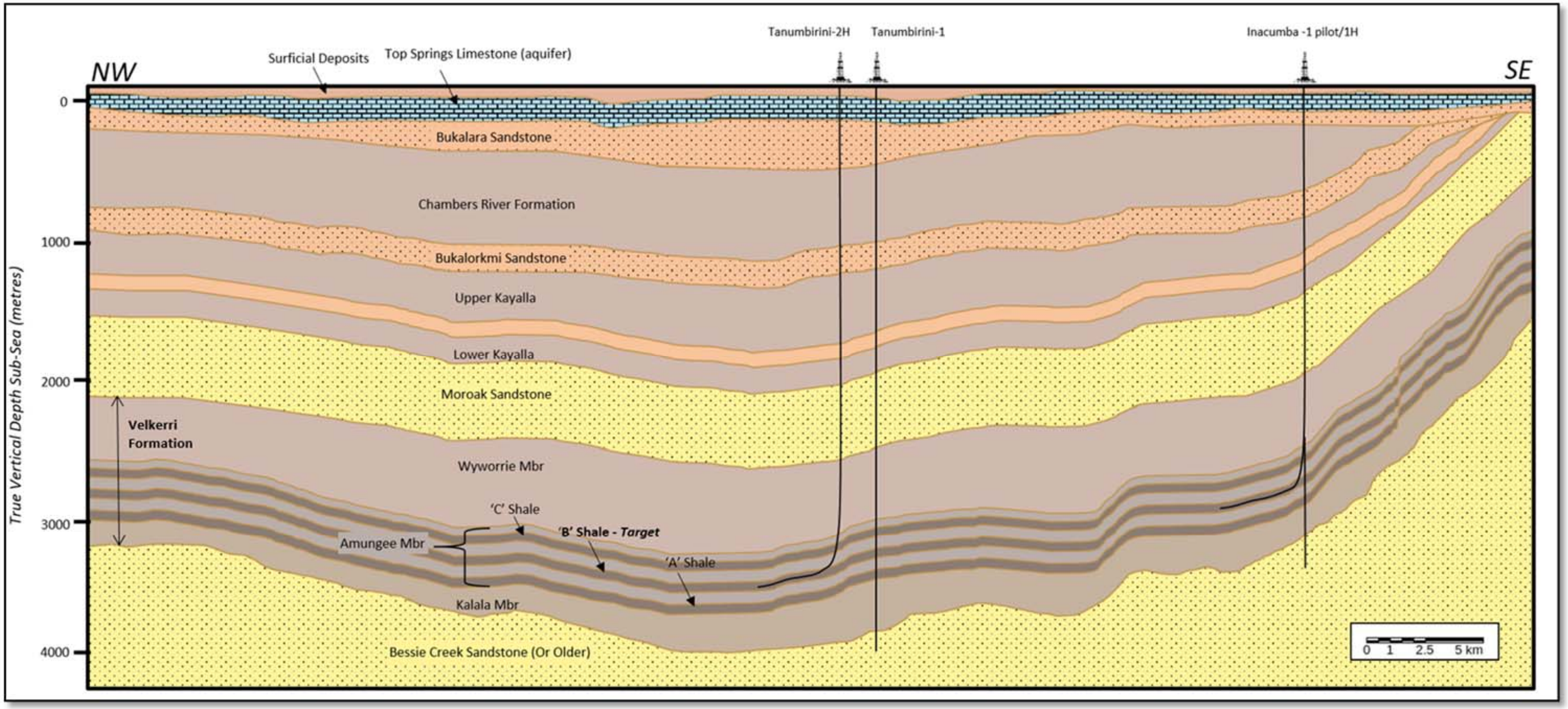


Figure 3-4 Illustrative section through the Beetaloo Sub-basin showing proposed target intervals of the Tanumbirini 2H and Inacumba 1/1H wells relative to the deepest aquifer

3.3.1 Inacumba 1/1H

The proposed Inacumba 1H horizontal well will appraise the south-eastern flank of the eastern extension of the Beetaloo Sub-basin approximately 20km south-east of Tanumbirini 1. Figure 3-5 outlines the expected formations and depths that will be intersected with a brief description of the general lithology of each formation/member, while Figure 3-6 provides a schematic of the proposed casing shoe depths.

Following completion of the well drilling operations, the operator proposes to conduct a program of hydraulic fracture stimulations in the horizontal section of the Inacumba 1H well bore, and subsequently flow test the well. The precise interval targeted by the horizontal section of the well will be confirmed once the results of the vertical pilot well are known, but the shallowest possible target is considered to be the Amungee Member C Shale (of the Velkerri Formation). The top of this unit is prognosed to be intersected at 2,462m TVD in the vertical pilot well. The deepest aquifer at this location, based on offset well data (including water bores), is expected to be the Bukalara Sandstone. The base of this unit is prognosed to be intersected at 477m TVD. Therefore a minimum offset of 1,985m is expected between the base of the deepest aquifer and the top of the shallowest primary target of the horizontal section of the well. This significantly exceeds the minimum offset, of more than 600m, between top target zone and base aquifer as mandated by the Code of Practice.

The Bukalara Sandstone, which is stratigraphically deeper than the Top Springs Limestone was penetrated by RN040939 and RN041242 and completed as water supply and monitoring bores. The waterbores did not drill to the base of the Bukalara Sandstone.

Planned hydraulic fracturing activity will involve conducting 15-25 fracturing stages using the plug and perforation technique as outlined in Section 3.4. Water soluble chemical tracers will be included to help allocate flowback returns to the specific treatment stage, with gas tracers confirming the zonal contribution of gas from each interval. Surface tiltmeters will provide understanding of the degree of horizontal fracture propagation as well as vertical fracture orientation.

Coiled tubing will be used to clear the wellbore following the fracturing, milling plugs and nitrogen lifting if required. The initial flowback phase is expected to take 1-2 weeks followed by appraisal (production) testing for up to one year. The flowback and appraisal (production) testing procedures and risks are addressed in Section 6.0.

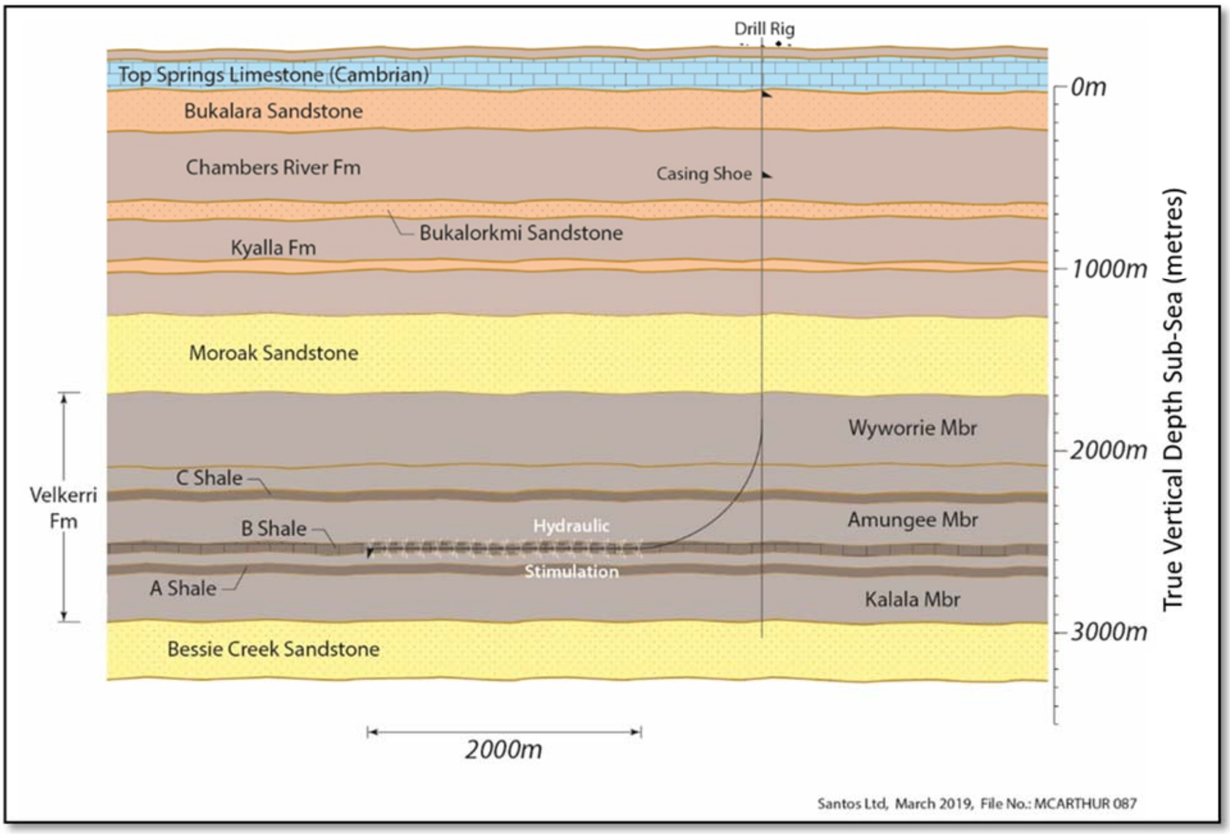


Figure 3-5 Schematic diagram illustrating offset between top of target interval and base of shallowest aquifer in Inacumba 1H

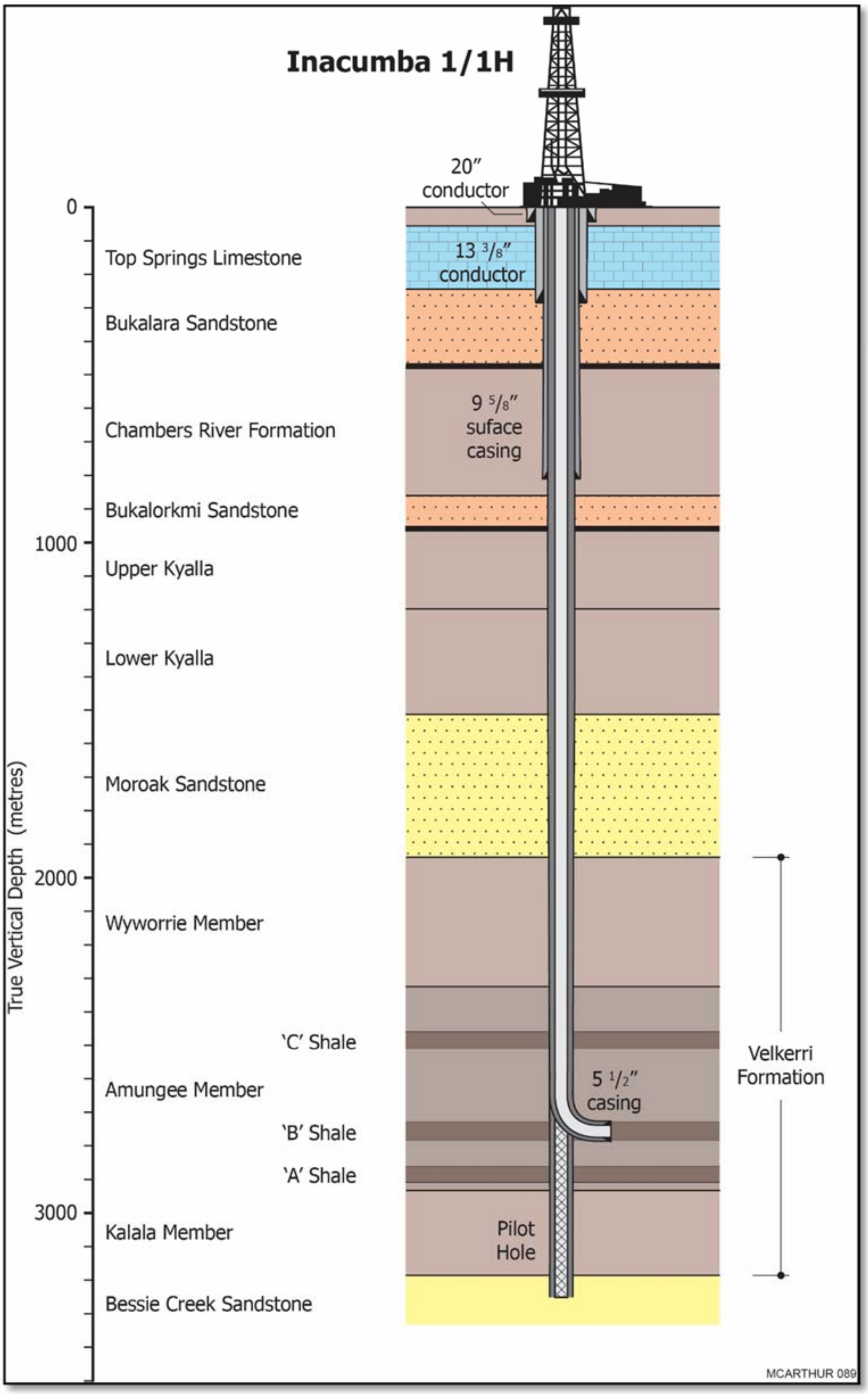


Figure 3-6 Schematic diagram illustrating locations of proposed casing shoes relative to stratigraphy (and Top Springs Limestone aquifer) in Inacumba 1/1H (horizontal section not to scale).

3.3.2 Tanumbirini 2H

The proposed Tanumbirini 2H horizontal well will appraise the deep basin area of the eastern extension of the Beetaloo Sub-basin. Tanumbirini 1, located approximately 50m to the north-east, provides depth control, and the Tanumbirini 1 log data have been used as control for trajectory planning. Figure 3-7 outlines the expected formations and depths that will be intersected with a brief description of the general lithology of each formation/member, while Figure 3-8 provides a schematic of the proposed casing shoe depths.

The proposed horizontal well will be geosteered to remain in the optimum zone of the Velkerri B Shale using real-time Logging While Drilling (LWD) tools. The optimum zone has been defined as an interval in the Velkerri B Shale with high Total Organic Content (TOC) and lower clay content. Tanumbirini 1 source rock analysis for core and cutting samples have been used to confirm TOC and calibrate petrophysical models for future data acquisition and indicates that the Tanumbirini 2H horizontal well should intersect a highly mature Velkerri B Shale interval with an expected dry gas composition i.e. primarily methane. The horizontal well is currently planned to reach a total depth of 5,800 mMD/3,450 mTVD.

Following completion of the well drilling operations, the operator proposes to conduct a program of hydraulic fracture stimulations in the horizontal section of the Tanumbirini 2H well, and subsequent flow testing. The primary target for the horizontal section of the well comprises the Amungee Member B Shale (of the Velkerri Formation). The top of this unit is prognosed to be intersected at 3,425m TVD. The deepest aquifer expected at this location is the Top Springs Limestone (Gum Ridge Formation). The base of this unit is prognosed to be intersected at 202m TVD. Therefore a minimum offset of 3,223m is expected between the base of the deepest aquifer and the top of the primary target of the horizontal section of the well. This significantly exceeds the minimum offset, of more than 600m, between top target zone and base aquifer as mandated by the Code of Practice.

The Bukalara Sandstone, which is stratigraphically deeper than the Top Springs Limestone, is recognised as an aquifer on a regional basis. However, based available data acquired during drilling of offset wells (including water bores) the Bukalara Sandstone is not considered to be of sufficient quality (porosity and permeability) to constitute an aquifer at this location. The base of the Bukalara Sandstone is prognosed to be intersected 582m TVD. Thus even if the Bukalara Sandstone were regarded as an aquifer at this location, the offset to the top of the target interval (3,425m TVD) would still be 2,843m; which far exceeds the minimum offset required under the Code of 600m.

Planned hydraulic fracturing activity will involve conducting 15-25 fracturing stages using the plug and perforation technique as outlined in Section 3.4. Water soluble chemical tracers will be included to help allocate flowback returns to the specific treatment stage, with gas tracers confirming the zonal contribution of gas from each interval. Surface tiltmeters will provide understanding of the degree of horizontal fracture propagation as well as vertical fracture orientation. Geophones will be located in Tanumbirini 1 during the Tanumbirini 2H fracturing operations to allow microseismic mapping of fracturing extent (height, length, and orientation).

Coiled tubing will be used to clear the wellbore following the fracturing, milling plugs and nitrogen lifting if required. The initial flowback phase is expected to take 1-2 weeks followed by appraisal (production) testing for up to one year. The flowback and appraisal (production) testing procedures and risks are addressed in Section 6.0.

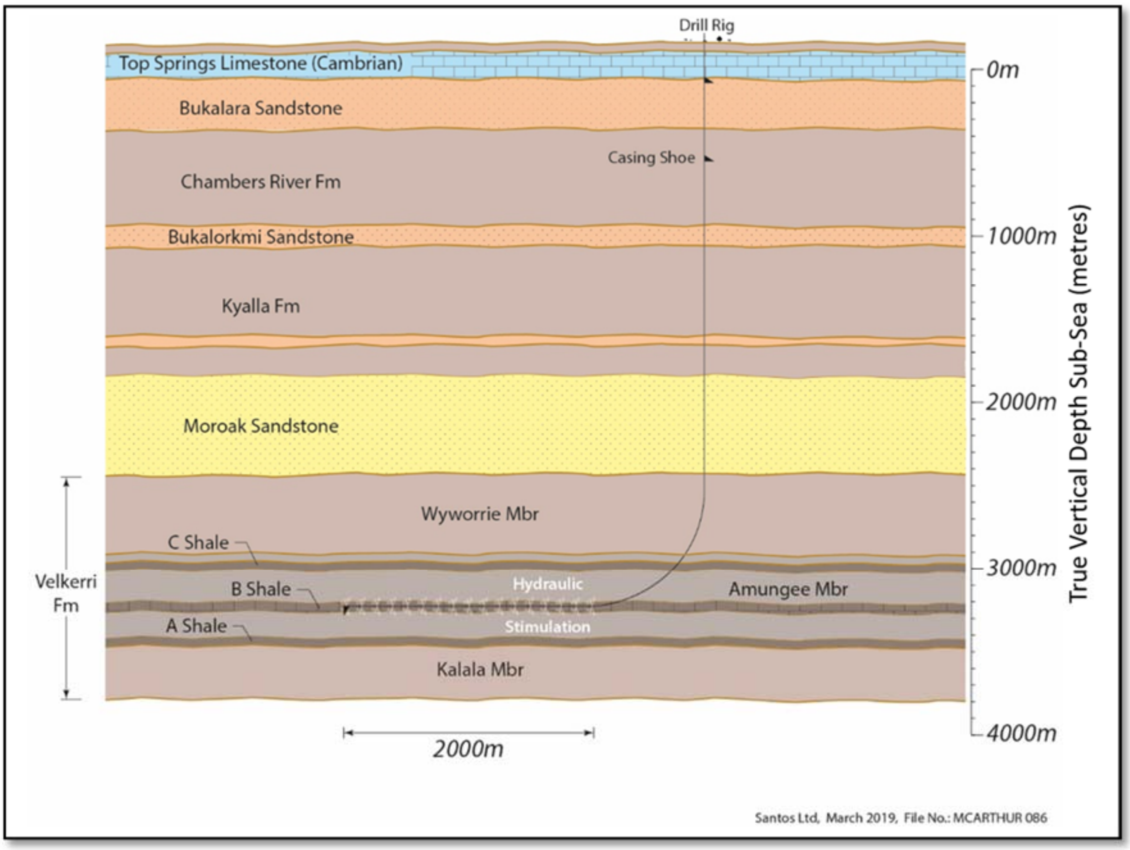


Figure 3-7 Schematic diagram illustrating offset between top of target interval and base of shallowest aquifer in Tanumbirini 2H

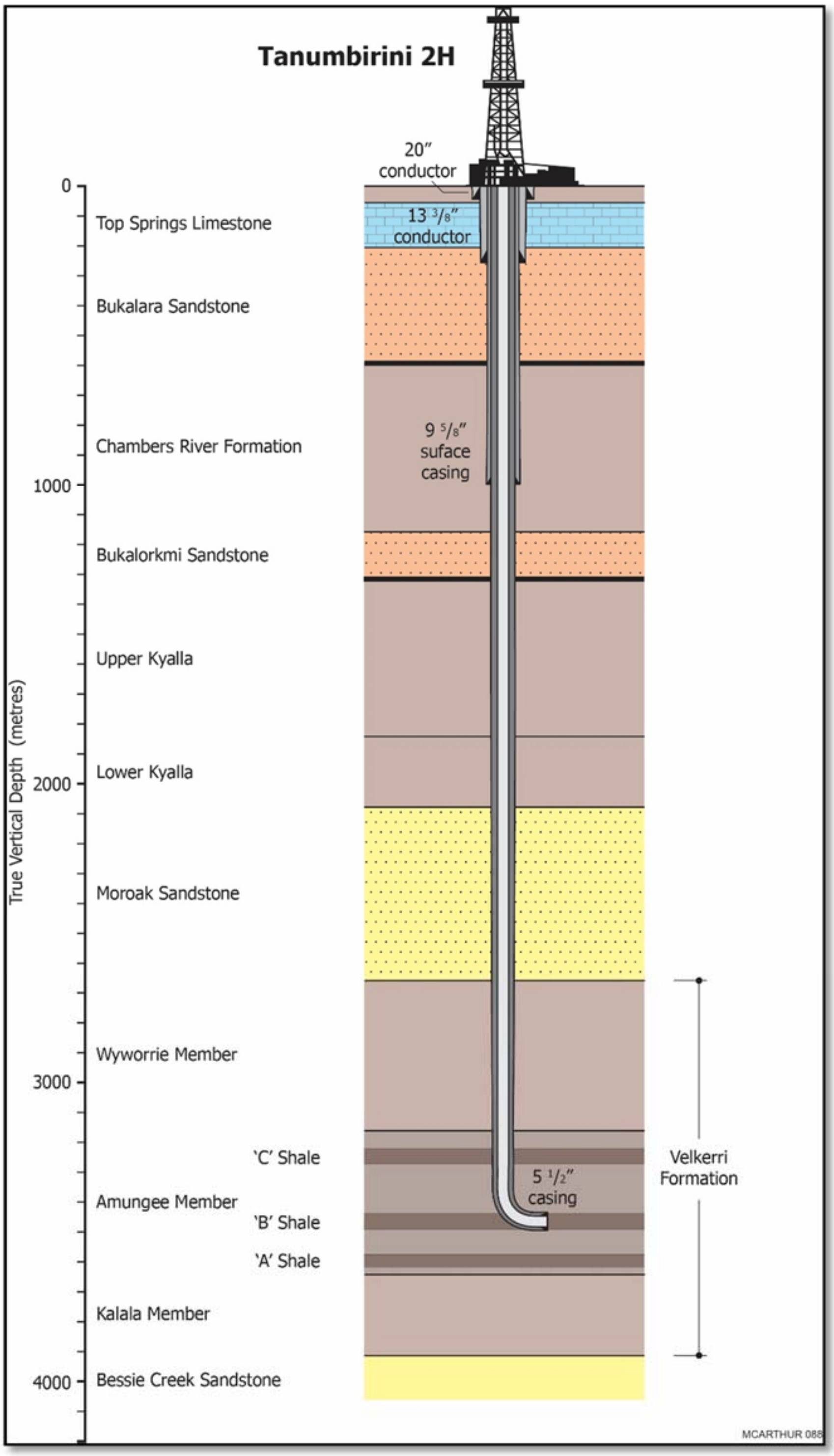


Figure 3-8 Schematic diagram illustrating locations of proposed casing shoes relative to stratigraphy (and Top Springs Limestone aquifer) in Tanumbirini 2H (horizontal section not to scale).

3.3.3 Tanumbirini 1

The Tanumbirini 1 vertical well will appraise the deep basin area of the eastern extension of the Beetaloo Sub-basin. Figure 3-9 outlines the formations and depths that were intersected with a brief description of the general lithology of each formation/member, while Figure 3-10 provides a schematic of the casing shoe depths.

The Tanumbirini 1 well was drilled to a total depth of 3946m (MD & TVD) and drilled through the Velkerri formation, which is the target for appraisal. The operator proposes to conduct a program of hydraulic fracture stimulations in various targets of the Velkerri formation, fracturing and testing the A, B, and C shales. The top of the Velkerri unit was intersected at 2,644m TVD. The deepest aquifer expected at this location is the Top Springs Limestone (Gum Ridge Formation). The base of this unit was intersected at 202m TVD. Therefore a minimum offset of 2,442m is expected between the base of the deepest aquifer and the top of the uppermost target of the Velkerri formation (Figure 3-9). This significantly exceeds the minimum offset, of more than 600m, between top target zone and base aquifer as mandated by the Code of Practice.

The Bukalara Sandstone, which is stratigraphically deeper than the Top Springs Limestone, is recognised as an aquifer on a regional basis. However, based available data acquired during drilling of offset wells (including water bores) the Bukalara Sandstone is not considered to be of sufficient quality (porosity and permeability) to constitute an aquifer at this location. The base of the Bukalara Sandstone is prognosed to be intersected 582m TVD. Thus even if the Bukalara Sandstone were regarded as an aquifer at this location, the offset to the top of the Velkerri (2,644m TVD) would still be 2,062m; which far exceeds the minimum offset required under the Code of 600m.

Planned hydraulic fracturing activity will involve conducting 5 fracturing stages using the plug and perforation technique as outlined in Section 3.4. Water chemical tracers will be included to help allocate flowback returns to the specific treatment stage, with gas tracers confirming the zonal contribution of gas from each interval. Surface tiltmeters will provide understanding of the degree of horizontal fracture propagation as well as vertical fracture orientation.

Coiled tubing will be used to clear the wellbore following the fracturing, milling plugs and nitrogen lifting if required. The initial flowback phase is expected to take 1-2 weeks followed by appraisal (production) testing for up to one year. The flowback and appraisal (production) testing procedures and risks are addressed in Section 6.0.

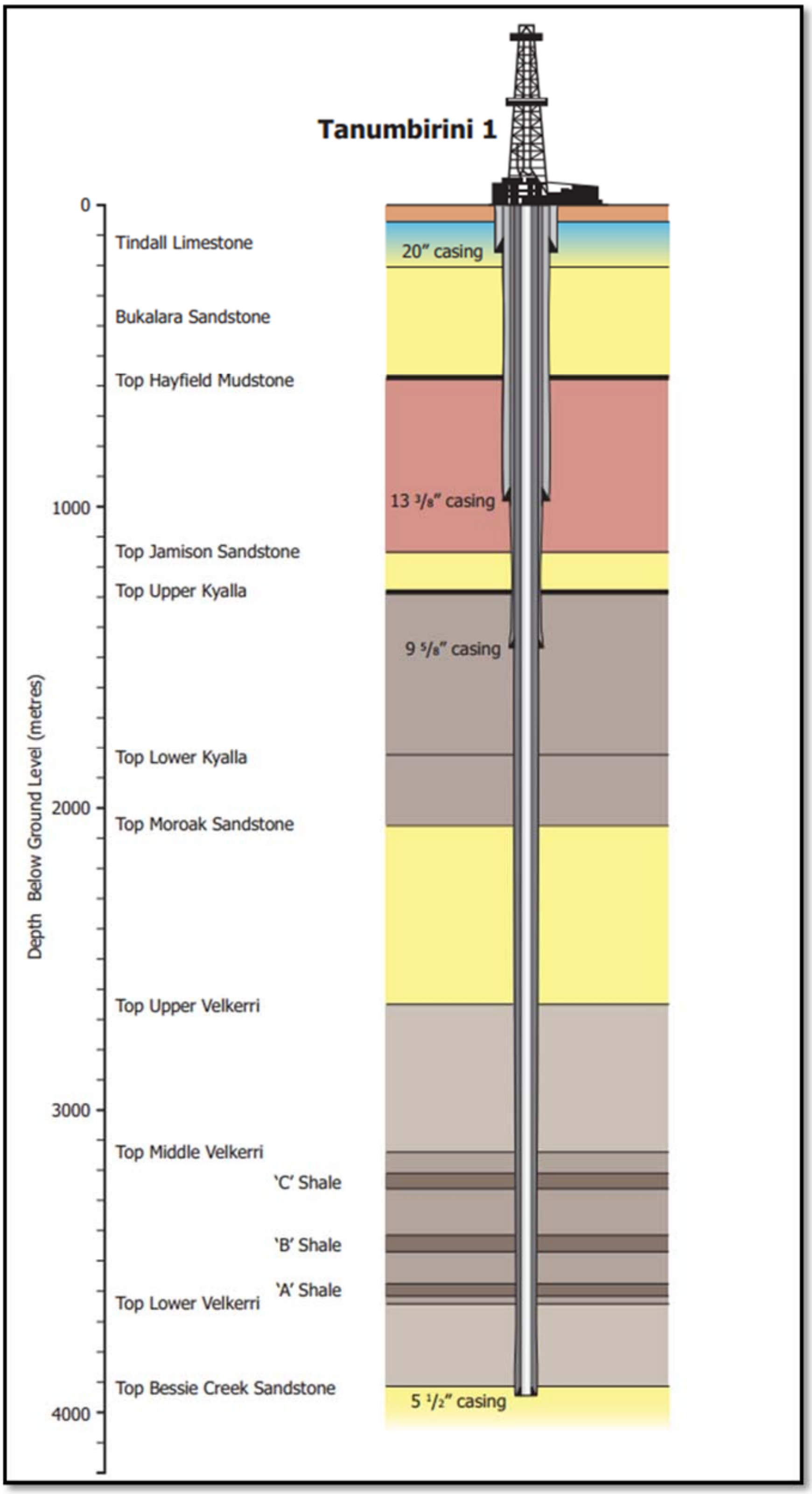


Figure 3-9 Schematic diagram illustrating offset between top of target intervals and base of shallowest aquifer in Tanumbirini 1

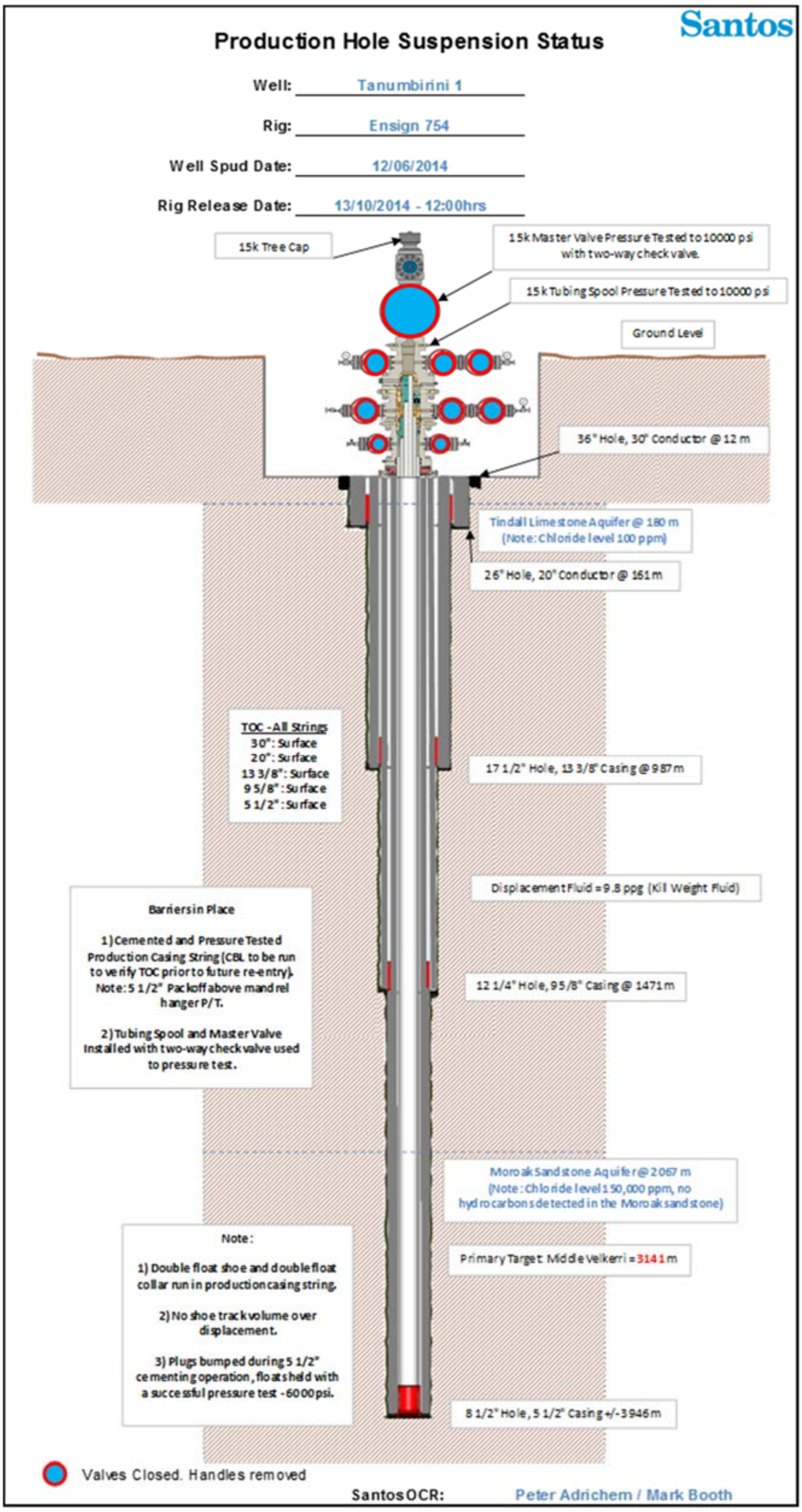


Figure 3-10Schematic diagram illustrating locations of casing shoes relative to stratigraphy (and Top Springs Limestone aquifer) in Tanumbirini 1.

3.4 Hydraulic Fracture Stimulation Program

Hydraulic fracture stimulation (HFS) is not part of the drilling process but is a completion technique applied after the well is drilled. The intent of hydraulic stimulation is to place highly conductive channels into the reservoir (illustrated in Figure 3-11) to increase the flow capacity of the well and increase the production of natural gas. Hydraulic stimulation involves the injection of hydraulic fracturing fluids (water, sand / proppant and minor chemical additives) at high pressure into a cased wellbore, and it is usually conducted over a number of intervals along the production zone of the well. This technique is commonly used in low permeability reservoirs that cannot sustain economic production, such as shale.

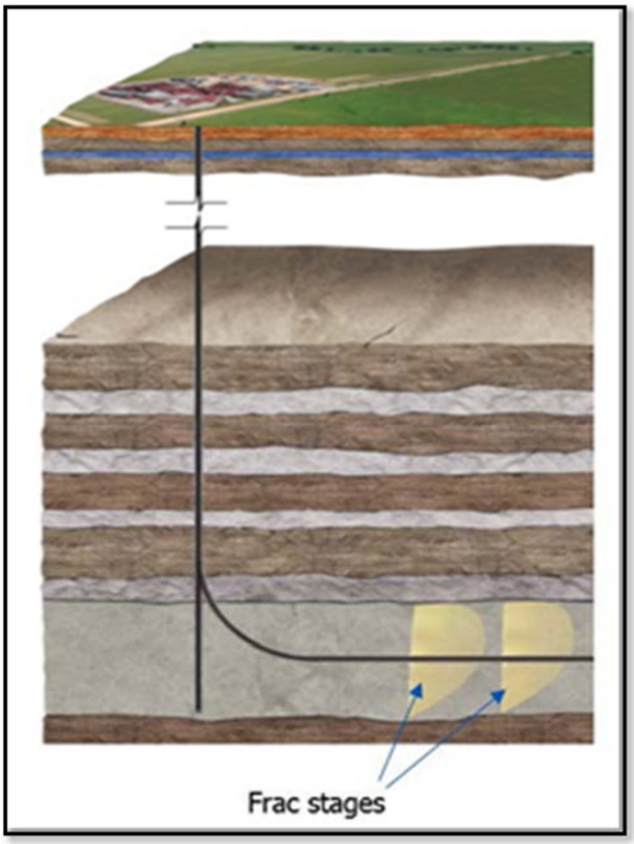


Figure 3-11 Illustration of Multi stage Fracture Stages in a Horizontal Well

This process has been extensively used in the industry since 1947. Santos has successfully used this technique on wells in the Cooper Basin for nearly 50 years and is currently performing the process in many basins around Australia. A photo from a 3 well pad location in the Cooper Basin (with mark-up of major equipment on location during the hydraulic fracturing operation) is shown in Figure 3-12.

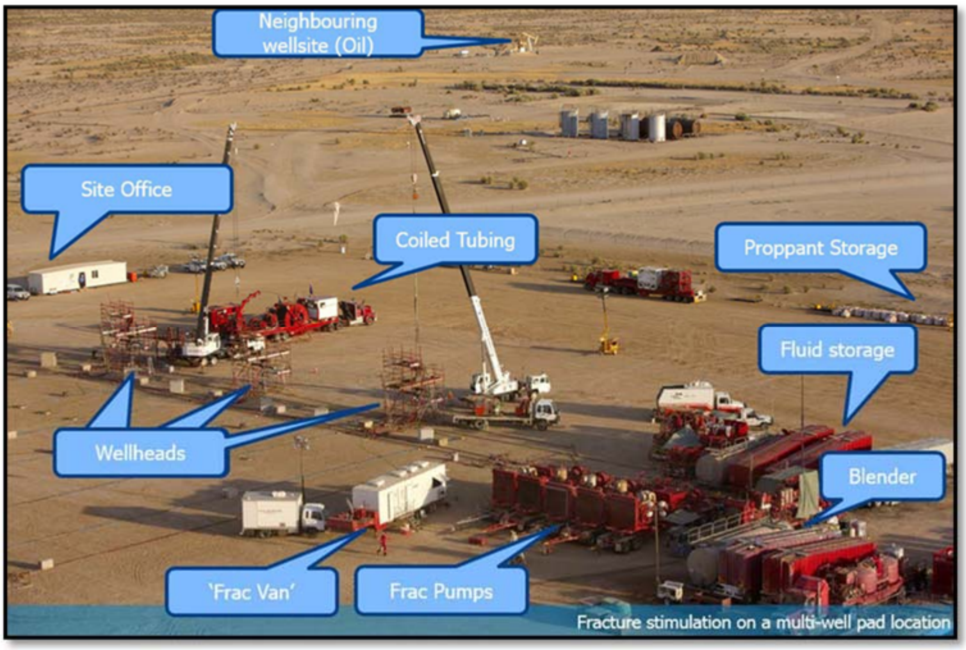


Figure 3-12 Fracture Stimulation equipment in a 3-well location (pad) in the Cooper Basin

The stimulation process involves pumping water, a specific blend of chemical additives and a propping agent such as sand or ceramic beads down the well at sufficient pressure to create a fracture in the target formation. Proppant keeps the fractures open once the pump pressure is released which thereby improves the productive potential of the well. A fracture created in deep shale reservoirs, will propagate laterally from the well in a vertical plane. Common dimensional terminology for the created fracture includes fracture half length (xf), fracture height (hf) and propped width (wf), as below in Figure 3-13.

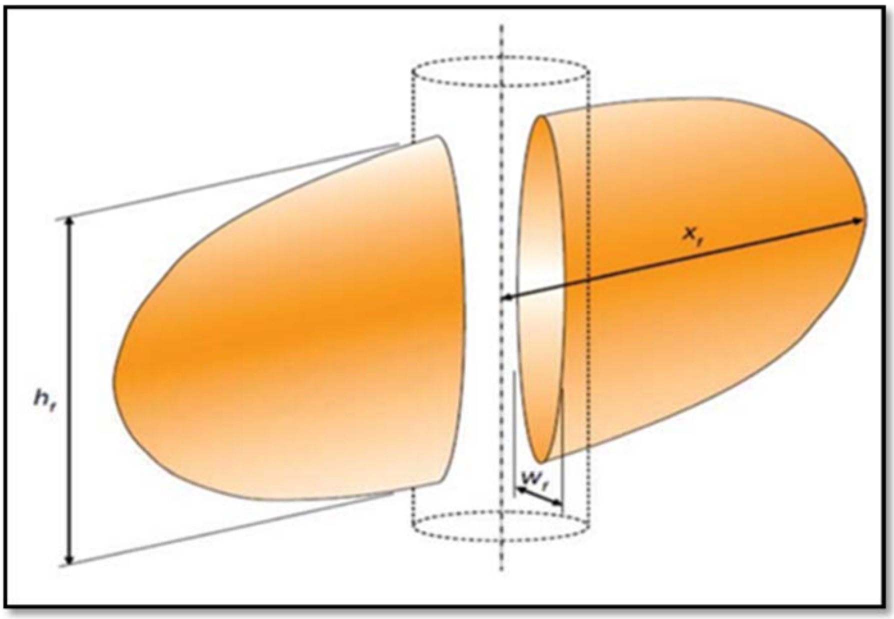


Figure 3-13 Conceptualised Shape of Hydraulic Fracture. (Source: Economides & Martin, 2007)

3.4.1 Hydraulic Stimulation Design

Open-hole and cased-hole logging provides information required for the hydraulic stimulation design process, including rock stress and lithological parameters. This data is processed using industry-accredited stimulation software to develop an optimal design. The basis of well specific hydraulic fracture design is to create a fracture within the target formation that will produce hydrocarbon through the number of required fractures. This is achieved by modelling fracture length, fracture conductivity, and fracture height for each created fracture as depicted in the figure below. A number of considerations influence the final design for each treatment, including:

- depth and thickness of the formation target
- lithology of formation target and bounding layers
- minimum and maximum horizontal stress across all layers (target and bounding)
- thickness of the seals above and below the target reservoir formation
- porosity and permeability of the formation
- pore fluid saturations (percentage of formation pore volume occupied by hydrocarbons or water)
- pore fluid properties (e.g. density, water salinity)
- well performance data, including flow rates, formation pressure and produced fluid properties
- formation boundaries (as identified from offset wells, log data, cuttings data, and/or seismic data)
- bulk rock density, elastic properties and compressibility
- natural fracture networks
- stress field analysis to determine the maximum principle stress direction and the minimum principle stress direction

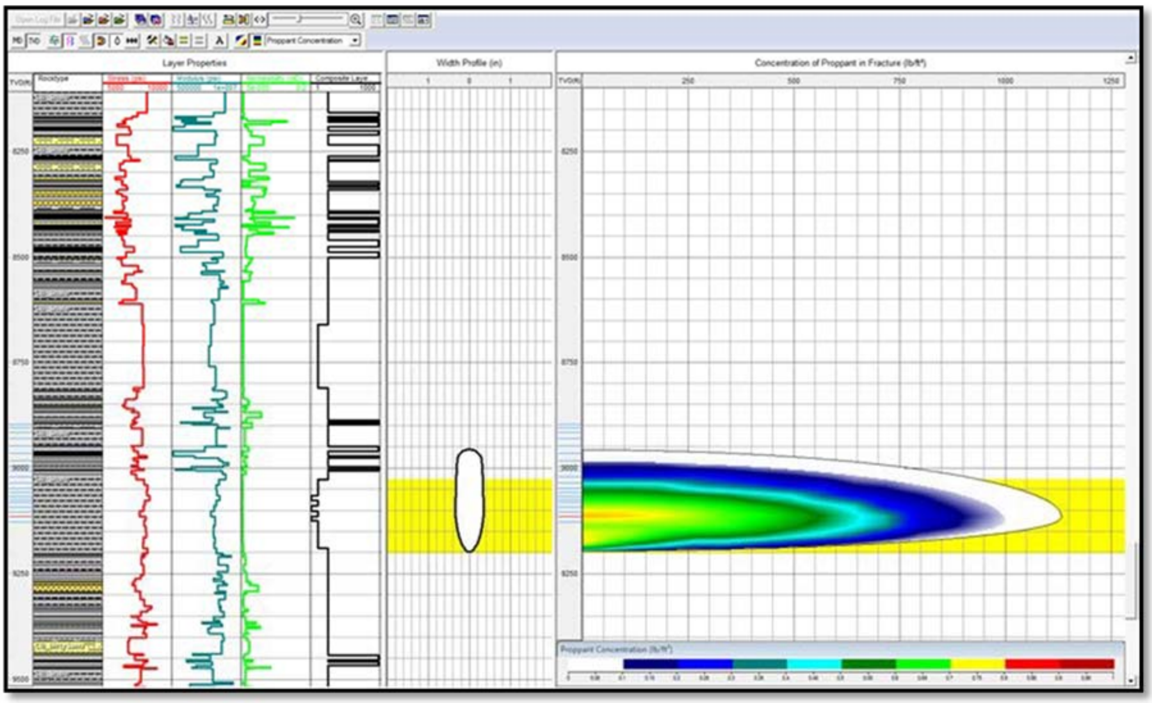


Figure 3-14 Modelled side view output from Industry Accredited Stimulation software for a Cooper Basin horizontal well shale hydraulic fracture (Source: Santos 2014)

3.4.2 Proppant and Chemical Additives

In shale hydraulic stimulation treatments, water accounts for more than 90% of the mixture and sand (proppant) accounts for about 5-9%. Chemical additives generally account for less than 1% of the mixture and assist in carrying and dispersing the sand in the low permeability rock, treating to water to be used to remove naturally occurring algae and bacteria and ensuring the fluids and formation are compatible and will have the desired physical properties.

In accordance with regulatory requirements, chemical additives are subject to disclosure and a Chemical Risk Assessment (CRA) of the Hydraulic Fracturing Fluid System is provided in Section 3.4.3 below.

The chemical additives are not specific to the hydraulic fracture stimulation process, having many common household uses such as in treating the water within swimming pools and within toothpaste, baked goods, ice cream, food additives, detergents, cosmetics and soap. The chemical additives used provide the following functions:

- Viscosity – gelling agents (natural plant based) are added to the water to provide an increase in viscosity to enable the proppant material to be transported down the well and into the created fractures.
- Friction reduction – to reduce the force required to pump the fluid, making the fluid more slippery and easier to pump at high pressures and high rates required to create a fracture.
- Biocide – added to treat the water to ensure there are no microbes or algae present in the water that will affect the gelling agents and to ensure they will not enter and affect the reservoir.
- Scale and corrosion – scale and corrosion inhibitors are added to prevent deposition of mineral scales and to prevent corrosion of the primary wellbore barrier (i.e. the steel casing).
- Surface tension – surfactants or surface tension modifiers are added to assist the flowback of fluids from the formation.

The process is initiated by pumping a pre-designed volume of the stimulation fluid without proppant, referred to as the “pad volume”. The purpose of the pad volume is to create the fracture geometry required to receive the designed proppant volume. Prior to and during pumping the pad into the well, the base gel is prepared and tested using specific Quality Assurance / Quality Control (QA/QC) procedures. Programmed and automated control systems are used to maintain the fluid properties during the pumping of the treatment process. The viscosity of the fluid is typically in the region of 10 to 40 centipoise (cp), depending on the specific fluid design. This may require the use of a base gel or cross-linked gel, both made from guar. Guar gum is a vegetable product which is ground into a powder and used to create a viscous liquid for hydraulic fracturing. Figure 3-15 shows the breakup of guar gum in its native form, seed form, splits and powder.

In shale fracture stimulation, it is generally possible to use only Friction Reduced (FR) water (instead of a base or cross linked gel), by the addition of a friction reducing agent. This fluid system has the effect of making the fluid slippery to minimise friction pressure lost to the casing.

Figure 3-15 Guar gum in its native form, seed form, splits and powder. (Economides and Martin, 2007).

Once the pad volume has been pumped, the injection of the “slurry stages” begins. Proppant is added to the blender and proportioned into the stimulation fluid. The concentration of proppant generally increases through the slurry stages as designed within the fracture treatment simulator. Previously mentioned chemical additives are incorporated to provide a suitable fluid for transporting proppant into the already created fracture.

In a cross-linked gel fluid system, breaker compounds are added at progressively increasing concentrations throughout the pad and slurry stages. The breaker comprises an oxidizing compound or enzyme that breaks the crosslink sites, as well as the long chain polymers. The end result is a fluid with significantly lower viscosity that can be more easily flowed back from the formation to assist with fracture clean-up. The “break time” is designed to coincide with the known pump time at reservoir conditions plus some additional time to ensure the treatment is pumped to completion. This enables the fluid to be more easily recovered from the formation.

Proppant addition begins at low concentrations and is staged up to the final designed concentration which is specific to the formation being hydraulically stimulated. Typical proppant concentrations will range from 0.5 lb/gal (60 kg/m3) to 8 lb/gal (1000 kg/m3) for conventional reservoir stimulation, and typically range from 0.5 lb/gal (60 kg/m3) to 2.0 lb/gal (240 kg/m3) for shale reservoir stimulation. Proppant used in hydraulic stimulation range from graded quartz sand to higher strength ceramic proppants. The strength of this inert material varies, with ceramic proppant being much stronger than quartz sand. Ceramic proppant is used in formations with higher effective stresses, to prevent it from crushing and losing the created fractures conductive properties. Figure 3-16 shows a typical sand and guar gum fluid mix.

Figure 3-16 Typical sand and guar gum fluid mix. (Source Economides and Martin, 2007)

Once the final slurry stage is pumped on surface, the flush stage is pumped. The flush stage is a friction reduced fluid that is used to displace the last stage of slurry down to the perforations. This leaves the wellbore volume free of proppant and ensures that the proppant is placed within the fracture. Once this flush volume has been pumped, the high pressure pumps are shut down and the fracture treatment is considered complete. The duration of the treatment is dependent on the specified volumes to be pumped and the rate at which the treatment is pumped, but is typically around 2 hours for a single shale stage treatment.

3.4.3 Chemicals Risk Assessment

A detailed Chemical Risk Assessment (CRA) for the two proposed hydraulic fracturing fluid systems is provided in Appendix A. These include Halliburton's Coil Tubing Hydraulic Fracturing System (Coil Chemical Additives) and their Standard Hydraulic Fracturing System (Hydraulic Fracturing Chemical Additives).

A tier assessment was conducted on the two hydraulic fracturing fluid systems using a screening of the potential human health and ecological hazards that should be considered for potential exposure to the hydraulic fracturing fluids during transportation, hydraulic fracturing activities (including storage), and subsequent treatment and disposal of flowback. The tier assessment includes the following steps:

Tier 1 - Identify chemicals of low human health and ecological concern that do not require additional chemical risk assessment in the tier assessment process nor additional management controls beyond stand proposed and regulatory imposed controls.

Tier 2 – Chemical additives that are not identified as a low human health and ecological concern, and therefore require additional risk assessment to characterise potential risks (and potentially the need for additional management controls). This is done using a quantitative evaluation of the risks based on the potential complete exposure pathways and the Tier 1 assessment.

A summarised outcome of the CRA report us provided below.

Tier 1 Assessment Results

The outcome of the Tier 1 assessment identified the chemical additives of low human health and environmental concern. Based on this outcome, no further (beyond the standard and regulatory imposed) management or mitigation are considered necessary for all but five of the chemical additives. Due to the very low concentrations used in the tracers (as described above) and their generally low toxicity, the tracers were not considered to pose significant hazards or risks and therefore not also subject to the Tier 2 assessment

Five chemical additives were identified that could potentially pose significant hazards or risks. These were evaluated in the Tier 2 Assessment.

Tier 2 Assessment Results

Worker

Potential exposure to hydrotreated light petroleum distillate (CAS number 64742-47-8) was conducted for an occupational worker receptor for each hydraulic fracturing system formulation. Attachment E in Appendix A presents the Tier 2 assessment for this chemical. The results indicate that the chemical is considered of low health concern for workers and that no additional management controls are necessary.

Avian Fauna

The risk associated with potential exposure to selected chemical additives and/or flowback in treatment tanks by avian wildlife was assessed for representative avian species. Attachment E in Appendix A presents the Tier 2 assessment provides the outcome of this assessment. The results indicate there were no unacceptable risk associated with potential exposure to avian species. Based on the outcomes of this assessment, no further management controls are considered necessary.

3.4.3.1 Management of Hydraulic Fracturing Chemicals

The details regarding how the chemical or other substance will be managed, including how the chemicals are handled and stored, is provided for in the Risk Dossiers for each chemical in the Chemical Risk Assessment (Appendix A Attachment C). For each chemical there is a Risk Dossier and the Risk Dossiers include a section on Safety and Handling and where relevant that section contains a subsection on storage and handling.

3.4.3.2 Transportation of Hydraulic Fracturing Chemicals

Transportation of hydraulic fracturing chemicals is regulated by the Australian Code for the Transport of Dangerous Goods by Road and Rail, a code that is given legal effect to in the Northern Territory by the Transport of Dangerous Goods by Road and Rail (National Uniform Legislation) Act 2010 (NT). This act is administered by NT Worksafe.

The details regarding how the chemical or other substance will be transported is provided for in the Risk Dossiers for each chemical in the Chemical Risk Assessment (Appendix A Attachment C). For each chemical there is a Risk Dossier and the Risk Dossiers include a section on Safety and Handling and where relevant that section contains a subsection on transportation information.

3.4.3.3 Prescribed Chemical Legislation

Prescribed chemical legislation is defined in the Petroleum (Environment) Regulations. Table 3-2 provides the prescribed chemical legislation requirements in relation to management of hydraulic fracturing chemicals.

Table 3-2 Prescribed Chemical Legislation Requirements in Relation to Management of Hydraulic Fracturing Chemicals

Prescribed Chemical Legislation	Requirements in Relation to Management of Hydraulic Fracturing Chemicals
Dangerous Goods Act 1998	The dangerous goods legislation in the Northern Territory covers explosives (including fireworks) and fuel gas (including autogas). The legislation sets out the requirements and allowances for licensing, packaging, storage, transportation and use of these two types of dangerous goods. No explosives will be used and no fuel gas will be used as part of the Hydraulic Fracturing process.
Medicines, Poisons and Therapeutic Goods Act 2012	You will need an authorisation for your workplace if you use: • dangerous poisons - Schedule 7 • prescription only medicines - Schedule 4 • controlled drugs - Schedule 8.
Waste Management and Pollution Control Act 1998	The WMPC Act applies in relation to a contaminant or waste that results from, directly or indirectly, the carrying out of a petroleum exploration activity, or petroleum extraction activity, by a person on land on which the activity is authorised by or under the Petroleum Act 1984, and where the contaminant or waste is not confined within the land on which the activity is being carried out. The WMPC Act also applies in relation to a contaminant or waste released from a pipeline during the conduct of an activity authorised under the Petroleum Act 1984, and where the contaminant or waste is not confined within land that is more than 1km from the centre of the pipeline. If a contaminant or waste is emitted or discharged from land on which a petroleum exploration activity, or petroleum extraction activity is being undertaken, it will be considered an incident as defined by the WMPC Act if it threatens or may threaten to cause pollution resulting in material or serious environmental harm. Similarly, if a contaminant or waste is emitted or discharged from land greater than 1km from the centre of a pipeline, it will also be considered an incident as defined by the WMPC Act if it threatens to or may threaten to cause pollution resulting in material or serious environmental harm. Where an incident causes, or threatens to cause, pollution resulting in material environmental harm or serious environmental harm, the person conducting the activity must notify the Northern Territory Environment Protection Authority in accordance with section 14 of the WMPC Act. The WMPC Act should be considered by the proponent due to the amount of transport required to and from the site, and potential for accidental release of contaminants especially to drainage line or waterway that may drain from the boundaries of the Exploration Lease EP 161. This includes release of any atmospheric emissions (dust, fumes, smoke, gas), as well as noise and odour that may have potential to affect the amenity of persons who occupy the area. In locations where the WMPC Act applies, the proponent has a General Environmental Duty under section 12 of the WMPC Act to take all measures that are reasonable and practicable to prevent or minimise pollution or environmental harm and reduce the amount of waste.

	In addition, the transport of any listed waste (Schedule 2 of the Waste Management and Pollution Control (Administration) Regulations 1998) must be conducted by a person licensed under the WMPC Act to transport that waste and that waste must be transported to a facility that is licensed under the WMPC Act to accept that waste.
Water Act 1992	All water for petroleum activities will be taken with a licence in accordance with the NT Water Act provisions The Water Act prohibits allowing hydraulic fracturing waste (whether treated or untreated) to come into contact with waters. This includes all types of waters (including water in a waterway, groundwater and tidal water). However, does not prohibit flowback fluid and produced water following hydraulic fracturing from being reused as the basis for fluids in future hydraulic fracturing events The Water Act prohibits extracting surface water for petroleum activities. It requires that the Controller can only grant a groundwater extraction licence for hydraulic fracturing related take within 1km of a landholder's bore where the landholder has agreed or the hydrogeological investigation and groundwater monitoring has been undertaken demonstrating that there will not be an adverse impact.
Work Health and Safety (National Uniform Legislation) Act 2011	The proposed Hydraulic Fracturing Program are subject to the *Work Health and Safety (National Uniform Legislation) Act 2011* and Regulations. The obligations under this Act are numerous Chapter 7 concerns Hazardous Chemicals and includes requirements for: • labelling hazardous chemicals (ss 341 to 343) • hazardous chemicals register (s 346) • manifest of hazardous chemicals (s 347) • placards (ss 349 and 350) • management of risks to health or safety (s 351) • review of control measures (s 352) • safety signs (s 353) • identification of risk of physical or chemical reaction (s 354) • specific control – fire and explosion (s 355) • keeping hazardous chemicals stable (s 356) • containing and managing spills including a spill contingency system to be in place (s 357). • protecting hazardous chemicals from damage (s 358) • fire protection and firefighting equipment (s 359) • emergency equipment (s 360) • emergency plans (s 361) • safety equipment (s 362).
Radiation Protection Act 2004	A person who manufactures, possesses, uses, stores, transports, disposes of or otherwise deals with a radiation source must take all measures that are reasonable and practicable to ensure the manufacture, possession, use, storage, transport, disposal or other dealing does not result in harm to the health or safety of persons or the environment caused by radiation emitted from the source. A person must not manufacture, sell, acquire, possess, use, store, transport, dispose of or otherwise deal with a radiation source other than in accordance with a licence authorising the person to do so.

	Radiation sources are defined by Schedule 4 of the National Directory for Radiation Protection – Australian Radiation Protection and Nuclear Safety Agency. It is not expected that a licence under the Radiation Protection Act 2004 will be required. It is likely all NORMS will fall within the exempt activity concentrations and exempt activities of radionuclides

3.4.4 Well Integrity

Santos has a long history of demonstrated management of well integrity during hydraulic fracturing operations. In nearly 50 years of hydraulic fracturing operations on over 1,150, wells Santos has implemented a primary barrier methodology to manage well integrity related risks. The primary barrier during the stimulation phase is the production casing, with the secondary barrier being the surface well pressure control.

Casing design scenarios are modelled using well-established and reviewed techniques to simulate the design loads for collapse, burst and tensile failures that could conceivably be observed during the operational and production phases. The results of these analyses direct the selection of casing grade and weight. All casing is tested by Santos and the contractor using specific Quality Assessment and Quality Control (QA / QC) procedures prior to installation to ensure compliance with the Santos engineering and regulatory specifications.

Cased-hole logs will be run inside the cemented casing to validate the quality and integrity of the cement sheath bond to the casing and to the formation. Typically, these logs include:

1. gamma ray - measures naturally occurring gamma radiation to characterise the rock or sediment in a borehole
2. casing collar locator - a magnetic device that detects the casing collars
3. cement bond log - an acoustic device used to measure the properties of the cement sheath and the quality of the cement bond between the casing and the formation

The cement bond log (CBL) is an acoustic log that can indicate whether casing is cemented or non-cemented. The CBL works by transmitting a sound or vibration signal into the casing, and then recording the amplitude of the arrival signal. Casing that has no or poor quality cement surrounding it (i.e. free pipe) will have large amplitude acoustic signal because the energy remains in the pipe and isn't transmitted to the formation. Casing that has a good cement sheath (fills the annular space between the casing and the formation and effectively couples the two) will have a much smaller acoustic amplitude signal as the energy is absorbed by the formation due to effective acoustic coupling. Santos uses experienced contractors to identify the key features of the cement quality to ensure the integrity of the cement seal for each casing pipe sheath.

Fracturing pressure at surface during the fracturing treatments is managed by redundant pressure control systems including programmable pressure triggers (kickouts) on each of the high pressure pumping units, which physically shutdown each pump (and associated pressure) if the trigger pressure is observed. This ensures that the production casing and wellhead are not exposed to pressure above their design specifications. The pressure triggers are set for each treatment to be significantly below the design specification of the well (primary production casing rating or wellhead rating).

If an issue with the primary barrier did occur during hydraulic fracturing operations, operations would cease and it would be repaired to meet the design requirements before going forward with additional operations to complete the well. It is important to note the location of intermediate and surface casing strings that provide additional integrity should an issue with the primary barrier occur. If surface casing are not cemented to surface, these string would be monitored during fracturing treatments to provide verification of their integrity. Additionally a pressure relief valve (PRV) would be installed to release any overpressure observed.

3.4.5 Perforations

When the formations requiring hydraulic stimulation are identified, the casing needs to be perforated to provide communication between the wellbore and the formation target zone. The perforating method selected for use depends on the type of hole, size and penetration depth required. The three primary types of perforating used are:

- *Wireline Conveyed Perforating (WCP)* – the most widely used perforating technique in the Cooper Basin. As the name suggests, WCP uses wireline to deploy the perforating charge.
- *Tubing Conveyed Perforating (TCP)* – uses the same technology as conventional wireline perforating but is run using a coiled tubing unit or jointed tubing (not wireline). TCP is the preferred perforating method when operating in underbalance or overbalanced conditions.
- *Hydro-jetting* – uses sand and water jetted through small holes in the bottom hole assembly to create holes in the casing across the target formation – there is no perforating charge. Hydro-jetting allows for targeted or pinpoint perforating, creating between 3 and 4 holes per event.

3.4.6 Process

A number of steps are involved to inform, support and undertake the hydraulic stimulation process. These steps include:

1. Diagnostic Fracture Injection Test (DFIT) is conducted to validate and update the proposed stimulation design. This involves injecting a small volume of water, shutting down the surface pumps and monitoring pressure. This stage is optional and typically only performed in the exploratory or appraisal stages of development, or until localised fracture characteristics are defined.
2. Main stimulation treatment consisting of injecting a pre-determined volume of stimulation fluid (pad volume), followed by injection of proppant at monitored concentrations and other additives to achieve fluid mobility (slurry stages), finally a flush stage displaces the last slurry stage through the perforations and into the fracture.
3. Isolation of the completed fracture stimulation stage using a drillable mechanical plug installed at a pre-designed depth.
4. Perforation of the next stage to be hydraulically stimulated and repetition of the process in steps 2 to 4 above until the final fracture stimulation stage is completed.
5. Removal of all mechanical isolation devices by milling out the mechanical isolations.
6. Flowback well to clean up fracture stimulation fluids and monitor hydrocarbon production. This step may also be combined with an appraisal Extended Production Test (EPT) to help define the field reserves and expected production life. The flowback of stimulation fluid is conducted through a separator, which separates and captures natural gas liquids, and flares produced gas through a vertical ‘flare stack’.

3.4.7 Fracture Diagnostics

Fracture Diagnostics are often used to determine the fracture effectiveness and allow for future optimisation. The plan for diagnostics for the three wells is summarised in Table 3-3.

Table 3-3 Fracture Diagnostics Plan

Well	Fracture Diagnostics
Inacumba 1H	Surface Tiltmeter Chemical Tracers
Tanumburini-2H	Surface Tiltmeter Chemical Tracers Downhole Microseismic (Monitoring from Tanumburini-1)
Tanumburini-1	Surface Tiltmeter Chemical Tracers Walkaway VSP (To calibrate Tanumbirini 2H downhole microseismic) Downhole Microseismic Monitoring

3.4.7.1 Tracers

Chemical tracers will be added to the slurry volume at a known concentration and will form a key component to the diagnostic and testing process. The presence and concentration of chemical tracers detected during flowback can be measured to determine the relative contribution of fluid recovery from each stage. The low dosage chemical additives are designed to be unique in composition and able to be absorbed into both the water or gas phase. This enables the operator to determine the performance of each fracture stage and incorporate optimisation learnings into future campaigns.

ProTechnics has been subcontracted to undertake Fluid Diagnostic Chemical Tracer tests. ProTechnics have proposed to use their FlowProfiler Gas tracers with a unique Chemical Fracture Tracer (CFT) and a unique Gas Fracture Tracer (GFT) added to each individual fracture stage. These tracers are 100 percent water soluble.

A detailed Chemical Risk Assessment (CRA) for all proposed hydraulic fracturing fluid is provided in Appendix A and is summarised in Section 3.4.3. The outcomes of the Tier 1 assessment shows that the low chemical concentrations used in the tracers and their generally low toxicity, the tracers were not considered to pose significant hazards or risks and therefore not required to be subject to the Tier 2 assessment. Based on this outcome, no further management or mitigation is considered necessary for the tracers.

3.4.7.2 Vertical Seismic Profiling

A walkway vertical seismic profile (VSP) is proposed to calibrate the subsurface velocity distribution and improve the accuracy of downhole microseismic event location.

A walkaway VSP involves the use of a mobile seismic source (a vibroseis truck is proposed in this program) at surface, which is moved to pre-determined offsets while the downhole receivers are held at a fixed location. This process may be repeated with the downhole tools held at different depths. This differs from a standard VSP, where the seismic source is held at a fixed offset while the downhole tools are moved at set intervals up through the well. A wireline logging unit and a separate unit able to lower/raise the tool string (ie. crane) is required near the well site.

A vibrator truck is the most suitable source to use for a walkaway VSP, which will require graded access tracks along the extent of source offsets required. The planned trajectory for the vibrator is along the 10km 2D seismic line set to be acquired in Q3, meaning the access track would have been already prepared to required specifications provided in the approved McArthur Basin Civils and Seismic EMP. Santos may wish to acquire a second walk away VSP line in an orthogonal direction to the first line. If required, this would be utilising a section of the existing MCSAN13-05 seismic line to avoid any additional ground disturbance. If the track is in poor condition prior to the commencement of VSP operations, a grader may be required to repair to a useable standard. The vibrator traverses will be limited to a maximum 5km offset from the Tanumbirini 1 wellbore, as defined by current cultural heritage clearance.

3.4.7.3 Downhole Microseismic

Geophones will be used to listen for the very small seismic events that are created during fracture stimulation. Triangulation is used from the geophone array to determine the location of the event and hence gain a picture for fracture dimension (height and length) and direction. This information can be further used to calibrate the hydraulic stimulation model predictions. Microseismic monitoring involves the use of sensitive receivers (“geophones”) at the surface or within one or more nearby wells to detect and locate in 3D space the releases of energy associated with the propagation of the stimulated fractures. The figure below shows an example of a side-view of the locatable microseismic events that were detected during the multi-stage hydraulic stimulation of a Cooper Basin horizontal shale well, with the positions of the events colour-coded by stimulation stage. The modelling and field results show good agreement.

The scope proposed for this program is to conduct downhole microseismic monitoring in the Tanumbirini 1 well bore whilst hydraulic fracture stimulations are pumped in the Tanumbirini 2H well bore. This downhole microseismic monitoring will utilise the same downhole array used to collect walkway VSP data. A wireline logging unit and a separate unit able to lower/raise the tool string (ie. crane) is required near the well site. The risk of environmental impact of conducting this operation is negligible, as tools are limited to the well pad and utilise equipment already located on site at the well pad.

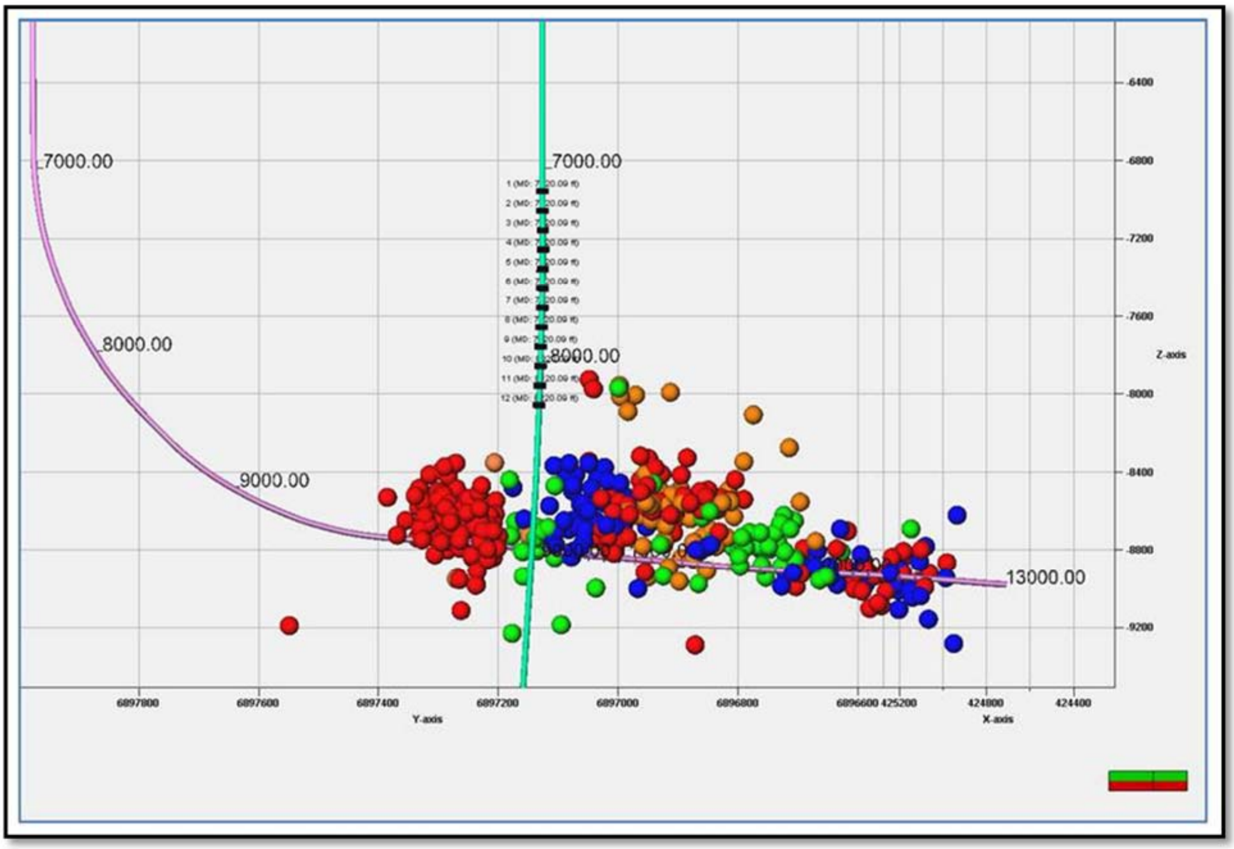


Figure 3-17 Microseismic events mapped during the 10 stage shale hydraulic fracture treatments pumped in the Cooper Basin. The different colours represent the different HFS stages (Santos 2014).

The microseismic results are supported by detailed studies such as by Fisher and Warpinski (2012) which have reviewed height growth data from unconventional (shale) plays in the US including the Barnett, Marcellus and Woodford shales. These studies have indicated that maximum height growth is typically far less than 300m when contained within a relatively homogeneous layer.

3.4.7.4 Surface Tiltmeters

An array of surface tiltmeters, located in shallow surface bores in the vicinity of Tanumbirini1 2H and Inacumba 1H, will be used to gain an understanding of the micro deformation that takes place during the fracture stimulation. Tiltmeters are sensitive surface tools for measuring very minor displacement or movement in the subsurface. These small changes can be used to determine the verticality of the fractures (i.e. the percent of the fracture that is horizontal parallel to the surface or in vertical fractures perpendicular to the surface) and also indicate the direction in which the fracture has propagated.

3.4.8 Equipment

The equipment and machinery required to carry out a hydraulic stimulation operation is highly mobile and able to be installed and removed relatively quickly (generally within a couple days). The equipment is designed to comply with state and federal regulations for road transport, and are fitted with safeguards such as an in-vehicle monitoring system (IVMS) to ensure compliance and monitor the driving behaviour of the individual contractors.

3.4.8.1 Wellhead

The wellhead is the point used to inject into and control the well, during hydraulic stimulation operations and any flowback operations. The wellhead provides the primary surface barriers for well control.

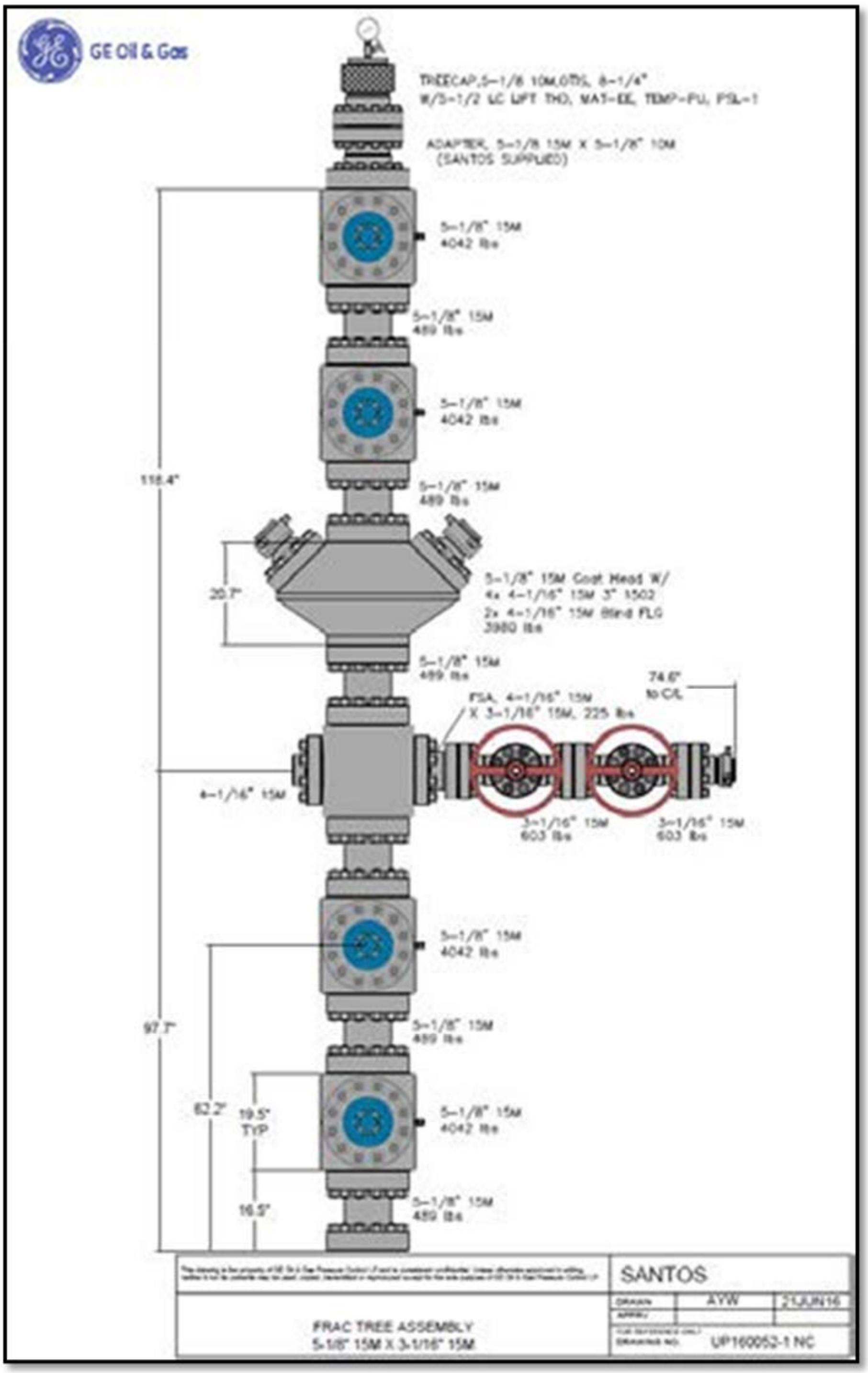


Figure 3-18 Typical hydraulic stimulation wellhead used for shale stimulation operations

Operationally, the integrity of the wellhead will be verified repeatedly during the fracturing operations by conductivity pressure tests against the main wellhead valves. Additionally pressure will be recorded of the secondary seals and the seals between the tubing head and spool.

Once the fracturing operations are completed the upper valves (above the production flowcross) can be removed as they are not required for flowback or appraisal (production) test operations.

3.4.8.2 Above ground storage tanks

On site, above ground water storage tanks provide temporary water storage for use in the hydraulic stimulation process. Source water can either be trucked from a nearby water source or piped along a temporary network. Small dosages of biocide are added to control algal growth particularly under warm and stagnant conditions. Following completion of works, temporary water storage infrastructure is removed from site.

Figure 3-19 Above ground storage tank

3.4.8.3 Sand Trailer Unit

A large, multi-compartment trailer that holds proppant (sand or ceramic material) is required for the treatment. When proppant is required, a conveyor system distributes proppant from the compartments to the blender unit.

Figure 3-20 Sand trailer unit. (Halliburton 2012)

3.4.8.4 Blender Units

In general, two different blending units are used: A pre-gel blender; and a down-hole blender. The pre-gel blender combines the source water with additives required for the base stimulation fluid and proportions of required additives to provide the final hydraulic stimulation fluid. The down-hole blender unit then proportions proppant to the stimulation fluid to provide the proppant concentrations specified in the treatment design. The final hydraulic stimulation fluid, without proppant, is referred to as the “clean fluid”. The final hydraulic stimulation fluid, with proppant added, is referred to as “slurry”. Chemical additives are precisely measured, controlled and recorded by the blender throughout the stimulation treatment process.

Figure 3-21 Blender unit. (Halliburton 2012)

3.4.8.5 High Pressure Pumps

Reciprocating triplex or quintaplex pumps that receive low pressure hydraulic stimulation fluid from the down-hole blender and inject these fluids at the required higher pressure into the well during the hydraulic stimulation process. 6-20 units are typically used on shale hydraulic fracture stimulation treatments. The pumps contain programmable pressure triggers (kick outs) to prevent pressure from exceeding the wellbore design limits. High pressure treating iron (pipes, manifolds, connectors, etc.) connecting the stimulation pumps and the wellhead also contain pressure safety valves (PSVs) that are set to open at a pre-set pressure to ensure the well components are protected.

Figure 3-22 High pressure pump. (Halliburton 2012)

3.4.8.6 Control or Data Acquisition Unit

Telemetry from all units connects to a central control room during hydraulic stimulation treatments. Treatment parameter data, including surface and bottom-hole pressure, pumping rate, chemical rate and fluid density, are monitored, recorded and plotted. Treatment supervisors monitor and control the treatment to ensure that the treatment is pumped according to design. Satellite communication facilities allow further ‘remote’ oversight by technical experts.

Figure 3-23 Control unit (Halliburton 2012)

3.4.9 Flow-back and Well Testing Activities

After fracture stimulation has been completed, flowback activities will be conducted to produce the fracturing fluid while removing the mechanical isolation plugs that were set during the fracturing operations. Coiled tubing will be used to remove these plugs, ensure the wellbore is cleaned of proppant, and use nitrogen to assist fluid recovery if necessary. This is expected to take from 7-14 days to obtain this initial clean-up, while it is expected to begin obtaining reservoir fluids along with the fracturing fluid recovery. Subject to a successful reservoir outcome (continuous well appraisal (production) rates), each well will be flow tested for an initial period of approximately 90 days and up to 12 months. During any flowback that has potential to return formation fluids, flow will be directed through a separator to capture fluids and separate gas to flare.

Once the injection process is complete, the internal pressure of the rock formation causes fluid to return or "flowback" to the surface through the shale gas well. This fluid, often referred to as flowback, contains the dissociation or breakdown products of the injected fluids plus naturally occurring geogenic compounds (i.e. material or substances that are mobilised through the process that must also be considered for potential health or environmental impact).

A considerable volume of the injected fluids are recovered as flowback. Studies performed by the US EPA (US Environment Protection Agency (EPA), 2004) indicated that approximately 60% of the fluids are recovered in the first three weeks, and total recovery back to surface was estimated to be from 68–82%; however, this is variable across different fields and can be less than 20% in some instances. The flowback water is typically temporarily stored tanks before treatment for reuse or disposal.

Initial flowback is typically performed with a mobile separator on location during exploration and appraisal when there are no or limited surface processing facilities. The separator is normally located on the well-pad and connected via relatively short flowlines that include debris catchers and choke manifolds to the wellhead.

The recovered fluids produced during the initial clean-up phase (following stimulation activities), are stored in Flowback Tanks, which are covered, double lined and located in a bunded containment area. Treatment of produced water or flowback fluid in open tanks requires the water to be able to be transferred to above ground enclosed storage tanks at least 8 hours in advance of a predicted significant rainfall event. For a description of the wastewater management associated with the production of flowback water refer to the Wastewater Management Plan (Appendix G).

Fluid samples are taken during the flowback period. The analysed samples are used to determine flow contribution from each of the fracture stimulation stages. Gas sampling is also performed in order to determine the composition of the gas (methane, ethane, butane, carbon dioxide, hydrogen sulphide [not expected], etc.). This will define the value of the product as well as optimising the casing and wellhead material specifications for future campaigns.

3.4.9.1 Flaring

Three-Phase Separator

Three-Phase Separator is a pressure vessel (horizontal or vertical) that uses gravity to separate well fluids into gas, oil and water. The separation process is controlled by various internal components. Typically, a three-phase separator will include:

- Inlet Diverter – Initial separation of well fluid into liquid and vapour.
- Weir Plate – Intentional overspill plate to separate oil and water.
- Mist Extractor – Collects any liquid droplets at the gas outlet.

The separator controls which substance is sent to the flare stack. Pneumatic level controllers in the water and oil compartments control the fluid levels within the separator preventing liquids from getting high enough and being released through the gas outlet (flare line).

When the separator is operated so that only natural gas will be flared.

An enclosed storage tank will be on site and downstream of the separator oil outlet. An oil vacuum truck or equivalent is traditionally used for the transport and disposal of condensate (if required).

Flare Stack

A Flare Stack allows a controlled release and burning of gas. A flare stack is commonly used in well testing, pipeline flaring and well clean-up operations. The stack used are trailer mounted and equipped with two swing-out riggers with jacks for structural support . The flare stack is raised and lowered by a hydraulic ram system. Firetail Flare Stack is an Australian Designed and manufactured flare stack that is capable of withstanding 3 second wind gusts of up to 100km/h. The Flare Stack has been designed in accordance with:

- AS1170.0 Structures Design Actions Part 0 General Principles
- AS1170.2 Wind Actions
- AS4100 Steel Structures & AS1554 – Structural Steel Welding
- ASME B16.5 – Pipe Flanges and Flanged Fittings

The flare stack contains Firetail's auto-ignition system (AIS) automatically creates an ignition every 1.3s, ensuring the flare stays lit. The AIS is installed to the pilot line which runs parallel to the main gas line. The pilot line remains lit until gas is sent through the main line from the separator.

Figure 3-24 Example Well testing Flare Set Up.

3.4.9.2 Coiled Tubing Unit

A Coiled Tubing Unit (CTU) is commonly required as part of hydraulic stimulation operations. In Plug and Perf operations, the Coiled Tubing Unit is generally used at the completion of hydraulic fracturing operations and prior to flowing back into the well, in order to clean the wellbore (remove any debris) and to remove or “mill out” the bridge plugs set in the well to hydraulically isolate each stage. Coiled tubing can also be used in place of wireline perforating by jetting holes through the casing and cement using abrasive jetting, or for performing nitrogen lifting to aid the well clean-up..

Figure 3-25 Coiled tubing unit. (Halliburton 2012)

Flowback tanks are used to receive fluids produced during stimulation operations and during the initial clean-up phase (following stimulation activities), and potentially during the early weeks and/or months (or possibly longer) of production testing operations. Typically the returning fluid decreases over time until it ceases and a hydrocarbon stream is solely produced.

3.4.9.3 Separator Package

Separators have the ability to effectively segregate hydrocarbons and water In order to optimise the flowing conditions and clean-up the well. After separation, the water or flowback is stored as described above. The gas is sent through to a flare stack where it is flared on location and any liquid hydrocarbon (oil/condensate) is stored in onsite storage tanks. Liquid hydrocarbons aren't expected from the Velkerri Formation reservoir targets in EP161; dry gas is most likely with the potential for wet gas (which will be gas at surface conditions and flare efficiently).

Figure 3-26 – Photo of Separator Package Installed on Multiple Well Pad in Cooper Basin

3.5 Tiltmeter and Passive Seismic Monitoring

The drilling of wells, civil works required to prepare for the Hydraulic Fracturing Program (including the upgrading of access routes, the creation of well pads, water storage pads, tanks and campsites) and civil works required to maintain existing and approved infrastructure are covered by a separate EMP (see Santos_EP161_2019_Drilling_EMP_Rev1) that has been submitted to DENR.

The only additional civil works required in preparation for the hydraulic fracturing operations are the installation of shallow bores or holes (roughly 12 meters in depth) for surface tiltmeter monitoring and surface site preparation for installation of passive seismic monitoring equipment.

3.5.1 Tiltmeter

Installation of surface tiltmeters requires drilling an array of approximately 50 shallow holes at each location (Tanumbirni 2H and Inacumba 1H). The proposed areas for tiltmeter installation shown in Figure 3-27, Figure 3-28 and Figure 3-29. Descriptions of the installation, access track preparations, monitoring, and recovery and restoration are described in this section.

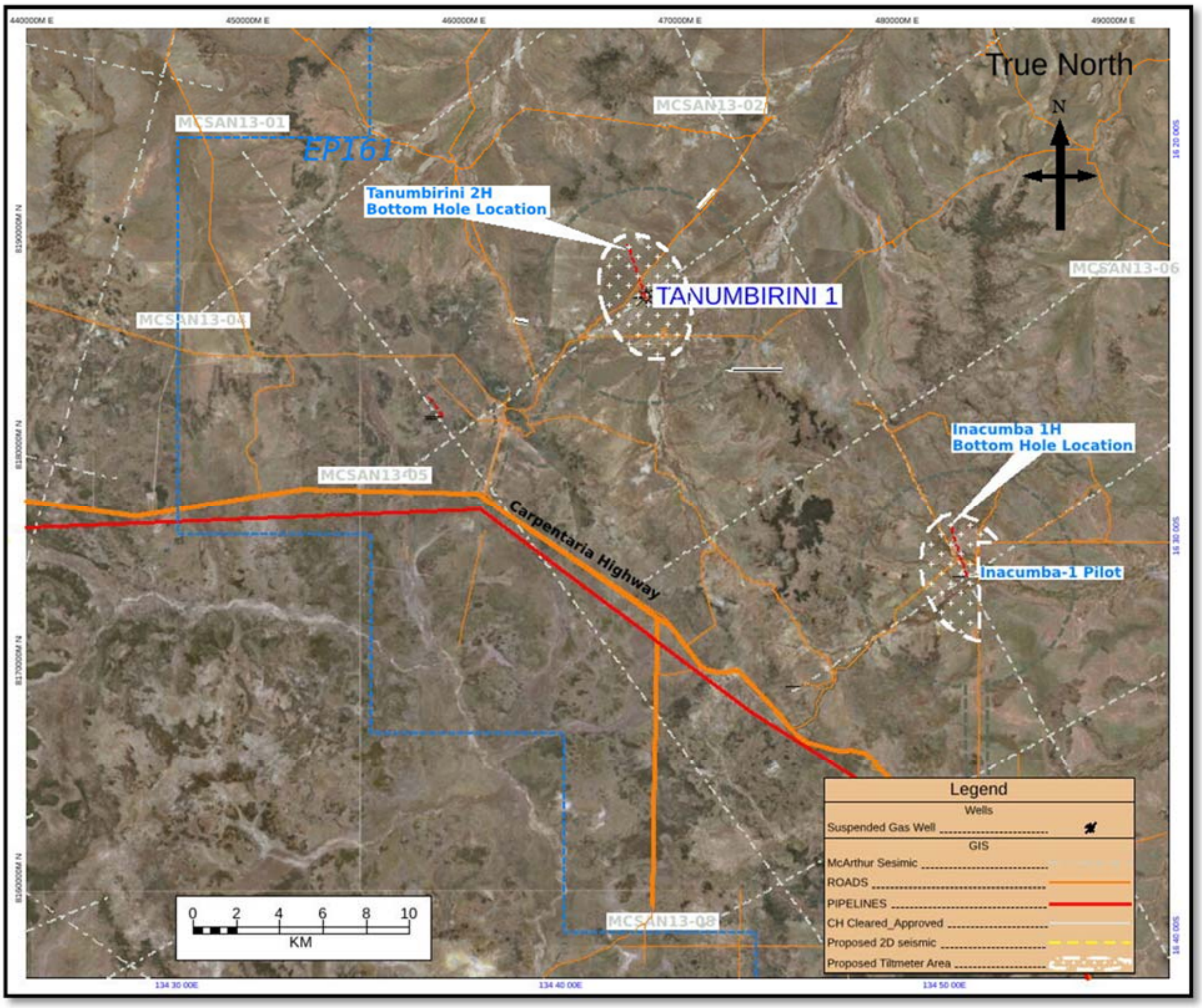


Figure 3-27 Approximate tiltmeter array area (white dash ovals) around each HFS location

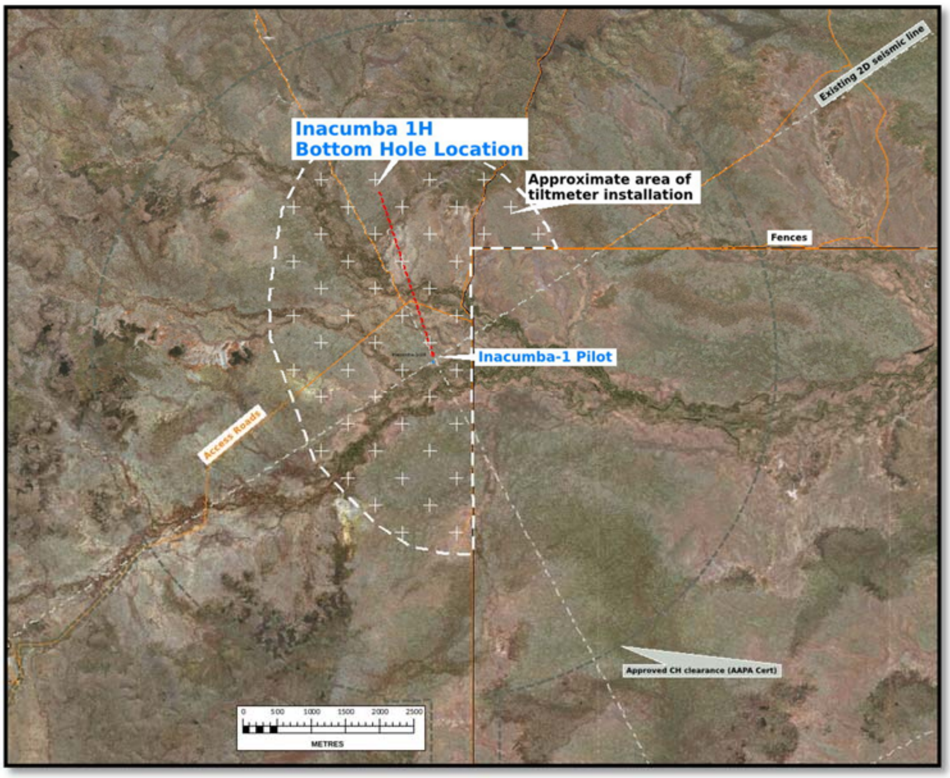


Figure 3-28 Proposed Surface Array of Surface Tiltmeters Locations for Inacumba 1H

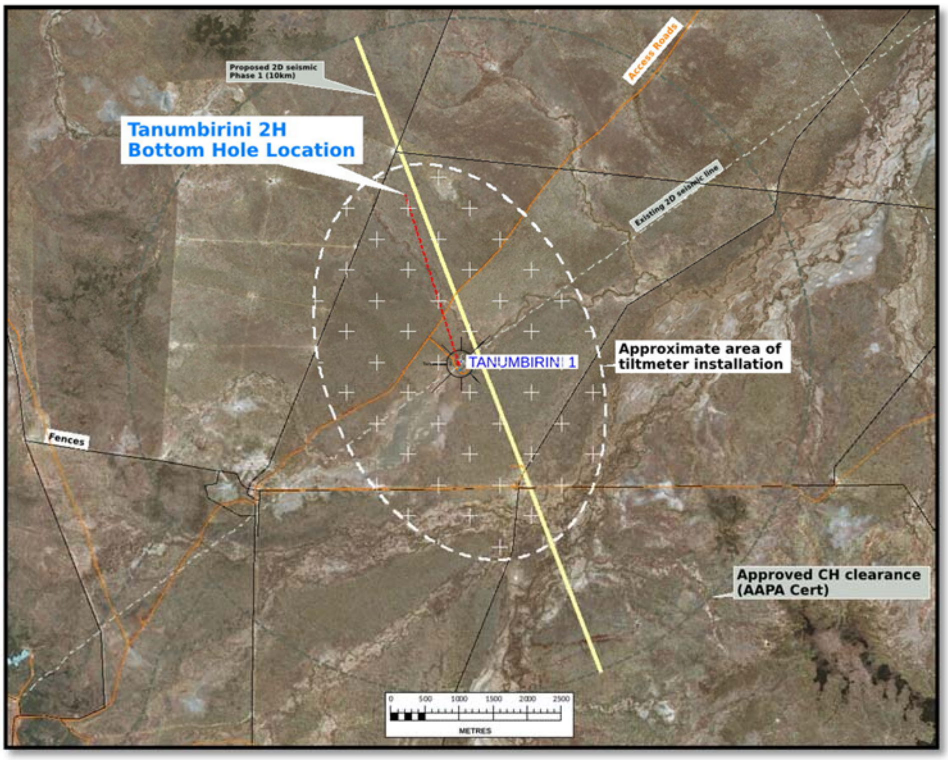


Figure 3-29 Proposed Surface Array of Surface Tiltmeters Locations for Tanumburini-1/2H

The indicative tiltmeter layout design is shown in Figure 3-30. Each tiltmeter instrument will be installed into a pre-drilled and cased hole. The tiltmeter holes will be drilled with an 8" or 10" diameter bit to a depth of around 12 metres.

Once the drilling is completed a 4" PVC pipe is then cemented in place within the hole. The cement secures the 4" PVC pipe to the ground around it to ensure good coupling for the tiltmeter. The cement ends around 1.2 metres below ground level. To further minimise unwanted external noise a larger 8 – 10" pipe, around 1.8 metres in length, is then placed around the smaller pipe to a depth of about 1.2 metres below the surface. The tiltmeter tools are then lowered into the inner 4" string of PVC. A small amount of sand is poured around the tools to give positive coupling to the surrounding ground. An end cap is then placed over the 8" PVC pipe to make the entire setup weatherproof.

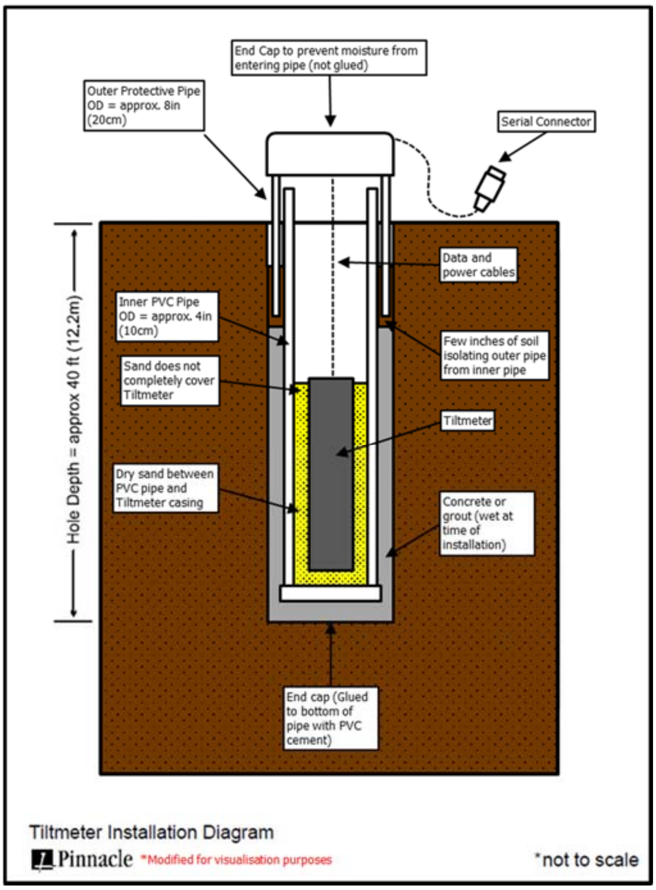


Figure 3-30 Section View of Hole/Tiltmeter Layout

Drilling of the tiltmeter holes will be performed by a light vehicle mounted rig as pictured below (Figure 3-31). There will also be an additional light vehicle and trailer for transporting extra equipment and consumables such as concrete and sand. As the vehicles are light vehicles only minimal (if any) line preparation will be needed for access. It is expected that most hole / tiltmeter sites will be accessible with no access track preparation at all.

Drill cuttings will be stacked adjacent the hole to be re-used to backfill the holes upon completion of the project. Drilling is estimated to be completed in a two week period.

Figure 3-31 Light Vehicle Mounted Drill Rig

3.5.1.1 Access Track Preparations

The proposed locations have not yet been finalised but wherever possible, they will be located close to existing roads or tracks for ease of access. These should all be accessible with no access track preparation. A small number of holes may be required that are remote of existing roads however no tree clearing will be required and no tiltmeters will be located riparian vegetation.

Each hole is likely to only have 2 or 3 light vehicles access it during the installation process.

Should access line preparation be required, the lines will be prepared to the standard of seismic lines and access line preparation will be a conventional approach using a dozer and possibly a grader.

3.5.1.2 Tiltmeter Recording

Once the tiltmeter installation is complete, the meters themselves are basically maintenance free and do not require any revisits until the project is complete and the meters are removed. The tiltmeters are expected to remain in-situ for 2 – 3 months, but can be left for longer periods if required.

3.5.1.3 Tiltmeter Recovery & Restoration

Once the tiltmeter survey is complete, the tiltmeters are removed and the location restored. To do this, each site is once again visited by 1 to 2 light vehicles and the meter is manually removed. The outer 8” PVC casing is also removed. The remaining 4” PVC casing is then terminated around 1.2m below ground and the resultant hole is backfilled to ground level using the drill cuttings from the initial drilling if possible.

If access lines where prepared, they will be inspected at the time of tiltmeter removal and if required a grader will be brought in to restore the access lines.

3.5.2 Passive Seismic Monitoring

In addition to the fracture diagnostic monitoring described above passive seismic monitoring at the Tanumbirini 2H (and/or Inacumba 1H) well site will be conducted during execution of the hydraulic fracture stimulation program. The objective is to establish baseline natural seismicity, and assess the seismicity of hydraulic fracturing activities.

The proposed passive seismic monitoring surface array will require the installation of approximately four solar powered monitoring stations, each connected to a buried triaxial surface geophone. The idealised layout of stations will be selected to minimise environmental impacts. There will be approximately four sites surrounding the horizontal well.

Each sensor site requires at least one 300mm x 300mm hole to be dug to bury a single 3 component surface geophone. The sensor can either be installed directly on the exposed base of the hole, or mounted on a concrete plinth. The hole will need to be backfilled using the dug up soil, or with sand if the local soil is deemed too rocky. Site preparation activities may be carried out simultaneously with tiltmeter site preparation, minimising light vehicle traffic in the area.

The geophone will be connected to a surface site. Depending on the remoteness of the site, solar power and wireless communications equipment may also be required to be installed. Both the surface site and solar array are mounted on separate galvanized steel poles cemented in to earthed, steel-reinforced concrete pads. Figure 3-32 and Figure 3-33 show the surface site requirements.

To allow for ongoing measurements, the sites are designed to be left indefinitely, with minor light vehicle traffic required for ongoing equipment maintenance.

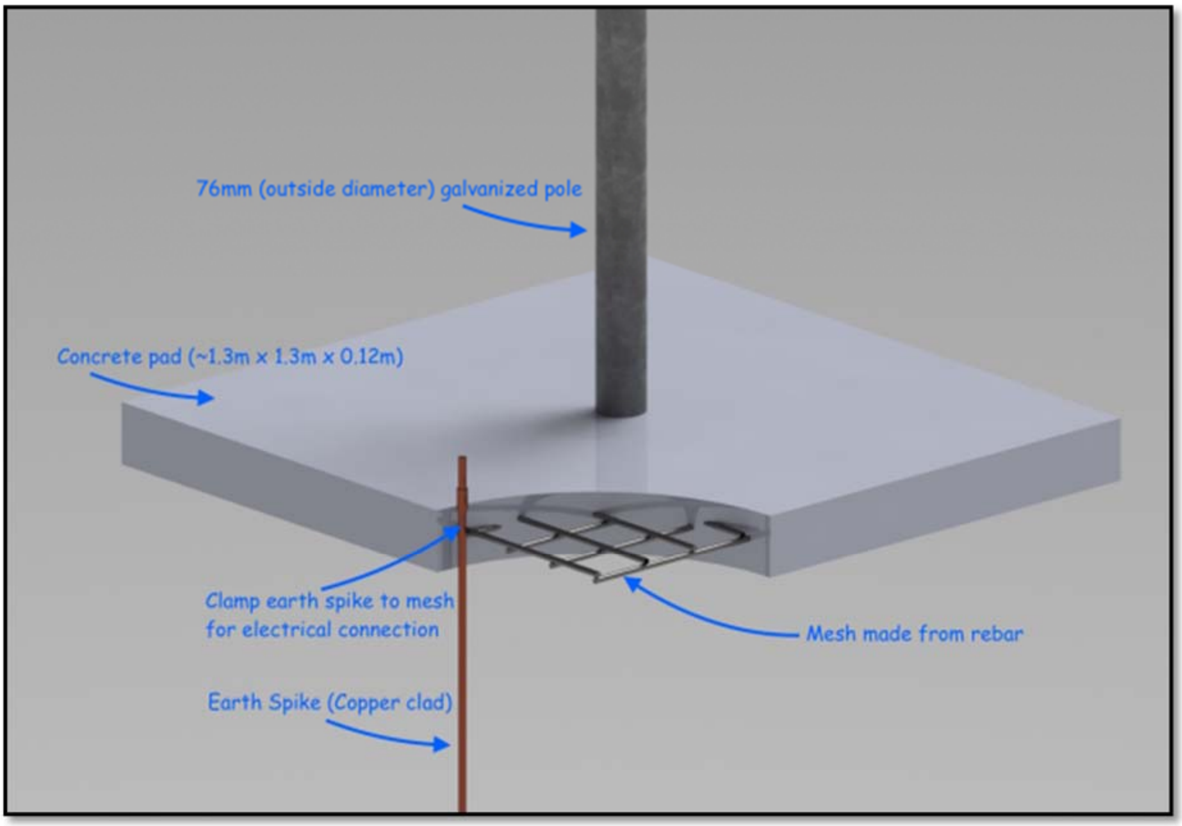


Figure 3-32 Surface station and solar panel assembly footing pad and earthing diagram.

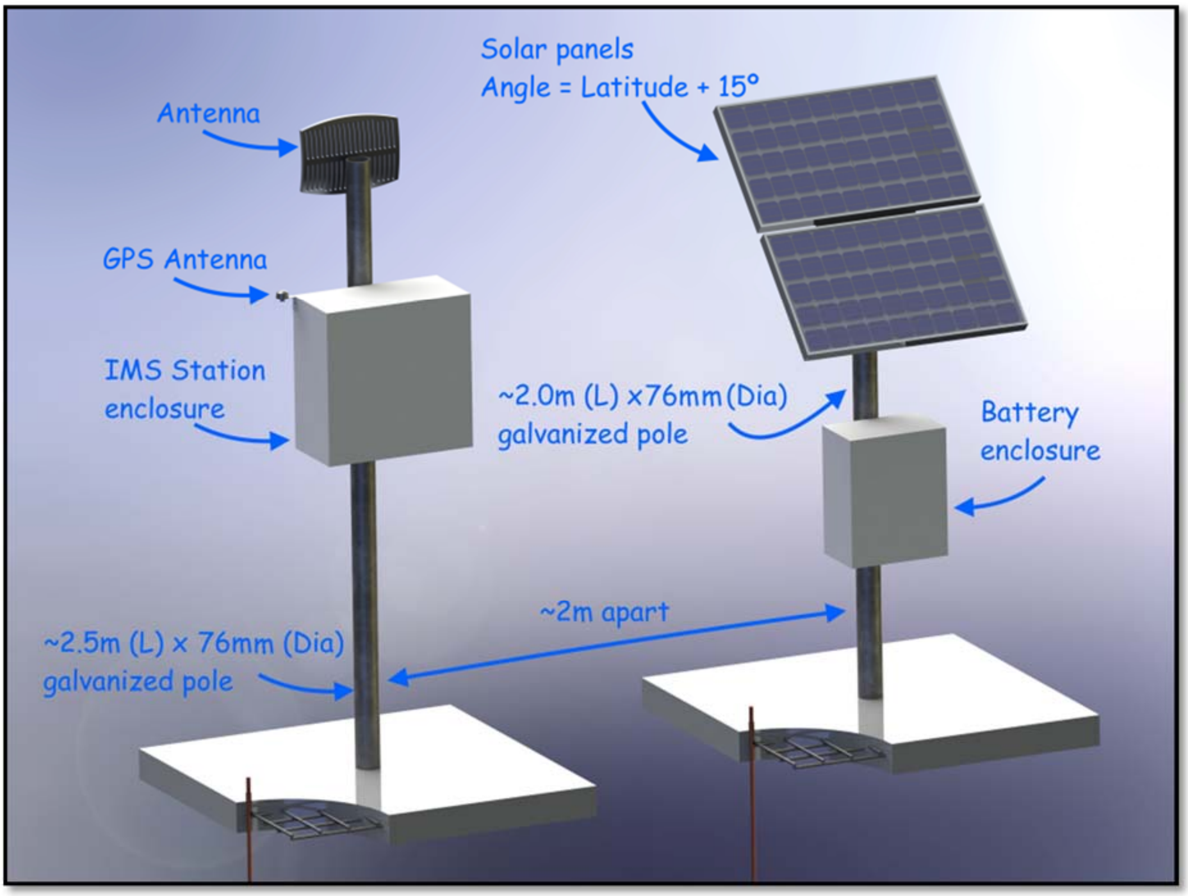


Figure 3-33 Surface station and solar panel assembly generalised layout.

3.6 Downhole Microseismic Monitoring

Downhole microseismic monitoring will utilise an array of geophones, which will be configured to obtain optimal receiver spacing for microseismic monitoring. The array will be lowered into the offset observation well at Tanumbirini 1 to monitor real-time fracture stimulation operations at Tanumbirini 2H.

As hydraulic stimulation activities are undertaken, the microseismic array will record seismic event magnitude and location, feeding data back through the wireline unit. Data may be transmitted offsite for real-time processing, allowing for a near real-time view of fracture propagation.

A wireline logging unit and a separate unit able to lower/raise the tool string (i.e. crane) is required near the well site. The environmental impact of conducting this operation is minimal, as tools are limited to the well pad and utilise equipment already located on site at the well pad.

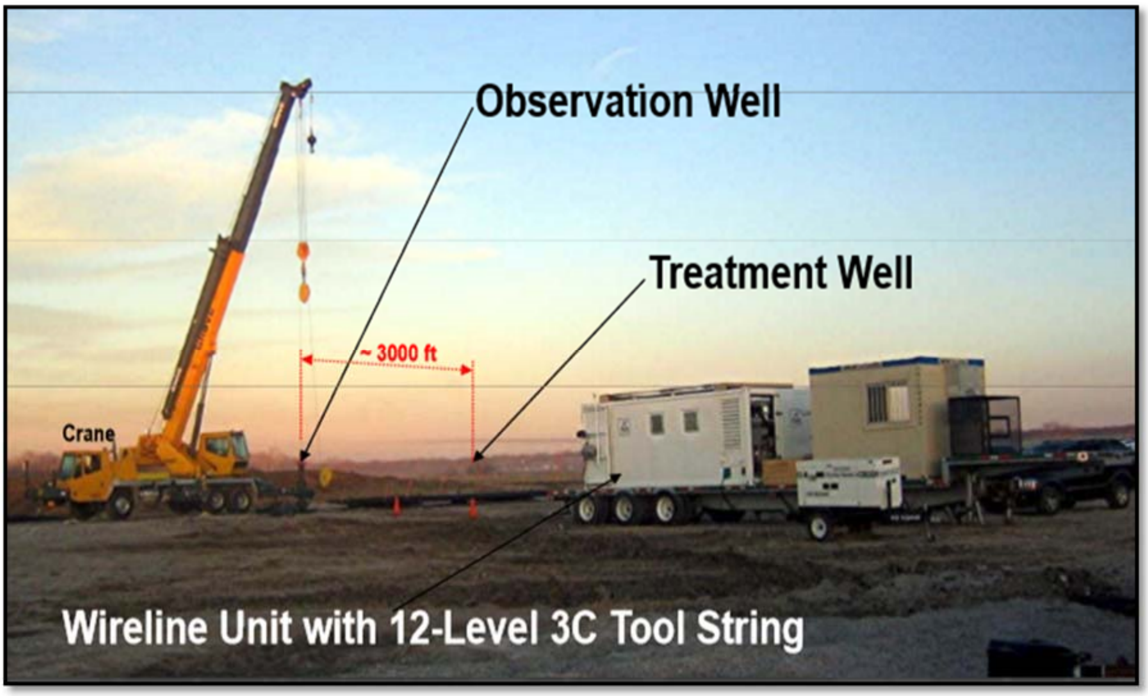


Figure 3-34 Surface equipment for downhole microseismic monitoring

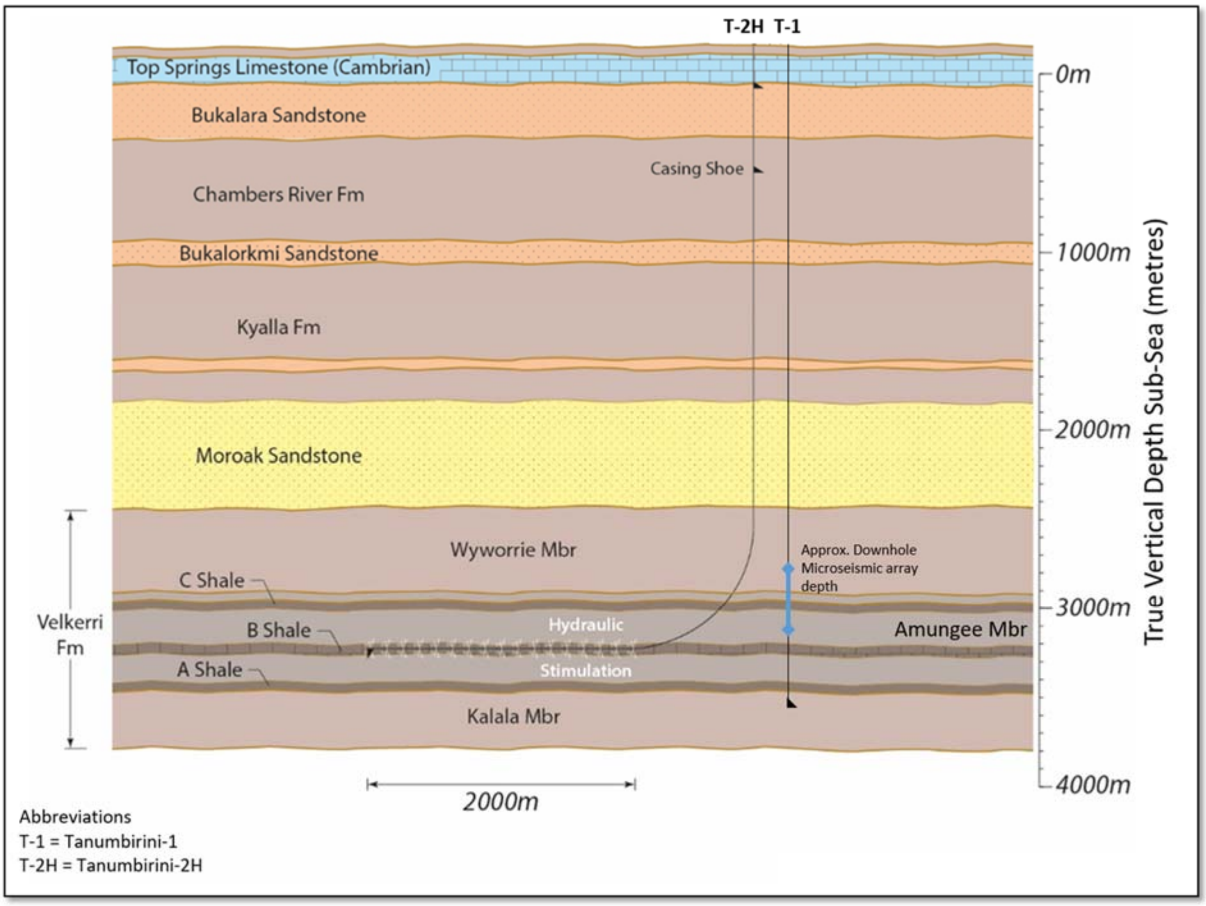


Figure 3-35 Tanumbirini 1 monitoring well with approximate depth of geophones

3.7 Completion Activities

At the end of the clean-up phase, a workover rig may be used to install production tubing and associated completion equipment such as packers, nipple profiles, tubing hanger, and the production tree. Production tubing which has a smaller internal diameter than casing, is generally required to ensure the well can continue to 'clean up' and there is sufficient vertical lift performance to enable fluid to be removed from the well under natural lift from the well.

3.8 Well Suspension Activities

Once all testing has been completed, the exploration well will either be suspended or plugged and decommissioned. The fundamental difference between the two being that suspended wells can be re-entered later for further down-hole activities. If the well is decommissioned, cement plugs will be installed as permanent barriers to flow prior to cutting off the wellhead. The cement plugs will be set and tested as per Santos Standards and Section B.4.15.2 of the NT Petroleum CoP. If the well is suspended, the barriers are, at a minimum, cemented casing and a wellhead. Whilst the well is suspended, pressures on the well will be continuously monitored as per Santos's Well Integrity Management System (WIMS) to confirm well integrity.

3.9 Operations Support Facilities for the Program

3.9.1 Camp

All camps will have its own sewage treatment plant. Treated water will be dispersed via drainage away from the camp to a designated irrigation area in accordance with the *Code of Practice for Small On-site Sewage and Sullage Treatment Systems and the Disposal or Reuse of Sewage Effluent*, issued by the NT Department of Health. Designated irrigation areas will be fenced adjacent to the camp. These areas will not require clearing and will be fenced to exclude livestock access.

All camps will be managed in compliance with the NT Environmental Health Fact Sheet No 700, Requirements for mining and construction projects and "Health requirements for mining and construction camps" available at https://nt.gov.au/property/building-and-development/health-and-safety/health-requirements-mining-construction-projects.

3.9.2 Traffic Management

Access to the project area is via the Stuart Highway, the Highway has a 130km/h posted speed limit in the vicinity of the project and is a two-way road with a sealed width of 7-metres and unsealed or grassed shoulders varying width.

Mobilisation of the HFS "spread" (the term used to describe the various trucks and equipment needed) arriving on location. Initial mobilisation of the HFS spread and associated services like coiled tubing and wireline will require approximately 35-50 loads/trailers mobilised to the nominated wellsite. There will also be 40-80 loads to each wellsite required to transport materials like proppant to the location. Demobilisation will involve moving all equipment out from location via the proposed access routes. There will be a daily commute by 4WD to mobilise and demobilise crews from the camp to the HFS spread.

The estimated operational trucking requirements during the Hydraulic Fracturing Program are shown in Table 3-4. The mobilisation will follow with traffic management measures that meet the requirements of the Department of Infrastructure, Planning and Logistics and will be shared with relevant NT Government agencies and other stakeholders prior to mobilisation.

Table 3-4 Estimated operational trucking requirements

Operational Trucking Activities	Total Loads	Frequency	Truck on location per week.
Food Truck Delivery	1	0.5 per week	1
Rubbish and Waste Removal	1	1 per week	1
Water Potable Trucking (if bore water isn't suitable)	1	2 per week	2
Fuel Delivery	1	1 per week	1
HFS Spread	30-50	1 per well	3 - 25
Optimised Logistics Support (Material Delivery)	111-170	40-60 per well	15-21

3.9.3 Airstrip

The landowner airstrip adjacent the Tanumbirini Homestead may be used for crew changes and emergency response evacuations. The 1,400 m airstrip is regularly used to deliver landowner mail and other private aircraft.

3.9.4 Waste Management

Refer to the Wastewater Management Plan for details.

3.10 Project Water Use

Santos intends to extract water utilising water extract licence (GRF10280) and associated water bores. This licence covers the water requirements of the HFS program and the activities covered in this EMP. Water will be stored at the bore in the fenced dams and then trucked to the wellsite pad where it will be stored in tanks before use in the stimulation campaign.

It is anticipated that 85.5 ML of water will be required. A breakdown of the water use volumes is provided in Table 3-5. Water consumption and extraction amounts will be submitted to DPIR and DENR upon completion of the Hydraulic Fracturing Program. Volumes of water used for dust suppression will depend on the weather conditions and the potential for dust production.

The personnel water use will be approximately 200 L/day per person, which is a total of approximately 0.5 ML/month, over 2 months, which is the anticipated duration of the HFS Program. This water may be supplied from the water bores or from a potable water supplier.

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Table 3-5 Estimated Water Use Volumes (ML)

Use	Scope	Q3 2019	Q4 2019	Q1 2020	Total Use
Stimulation fluid make-up	32ML for Inacumba 1H and 32ML for Tanumbirini 2H and 7 ML for Tanumbirini 1.	20	51	0	71

Use	Scope	Q3 2019	Q4 2019	Q1 2020	Total Use
CTU Cleanup and Flowback	1.2ML for Inacumba 1H and 1.2ML for Tanumbirini 2H and 0.5 ML for Tanumbirini 1.	0	2.9	0	2.9
Completion	0.5 ML per Well	0	1.5	0	1.5
Operational Activities	Road and site maintenance at 1ML per month Vehicle wash downs (0.1 ML per Month)	3.3	3.3	1.0	7.6
Camp Use	200 L/day per Person (0.5 ML per Month)	0.5	1.2	0.5	2.2
Totals		**23.8**	**59.9**	**1.5**	**85.2**

Table 3-6 shows the Cumulative water use volumes when also considering the 2019 Civils and Seismic and Drilling EMPs.

Table 3-6 Cumulative Water Use

Source of Water Use	ML
EMP: McArthur Basin 2019 Civils and Seismic Program	45.5
EMP: McArthur Basin 2019 Drilling Program	12
EMP: McArthur Basin 2019 Hydraulic Fracturing Program	85.2
Cumulative water use	**142.7**

3.11 Greenhouse Gas Emissions

Greenhouse gas (GHG) emissions for the hydraulic fracturing program EMP were estimated using tools developed for the National Greenhouse and Energy Reporting scheme. Emissions associated with fuel combustion were estimated using factors and formulas in the Emissions and Energy Threshold Calculator – 2018, based on the National Greenhouse and Energy Reporting (Measurement) Determination 2008 (NGER Determination) for the 2017-18 reporting year. Greenhouse gas emissions associated with fugitive emissions were calculated using the Emissions Factors from the National Greenhouse and Energy Reporting (Measurement) Determination 2008 and the Australian National Greenhouse Accounts National Inventory Report 2011 Volume 1.

The GHG estimates for drilling program is provided in the Table 3-7 below.

Table 3-7 Greenhouse Gas Emissions for the Hydraulic Fracturing Program EMP

Source of GHG Emissions	Key Inputs	Assumptions	tCO2-e
Transport fuel combustion	2.5 kL Diesel oil (post-2004 vehicles)	General Transport - Diesel volumes estimated at 100L/day for 25 days. Estimate based on the Emissions and Energy Threshold Calculator – 2018.	7
Diesel combustion HFS	224 kL Diesel oil	HFS spread average fuel consumption is 8,000L/day for 25 days plus additional 24kL for by coil/wireline/slickline. Estimate based on the Emissions and Energy Threshold Calculator – 2018.	607
Fugitive emissions HFS	25.9 tonnes of methane (CH4)	Based on Australian National Greenhouse Accounts National Inventory Report 2011 Vol 1 Emissions Factor for gas well completions of 25.9 tonnes. Conversion of emissions factor from CH_4 to CO_2 (25 tCO_2-e/CH_4).	648
Flaring[1]	Flared gas 1.7 Bcf 35,700t	Based on the National Greenhouse and Energy Reporting (Measurement) Determination 2008 (Section 3.44) Emissions factor of CO_2-e/tonnes flared: CO_2 factor tCO2-e is 2.8 (35,700t x 2.8) = 99,960 CH_4 factor tCO2-e is 0.8 (35,700t x 0.8) = 28,560 N_2O factor tCO2-e is 0.03 (35,700t x 0.03) = 1,071	129,591
Total			**130,853**

1. *Flaring is the combustion of fuels for non-productive (non-commercial) reasons. For the estimation of emissions from flaring of fuel "Method 1" has been used.*

Table 3-8 shows the cumulative GHG Emissions for the 2019 Civils and Seismic and Drilling EMPs.

Table 3-8 Cumulative Greenhouse Gas Emissions

Source of GHG Emissions	tCO2-e
EMP: McArthur Basin 2019 Civils and Seismic Program	11,714
EMP: McArthur Basin 2019 Drilling Program	2,758
EMP: McArthur Basin 2019 Hydraulic Fracturing Program	130,853
Cumulative emissions	**145,325**

3.12 Rehabilitation

Rehabilitation is discussed in the Rehabilitation Management Plan (Section 7.3).

3.13 Geological Hazard Assessment

A geohazard assessment (Table 3-9) has been performed to identify subsurface hazards that could pose an environmental risk during the HFS Program (see McArthur Basin Hydraulic Fracturing Program EMP for evaluation during previous well operations). Hazards identified are assessed in

Chapter 6 as part of the comprehensive Risk Assessment. The seismic sections have been reviewed and no major geohazards or faults have been identified at the proposed locations.

Table 3-9 Environmental Risk Geological Hazard Assessment

Hazard Type	Assessment/Observations
Fault Penetrations	Based on the available date, wells have been located to avoid intersections with major fault zones. Inacumba 1H is located approximately 10 km from the interpreted Sub-basin edge and there is no evidence of any major faults in the area of Inacumba 1H. Tanumbirini 2H is proposed for the central part of the Sub-basin where there are no significant structures are evident.
Hazardous Gases	Hydrogen sulphide or other hazardous gases are unlikely to be observed based on mud gas data acquired across the Sub-basin and the reported gas composition from the Amungee NW-1H well testing results. Hydrogen sulphide detectors will be used during stimulation, flowback and appraisal (production) operations as per best practice for exploration activities.

Figure 3-36 and Figure 3-37 display the 2D seismic sections that intersect with the Inacumba 1/1H and Tanumbirini 1/2H locations respectively. Figure 3-36 is a section from the MCSAN 13-02 seismic line oriented north-west to south-east and includes the approximate location of the proposed Inacumba 1 pilot well and the subsequent Inacumba 1H well. The horizontal section of Inacumba 1H is proposed to be drilled down-dip at approximately 86 degrees following structure to remain within the primary target zone. An alternative scenario would be to drill the horizontal section in the opposite orientation: i.e. up-dip at approximately 97 degrees following the structure to remain in the primary target zone. No change to environmental risk will follow from the decision to drill up- or down-dip.

Figure 3-37 is a section from the MCSAN 13-05 line running south-west to north-east tied to Tanumbirini 1. Tanumbirini 2H horizontal well is proposed to be drilled at a bearing of approximately 342 degrees. MCSAN 13-05 is oriented orthogonal to the proposed horizontal well azimuth, however, the data have been used to assess the absence of major structures or faults in this area (supported by the results from Tanumbirini 1). The acquisition of a 2D seismic control line oriented approximately north-west to south-east has been proposed that will provide further depth control and assessment of structural features, and is planned to be acquired approximately three months before Tanumbirini 2H is drilled.

The seismic sections has been reviewed and no major geohazards or faults have been identified at the proposed locations.

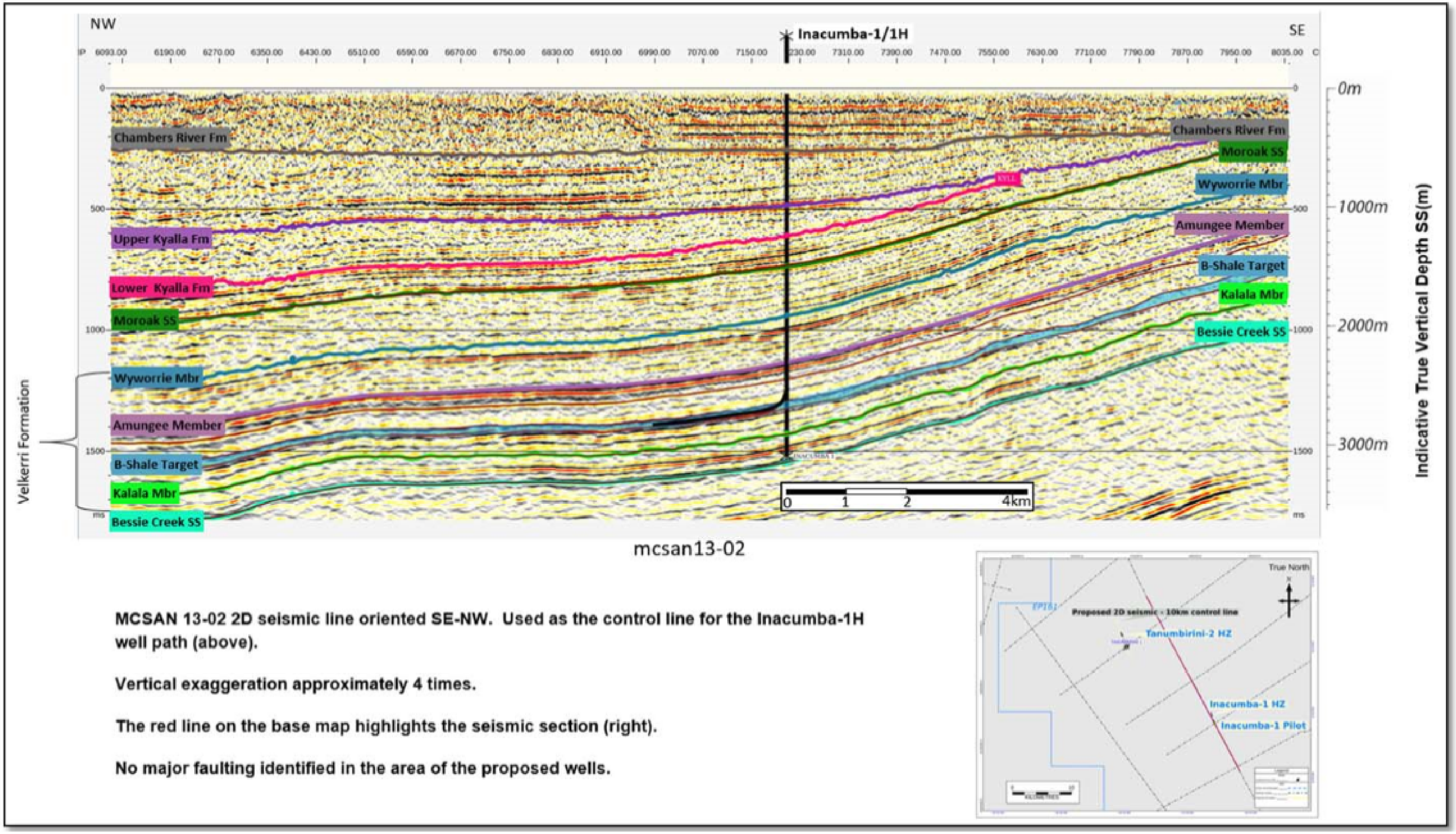
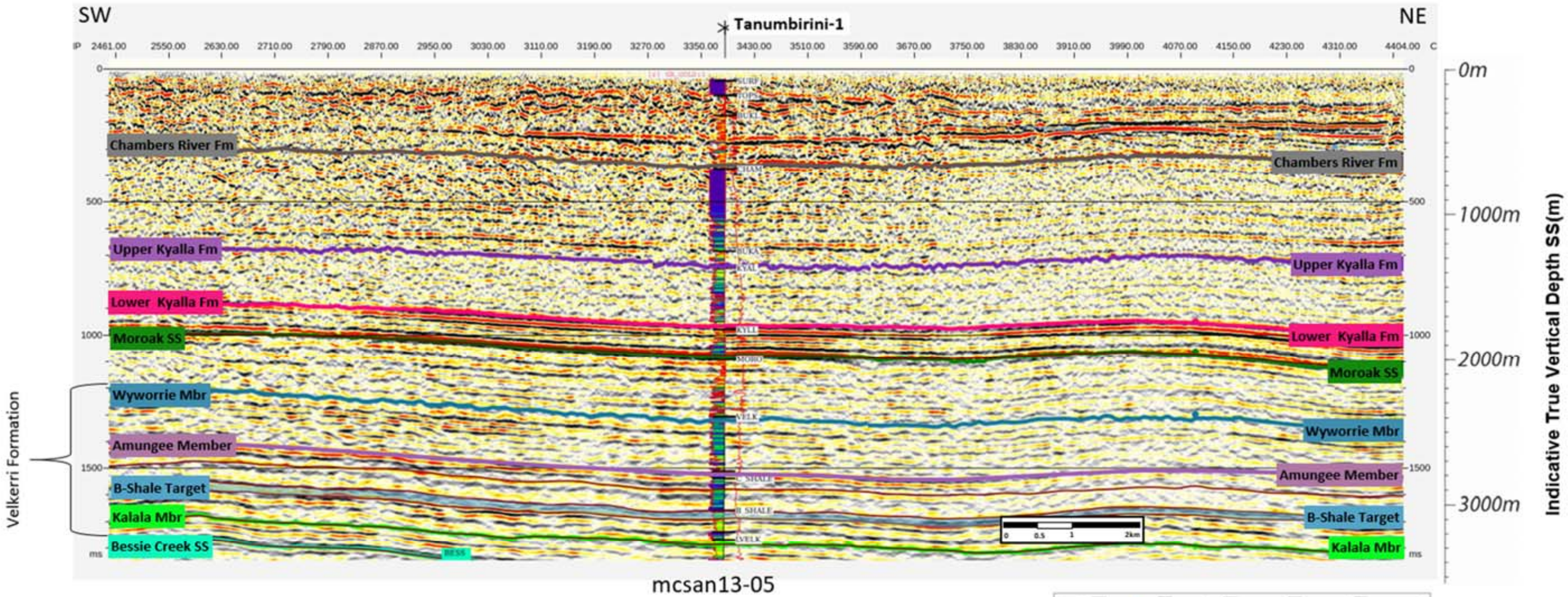


Figure 3-36 2D Seismic Sections that Intersect with the Proposed Locations at Inacumba 1/1H



MCSAN 13-05 2D seismic line oriented SW-NE intersecting Tanumbirini-1 (above).

Vertical exaggeration approximately 4 times.

The red line on the base map highlights the seismic section (right).

No major faulting identified in the area of the proposed well.

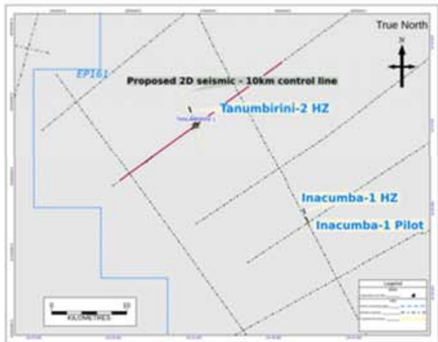


Figure 3-37 2D seismic sections that intersect with the proposed locations at Tanumbirini 1/2H

3.14 Environmental Controls

Santos employs a number of control measures to manage environmental risks associated with this Hydraulic Fracturing Program. These controls manage the risk to the environment and ensure that aquifers are protected and risks managed to a level as low as reasonably practicable and acceptable. A full assessment of the project's environmental risks are provided in Section 6.0. A summary of specific environmental controls employed during the fracturing and appraisal (production) testing is provided in Table 3-10 below.

Table 3-10 Hydraulic Fracturing Program Environmental Controls

Activity	Environmental Controls
All	Activities will be undertaken in accordance with the NT Petroleum CoP. Prior to commencing activities (including stimulation, completion, workover, well testing and decommissioning), a well operations management plan (WOMP) will be approved for those activities. Well control and BOP equipment (if required) will be installed and maintain and during all well activities The mechanical integrity of the well will be tested by pressure testing prior to hydraulic stimulation or DFIT operations. The results of these tests will be provided to DPIR. Regular annulus pressure monitoring will be conducted to provide assurance of the integrity of subsurface well barrier elements and their interface with the wellhead throughout the lifetime of the well. This will be included in the WOMP. Through casing design and cementing design any petroleum fluids produced from a well will not crossflow to any aquifer. An Emergency Response Plan will be in place.
Fluid storage and spill management	Fracturing source water will be stored in above ground storage tanks. Flowback fluids during initial clean-up and appraisal (production) testing will be captured into above ground tanks. Refer to the Wastewater Management Plan and Spill Management Plan for details.
Ongoing monitoring of barriers	Barrier verifications and monitoring throughout well completion, maintaining primary and secondary well control measures. Well schematic drawings of well barrier arrangements will be available for every phase of the well lifecycle. All new barriers or new operating envelopes will be verified, documented and reported prior to handover of well to production, suspension or abandonment. This will be done by submission of updated Well Barrier Verification Form to DPIR.
Hydraulic Fracturing Specifics	Wells are located away from known geohazards. Geohazards encountered during drilling are risk assessed to ensure stimulation activities can occur safely. Stimulation activities will not occur until the integrity of a well has been confirmed

Activity	Environmental Controls
	Well barrier integrity tests to be outlined in the WOMP and approved by DPIR prior to stimulation. Chemical additives used in the stimulation process are risk assessed and are made public. Real-time monitoring of the pressure during stimulation to detect anomalous pressure behaviour. Spill Management Plan will be implemented, with secondary containment used for all chemical storage and handling areas on-site. A traffic light system will be implemented in response to NT inquiry recommendation, to assess seismic risk to surface facilities.
Flowback and Production Testing Specifics	All produced hydrocarbons will be measured and either flared or transported off-site for sales/disposal. A Wastewater Management Plan has be developed and will be implemented. A 'Reduced Emission Completion' will be utilised in accordance with the United States EPA New Source Performance Standards and NT Petroleum CoP. All flares will be designed to meet the requirements of the NT Petroleum CoP including: • Continuous Ignition systems • 98% Combustion Efficiency as per USEPA standards • Bushfire risk management plan implemented • Separation distances from sensitive places and combustion material. Open tanks are to have enough freeboard in accordance with the NT Petroleum CoP. Covered tanks with sufficient storage volume on location to be utilised during wet season. All flowback to be transferred to enclosed / covered tanks within 72-hours when a significant rainfall event is predicted. Flowback volumes are to be reduced by natural or enhanced evaporation. Flowback to be transported off-site by a licenced transport operator to an approved facility. Condensate will be stored within designation double-lined storage tanks as per AS 1940. Any waste fuels and lubricants will be stored and transported off-site in accordance with the requirements in the NT Waste Management and Pollution Control Act.

4.0 Description of the Existing Environment

This section describes the physical, biological, cultural and socio-economic environment that may be affected by the proposed activity and identifies particular values and sensitivities of the environment that may be affected by the activity (referred as the 'Project Area'). The existing environment has been described using the Environmental Factors described in the 'Guidelines for Environmental Factors and Objectives' (NTG 2018).

The information has been sourced using Santos data, publicly available information, the Australian Government Protected Matters Search Tool (PMST) (Appendix B) and NT NRM Report (Appendix C).

4.1 Physical Environment

4.1.1 Climate

Exploration Permit EP 161 is located in a semi-arid, subtropical climatic region, under the influence of the monsoonal climate to the north where there is a distinctive wet and dry season. The majority of rainfall occurs during the short, hot summer months between November and March. Rainfall events are usually associated with intense thunderstorms or widespread monsoonal activity. The local area averages 50 days of rain per annum (NTG 2018). Little rainfall occurs during the remainder of the year when the climate is characterised by mild days and cool nights (Knapton and Fulton 2015).

EP 161 is situated between the Daly Waters Airstrip weather station (#014626) and the McArthur River Mine Airport weather station (#014704). There is also a weather station (#14628) located within the Exploration Permit at Tanumbirini Station capturing monthly rainfall data between 1970 and 2018 however, no other climate statistics have been recorded from this weather station. Table 4-1 shows climate averages data for Daly Waters, McArthur River and Tanumbirini Station.

The most rain during the year falls in January and February. Tanumbirini Station's maximum rainfall occurs during January, with an average of 216.2 mm recorded between 1970 and 2018. The least amount of rainfall occurs during July and August across all three weather stations however, Tanumbirini Station receives more rain during the dry season on average than Daly Waters or McArthur River Mine (Table 4 1).The annual rainfall pattern varies between the three weather stations however, the overall mean annual rainfall increases towards the coast.

The minimum and maximum daily temperatures in Daly Waters is slightly less than McArthur River Mine throughout the year. The highest temperatures for both areas are experienced in November, with temperatures of 38.2 and 38.7 respectively. The lowest temperatures are experienced in July, with an average daily temperature between 12.0 and 12.7 at both stations. The average temperature increases closer to the coast (BoM 2018a).

Table 4-1 Average Climate at Daly Waters, Tanumbirini Station, and McArthur River Mine

Month	Daily maximum temperature (degrees C)		Daily minimum temperature		Mean monthly rainfall (mm)			Relative humidity 9 am (%)		Mean daily evaporation (mm)		Mean Wind speed 9 am (km/hr)	
	DW	MR	DW	MR	DW	TS	MR	DW	MR*	DW	MR*	DW	MR*
Annual rainfall					680.8	736.9	766.9						
Minimum	28.9	29.9	12.0	12.3	0.4	1.2	0.3	42	46	6.6	5.8	4.5	5.5
Maximum	38.2	38.7	24.4	25.0	180.7	216.2	220.7	74	75	10.5	9.8	7.8	9.4
Average	34.0	34.6	19.1	19.7				55	57	8.3	7.5	6.6	7.8

Legend: DW – Daly Waters, MR – McArthur River Mine Airport, TS-Tanumbirini Station

4.1.2 Topography

Tanumbirini Station is situated on the north eastern boundary of the Beetaloo Sub-basin, approximately 250-280 metres above sea level at the Carpentaria Highway (Fulton and Knapton 2015). The station is situated on a drainage divide that separates inland drainage of the Sturt Plateau from the north east flowing streams that lead into the Gulf of Carpentaria.

To the west and south west are the gently undulating plain of the Sturt plateau, and to the north and east towards the Gulf of Carpentaria are the laterite plains., The undulating terrain is characterised by scattered low, steep hills and dissected plateaux on exposed Proterozoic and Palaeozoic sedimentary rocks which was formed by laterite capping on Cretaceous aged sedimentary rocks (Fulton & Knapton 2015).

4.1.3 Geology

Gas exploration on EP 161 targets shale sequences within the Beetaloo sub-basin, which forms part of the greater McArthur Basin (Figure 4-1). The Beetaloo Sub-basin comprises a thick sequence of flat-lying mudstone and sandstone formations (Roper Group) which is estimated to reach 5,000 m in thickness in the centre of the basin.

The Beetaloo Sub-basin is an ancient Proterozoic sedimentary basin that has been relatively tectonically quiescent throughout its long history, as evidenced by the lack of significant structural deformation (Figure 3-36 and Figure 3-37). The principle exploration target within the Beetaloo Sub-basin is the Velkerri Formation, which is thought to have been deposited ~1.4 billion years ago. This comprises intervals of high organic content fine-grained rocks ("shales") contained within clay-rich and organically-lean layers. These clay rich, organically lean layers act as impermeable aquitards to fluid migration, as illustrated by the organic-enriched layers still containing gas hundreds of millions of years after it was generated). They also provide effective barriers to fracture growth during hydraulic fracture stimulation operations. Given the lack of major faults and structures across the deeper areas of the Beetaloo Sub-basin there is a low geohazard risk associated with through-going faults, therefore a low likelihood of the perceived risk of communication to shallow aquifers occurring.

The Velkerri Formation is overlain by other formations of the Roper Group (Maiwok Sub-group), including the Moroak Sandstone, Kyalla Formation, Bukalorkmi Sandstone and Chambers River Formation. These comprise a thick sequence of fine grained siltstones and mudstones interbedded with sandstones, which provide excellent isolation between the target zones in the underlying Velkerri Formation and the overlying aquifer (Top Springs Formation).

The Roper Group sediments are unconformably overlain by Neoproterozoic sediments of the northern Georgina Basin, which constitute the Kiana Group Bukalara Sandstone at this location. On a regional basis the Bukalara Sandstone is recognised as an aquifer and has been used for agricultural purposes at Nutwood Downs and Hodgson River pastoral lease properties . Historically the Bukalara Sandstone has not been penetrated by (shallower) bores on Tanumbirini Station due to the presence of the overlying Cambrian Limestone Aquifer, and therefore was not recognised as a local aquifer. Bores RN040939 and RN041242 drilled in August and September 2019 respectively, penetrated the Bukalara Sandstone with observations of high variability in reservoir quality and possibly only a few thin intervals of higher permeability contributing to high water yield.

The Bukalara Sandstone is unconformably overlain by the Cambrian age Top Springs Limestone (also known as the Gum Ridge Formation, and informally as the Cambrian Limestone Aquifer). This unit is recognised as a regional aquifer and is considered to be the deepest aquifer present at the proposed well locations. The Top Springs Limestone is unconformably overlain by undifferentiated Cretaceous to Quaternary sediments.

An illustrative section through the Beetaloo Sub-basin is presented in Figure 4-1 and a map illustrating the structural outline of the Beetaloo Sub-basin is shown in Figure 4-2 and the stratigraphy described in this section is referenced from NTGS Special Publication 5 (Ahmad and Munson 2006, 2014 respectively).

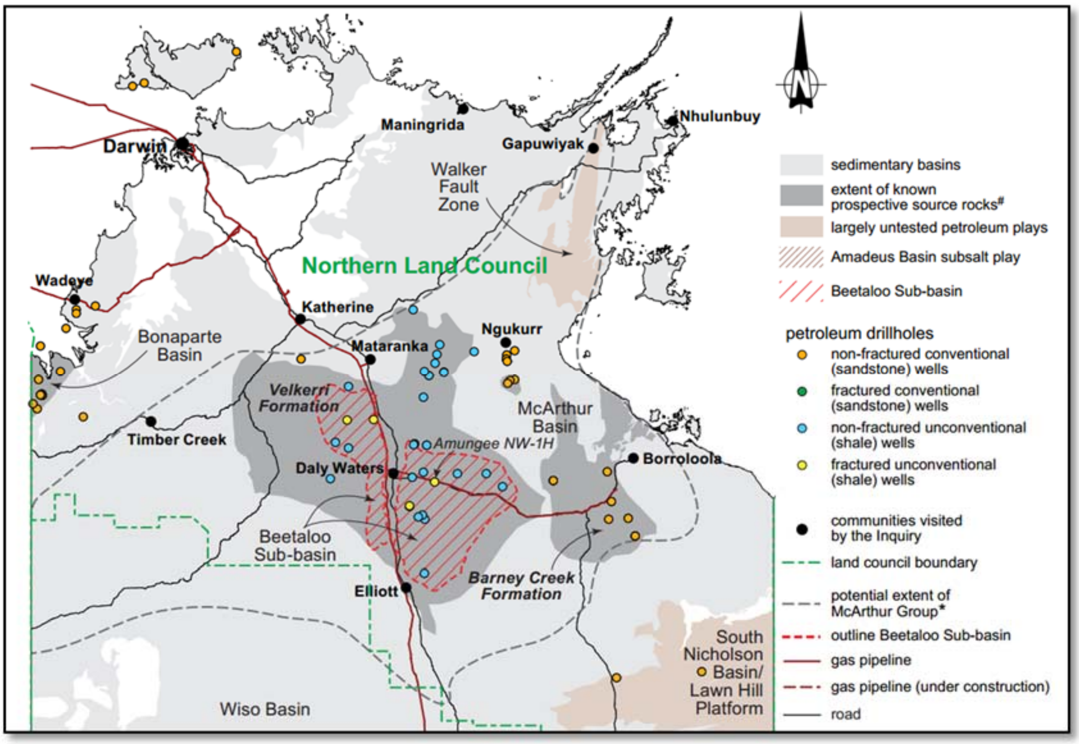


Figure 4-1 Geological setting of the Beetaloo Sub-basin / McArthur Basin (source: DIPR, ref: Final Report of the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory figure 6.2)

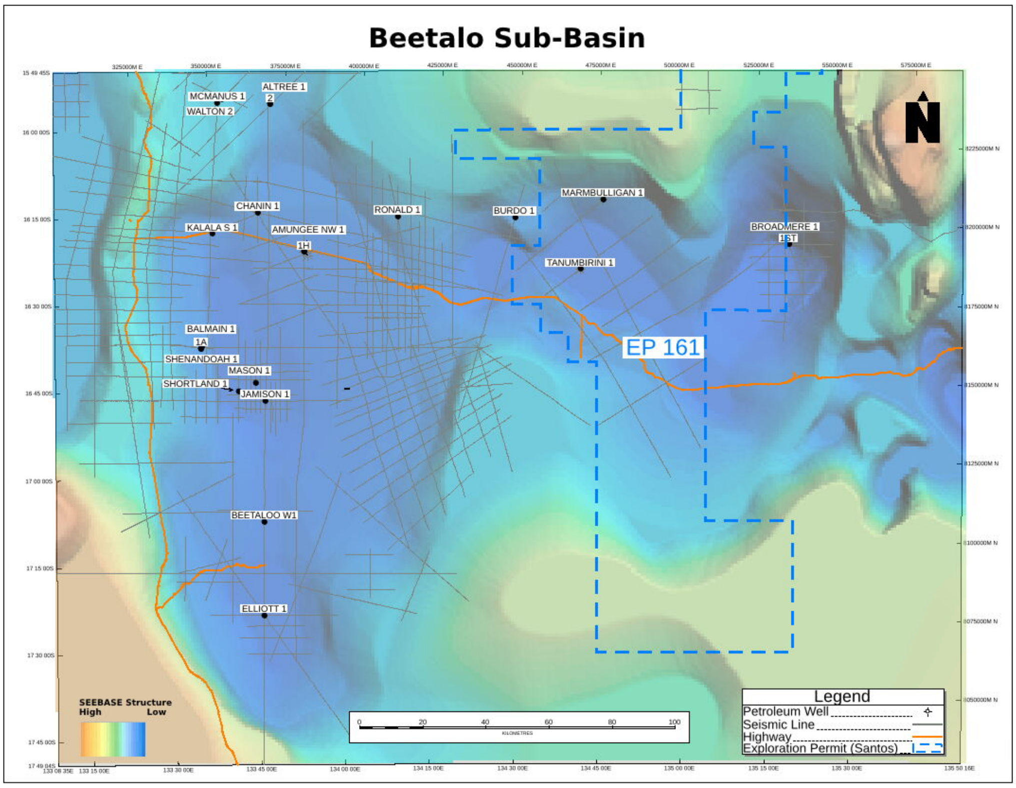


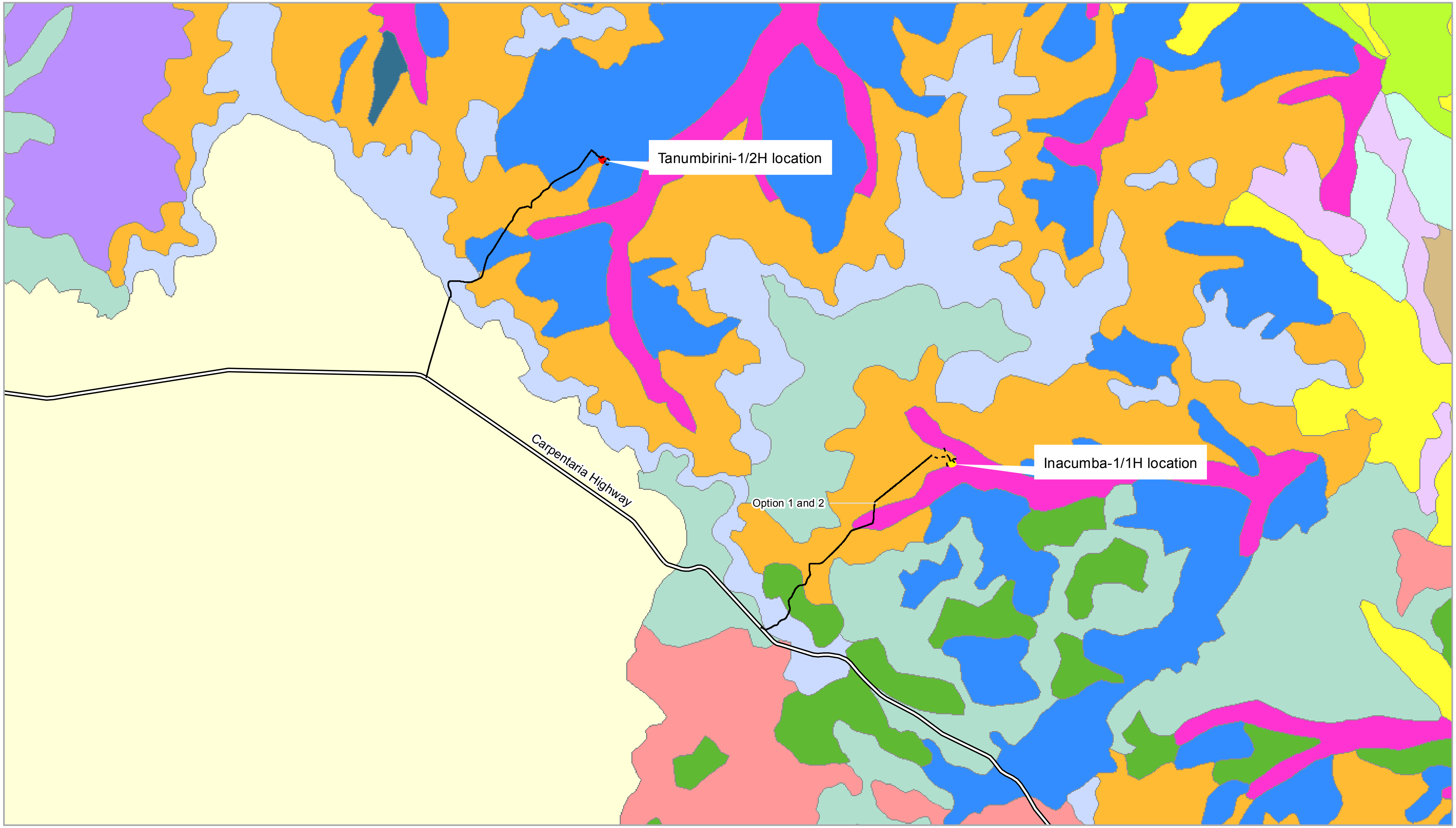
Figure 4-2 SEEBASE structural outline of the Beetaloo Sub-basin

4.1.4 Soils

An NT NRM Report was generated on 4 December 2018 from a search of the NRM Infonet tool (NTG, 2018). The Project Area soils are dominated by kandosols and rudosols (Appendix C). Rudosols are very shallow soils or those with minimal soil development and include very shallow rocky and gravely soils across rugged terrain. Kandosols are massive and gravelly soils (formerly red, yellow and brown earths) that are widespread across the Sturt Plateau bioregion.

4.1.5 Land Systems

Land systems are defined because of their distinct differences from the surrounding areas and by the recurring pattern of geology, topography, soils and vegetation. Land system information for the permit areas is described in Table 4-2 and shown in Figure 4-3.



Legend

Proposed Access Road	Bukalara	Jumpup	Miller
Principal Road	Coolibah	Lancewood 2	Seigal
Inacumba Lease	Cresswell	Lancewood 3	Tanumbirini
Tanumbirini Leases	Dalglese	Lansen	Wearyan
Beetaloo	Inacumba	McArthur	

1:220,000 @ A4

0 2.5 5 7.5 10

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

N

Santos
McArthur Basin
Environmental Management Plan

Land Systems

Project No. 43-22812
Revision No. A
Date 2/04/2019

FIGURE 4-3

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Print date: 02 Apr 2019 - 14:48

Data source:NTG - Land systems South 1M, Land systems North NT (2017). GA: Roads, Waterways (2015) Santos: Proposed Access Roads, Existing Access Roads, Inacumba and Tanumbirini Lease Pads, (2019) Created by: cmacgregor

Table 4-2 Percentage of Land Systems and Total Area within EP 161

Land System	Landscape Class	Class Description	Landform	Soil descriptions	Vegetation description	% of Total area
Beetaloo	Lateritic plains and rises	Plains and rises associated with deeply weathered profiles (laterite) including sand sheets and other depositional products; sandy and earth soils	Information not available	Information not available	Information not available	<1%
Coolibah	Alluvial floodplains	Alluvial floodplains, swamps, drainage depressions and alluvial fans; sandy, silty and clay soils on Quaternary alluvium	Level to gently undulating plains on unconsolidated transported materials, rarely sedentary	Grey and brown clays, minor black earths	Mid-high open woodland of *E. microtheca, Excoecaria parvifolia* over *Chrysopogon fallax, Sorghum plumosum, Aristida spp*	1%
Inacumba	Lateritic plains and rises	Plains and rises associated with deeply weathered profiles (laterite) including sand sheets and other depositional products; sandy and earth soils	Gently undulating rises and undulating plains to low hills on ferruginised Lower Cretaceous sediments (laterite) and weathered sandstones	Lithosols	Mid-high open woodland of *C. dichromophloia, E. miniata, E. tetrodonta, C. ferruginea, E. leucophloia* with isolated stands of A. *shirleyi* on steeper slopes over *Eriachne spp, Chrysopogon fallax, Plectrachne pungens*	35%
Lancewood 2	Lateritic plateaux	Plateaux, scarps and some rises on deeply weathered sediments; shallow soils with rock outcrop	Plateau margins, escarpments and rugged low hills and plateaux	Lateritic lithosols	Mid-high open forest of *Acacia shirleyi* over *Schizachyrium* fragile, *Chrysopogon fallax, Triodia bitextura*	<1%
Lancewood 3	Sandstone plains and rises	Plains, rises and plateaux on mostly on sandstone, siltstone, claystone, shale and some limestone; commonly shallow soils with surface stone and rock outcrop	Gently undulating plains and drainage floors on claystone	Grey and Brown clays	Tall open grassland of *Chrysopogon fallax, Eulalia aurea, Iseilema vaginiflorum*	25%

Land System	Landscape Class	Class Description	Landform	Soil descriptions	Vegetation description	% of Total area
McArthur	Alluvial floodplains	Alluvial floodplains, swamps, drainage depressions and alluvial fans; sandy, silty and clay soils on Quaternary alluvium	Broad or narrow fluvial corridors conducting regional drainage across various land systems towards the coast	Grey and brown clays, red and yellow earths and siliceous sands	Mid-high open woodland of *C. terminalis, E. microtheca, Excoecaria parvifolia, Lysiphyllum cunninghami, C. papuana* over *Chrysopogon spp, Eulalia fulva, Iseilema vaginiflorum*	2%
Tanumbirini	Lateritic plains and rises	Plains, rises and plateaux on mostly on sandstone, siltstone, claystone, shale and some limestone; commonly shallow soils with surface stone and rock outcrop	Gently sloping pediplains below, but isolated from lateritic escarpments	Lateritic yellow earths and brown clays	Mid-high open woodland of *E. chlorophylla, Erythrophleum chlorostachys, C. polycarpa, E. tetrodonta, Terminalia grandifolia* over *Chrysopogon fallax, Eulalia fulva, Plectrachne pungens*	36%

4.1.6 Groundwater

Table 4-3 summarises the regional hydrostratigraphy of the Beetaloo Basin.

Table 4-3 Regional hydrostratigraphy of the Beetaloo Basin (taken from Fuller and Knapton, 2015)

PROVINCE	PERIOD / AGE	FORMATION		AQUIFER STATUS	THICKNESS (m)	YIELD (l/s)	AVE. EC (μs/cm)
CARPENTARIA BASIN	CRETACEOUS 145 – 66 Ma	Undifferentiated		*Local Aquifer*	0 - 130	0.3 - 4	1800
GEORGINA BASIN	CAMBRIAN 497-630 Ma	Cambrian Limestone Aquifer (CLA)	Anthony Lagoon Beds	REGIONAL AQUIFER	0 – 200	1 - 10	1600
			Gum Ridge Formation	REGIONAL AQUIFER	0 – 300	0.3 - >20	1400
		Antrim Plateau Volcanics		REGIONAL AQUITARD *Local Aquifer*	0 – 440	0.3 - 5	900
		Bukalara Sandstone		*Local Aquifer*	0 – 75	0.3 - 5	1000
BEETALOO BASIN (ROPER GROUP)	NOT KNOWN	Hayfield Mudstone		REGIONAL AQUITARD *Local Aquifer*	0 – 450	-	32000
		Jamison Sandstone		*Local Aquifer*	0 – 150	-	138000
	MESO-PROTEROZOIC 1430-1500 Ma	Kyalla Formation		REGIONAL AQUITARD	0 – 800	-	-
		Moroak Sandstone		*Local Aquifer*	0 – 500	0.5 - 5	131000
		Velkerri Formation		REGIONAL AQUITARD	700 – 900	-	-
		Bessie Ck Sandstone		*Local Aquifer*	450	0.5 - 5	-

The major hydrogeological units of the Roper River catchment are the Cambrian limestones of the Daly, Wiso and Georgina Basins. These major groundwater systems provide dry season inputs to the Roper River (Knapton, 2009).The Cambrian Limestone Aquifer (CLA) forms the major water resource in the region and where it is absent, local scale, Proterozoic fractured rock aquifers are utilised with varied success. The Bukalara Sandstone is also considered to be a local aquifer in the Project Area, with the nearest recognised water bores into the Bukalara Sandstone located north of Nutwood Downs Station, approximately 100 km from the Project Area. .

The CLA is a regional scale aquifer that provides groundwater resources for pastoral enterprises, domestic bores at homesteads and town water supplies at a number of small communities across the region. The CLA is subdivided into the Anthony Lagoon Beds (ALB) and the Gum Ridge Formation (GRF).

Figure 4-5 shows the elevation of the base of the GRF relative to the proposed well locations. This shows that the GRF is expected to be present at the proposed well locations.

The Anthony Lagoon Beds also overly the GRF across parts of the basin. Figure 4-6 shows the elevation of the top of the Gum Ridge Formation, and the lateral extent of the ALB. This map shows that the ALB are not expected to be present at the location of the proposed well sites.

Where fractured and cavernous the GRF can support bore yields of up to 100 L/s although yields from pastoral bores are typically less than 5 L/s but often reflect the stock water demand rather than the potential aquifer yield (Fulton 2018). Bore RN040939 penetrated the Bukalara Sandstone with a maximum yield of 23 L/s reported.

Depth to groundwater in the CLA ranges from 32 to 123 mBGS (metres below ground surface) with groundwater levels generally deeper further away from the basin margin in the south-west of EP 161 (Fulton 2018).

The regional groundwater flow direction in the GRF is north-west toward Mataranka, where the aquifer discharges into the Roper River approximately 100 km north-west of the Beetaloo Sub-basin where it supports significant groundwater dependent ecosystems (Fulton 2018).

The groundwater flow direction in the GRF broadly follows the north-west regional flow pattern however, gradients are very flat (0.0001) with little change in groundwater elevations observed over large distances. This is shown in Figure 4-8. Large decadal changes in discharge rates to the Roper River suggest that most recharge of the Roper River occurs close to the discharge zone, i.e. beyond the Beetaloo Sub-basin region (Fulton 2018).

Groundwater recharge mechanisms to the CLA are poorly characterised but are likely to be dominated by infiltration through sinkholes and soil cavities. Recharge is likely to be lower in areas where the overlying Cretaceous deposits, which contain clay and mudstone sequences, are thick and continuous (Fulton 2018). The Project Area straddles the north-east margin of the Georgina Basin. The Top Springs Limestone (main constituent of the CLA in the area) is present across the centre and south-west of the Project Area but pinches out in the north-east where Roper Group formations outcrop (Fulton 2018).

Drilling and geophysical logs confirm a local stratigraphy as per Table 4-4. This was confirmed by geophysical logging of the Tanumbirini 1 exploration well at the location of the proposed well sites.

Table 4-4 Stratigraphy logged at the location of Tanumbirini 1

Formation	Depth to formation top (m)	Thickness (m)
Undifferentiated Cretaceous	Surface	43.9
Gum Ridge Formation	52	150
Bukalara Sandstone	202	380
Chambers River Formation	582	570
Bukalorkmi Sandstone	1152	145
Kyalla Sandstone	1297	772
Moroak Sandstone	2069	368
Velkerri Formation	2437	1482.5
Bessie Ck Sandstone	3920	>30.5

A baseline survey of water bores in the vicinity of the proposed well sites was undertaken in 2018. The bore locations are shown in Figure 4-9. This shows that the Gum Ridge Formation is expected to be absent (north and east of the proposed well locations) there are more bores completed in undifferentiated Proterozoic fractured rock aquifers are targeted by water bores. These fractured rock aquifers are not present at the location of the proposed well sites.

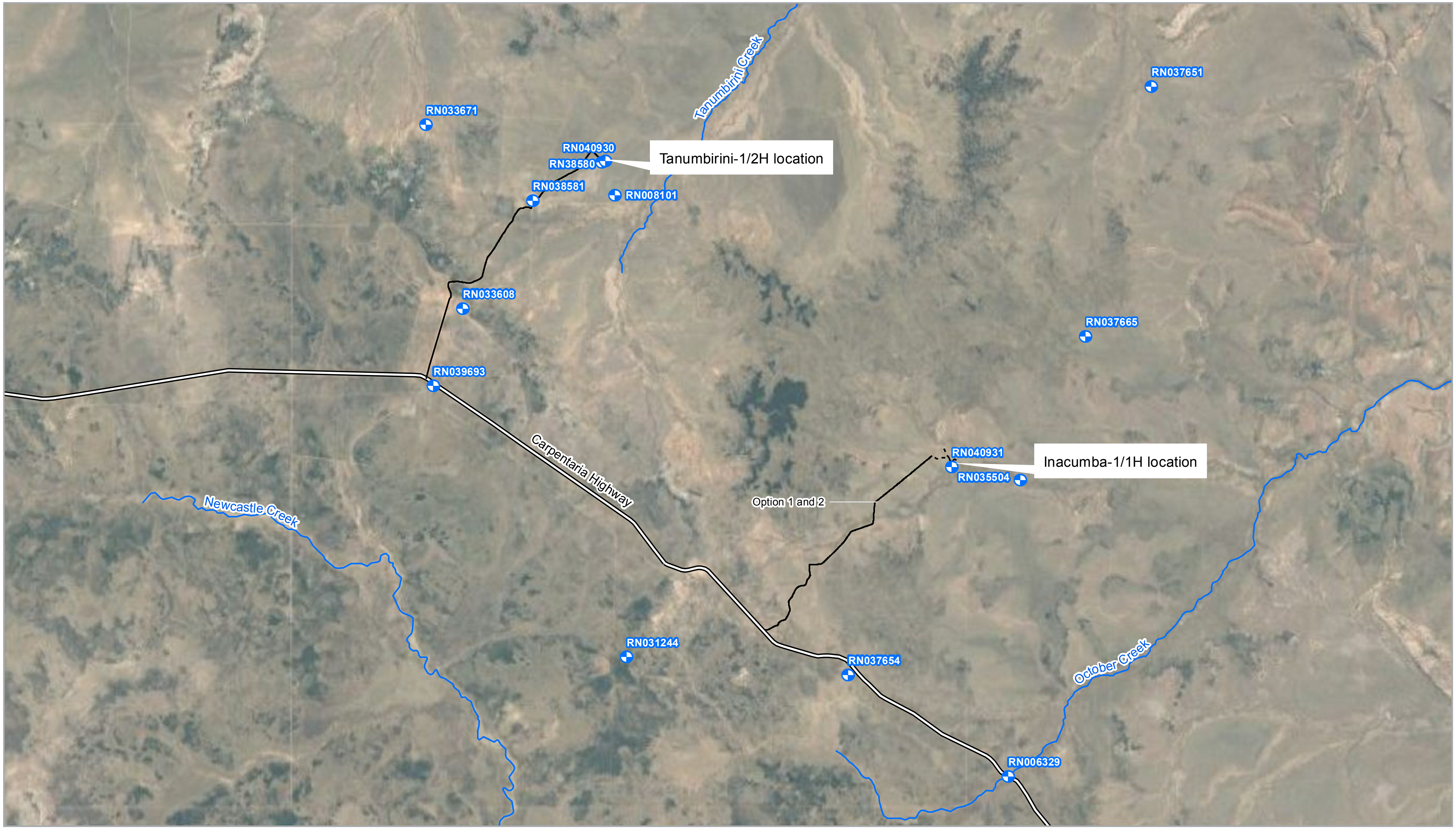
Groundwater Electrical Conductivity (EC) in the CLA ranges from 1170 - 2260 µS/cm (average of 1580 µS/cm) and the pH is typically neutral (6.3 - 7.3) (Fulton 2018). Figure 4-7 maps the distribution of total dissolved solids (mg/L) detected in all groundwater relative to the proposed well sites. Santos has established groundwater monitoring bores at the Tanumbirini 1/2H location and Inacumba 1/1H location. The groundwater from these bores is fresh, ranging between 800-1000 mg/L TDS. Table 4-5 provides a more detailed breakdown of the groundwater chemistry in the Gum Ridge Formation (compliant with the sampling and testing requirements outlined in the Preliminary Guideline: Groundwater Monitoring Bores for Exploration Wells in the Beetaloo Sub-basin (DENR, 2018)).

The existing bores that Santos will monitor as part of their groundwater monitoring program are shown in Figure 4-4. In addition, CSIRO led baseline studies are underway with extensive effort being put into the understanding of recharge, this information will form part of the Strategic Regional Environmental Baseline Assessment (SREBA) managed by the NT government.

Table 4-5 Groundwater chemistry from installed Control Monitoring Bores

		Bore ID	RN040930	RN040931
		Description	TANUMBIRINI 2 CONTROL MONITORING BORE	INACUMBA 1 CONTROL MONITORING BORE
		Sample Date	9/12/2018	17/12/2018
Analyte	**Unit**	**Limit of detection**	**Result**	**Result**
Bicarbonate Alkalinity as CaCO3	mg/L	1	417	363
Carbonate Alkalinity as CaCO3	mg/L	1	< 1	< 1
Hydroxide Alkalinity as CaCO3	mg/L	1	< 1	< 1
Total Alkalinity as CaCO3	mg/L	1	417	363
Electrical Conductivity @ 25°C	µS/cm	1	1330	1560
Total Dissolved Solids @180°C	mg/L	10	824	976
Suspended Solids	mg/L	5	< 5	35
Calcium (dissolved)	mg/L	1	137	134
Magnesium (dissolved)	mg/L	1	57	88
Potassium (dissolved)	mg/L	1	12	22
Sodium (dissolved)	mg/L	1	78	103
Total Hardness as CaCO3	mg/L	1	577	697
Chloride	mg/L	1	106	148
Fluoride	mg/L	0.1	1.0	1.8
pH - Lab	pH Unit	0.01	7.97	8.06
Sulfate as SO4 2- (dissolved)	mg/L	1	208	328
Aluminium (total)	mg/L	0.01	< 0.01	< 0.01
Aluminium (dissolved)	mg/L	0.01	< 0.01	0.30
Barium (total)	mg/L	0.001	0.039	0.028
Barium (dissolved)	mg/L	0.001	0.040	0.036
Boron (total)	mg/L	0.05	0.18	0.31
Boron (dissolved)	mg/L	0.05	0.16	0.27
Chromium (total)	mg/L	0.001	< 0.001	< 0.001
Chromium (dissolved)	mg/L	0.001	< 0.001	< 0.001
Copper (total)	mg/L	0.001	< 0.001	< 0.001
Copper (dissolved)	mg/L	0.001	< 0.001	0.002
Iron (total)	mg/L	0.05	< 0.05	< 0.05
Iron (dissolved)	mg/L	0.05	0.23	7.33

		Bore ID	RN040930	RN040931
		Description	TANUMBIRINI 2 CONTROL MONITORING BORE	INACUMBA 1 CONTROL MONITORING BORE
		Sample Date	9/12/2018	17/12/2018
Manganese (total)	mg/L	0.001	0.026	0.142
Manganese (dissolved)	mg/L	0.001	0.029	0.163
Molybdenum (total)	mg/L	0.001	0.003	0.046
Molybdenum (dissolved)	mg/L	0.001	0.003	0.050



Legend

- Groundwater Bores
- Proposed Access Road
- Major Waterways
- Principal Road
- Inacumba Lease
- Tanumbirini Leases

1:220,000 @ A4

0 2.5 5 7.5 10

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

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Groundwater Bores

FIGURE 4-4

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Print date: 02 Apr 2019 - 14:46

Data source: Google Earth: imagery (Jun 2016, captured Mar 2017 . GA: Roads, Waterways (2015) Santos: Proposed Access Roads, Existing Access Roads, Inacumba and Tanumbirini Lease Pads, (2019) Created by: cmacgregor

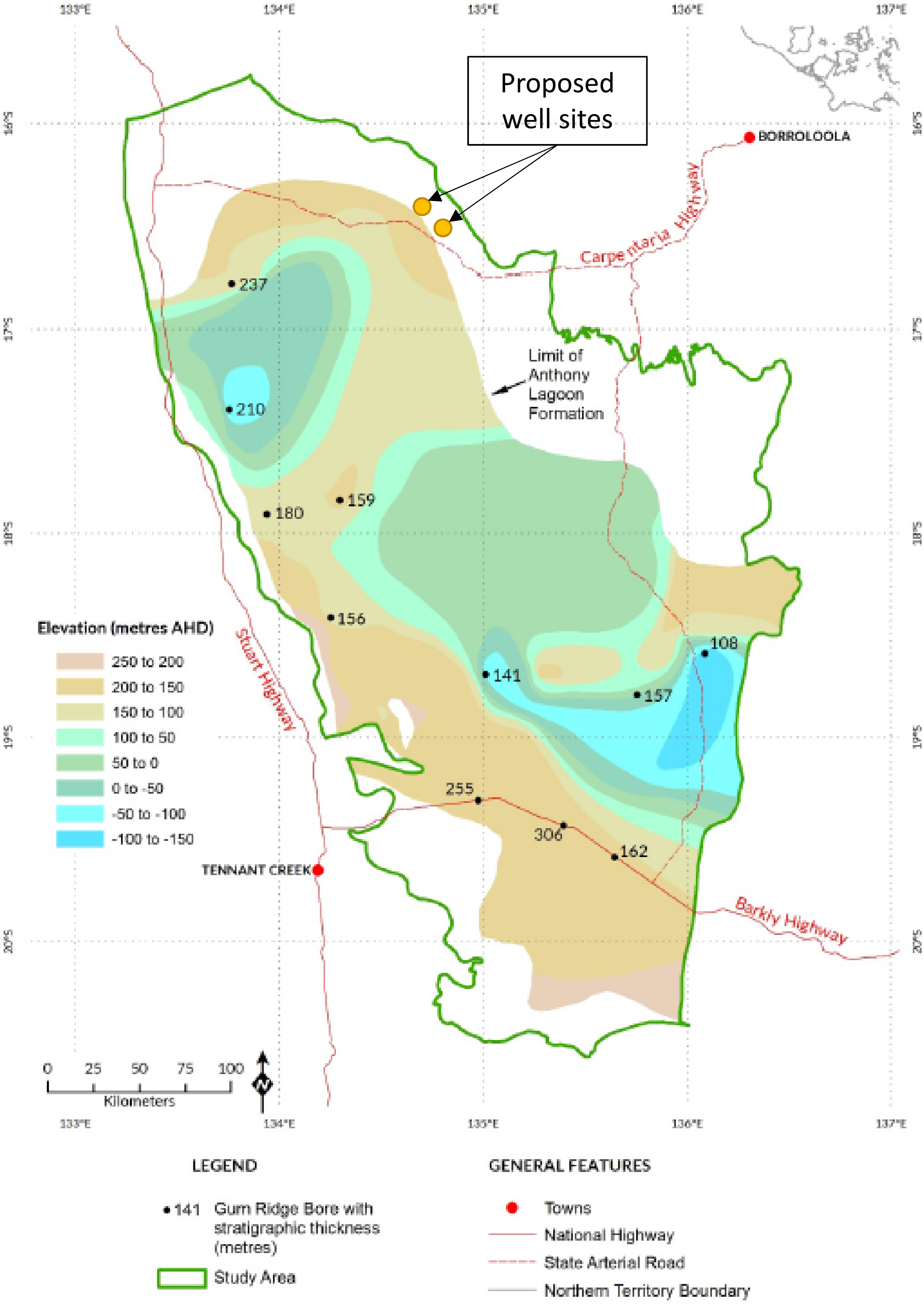


Figure 4-5 Elevation (mAHD) of the top of the Gum Ridge Formation relative to the proposed well sites (adapted from Tickell and Bruwer (2017) *Georgina Basin Groundwater Assessment: Daly Waters to Tennant Creek*)

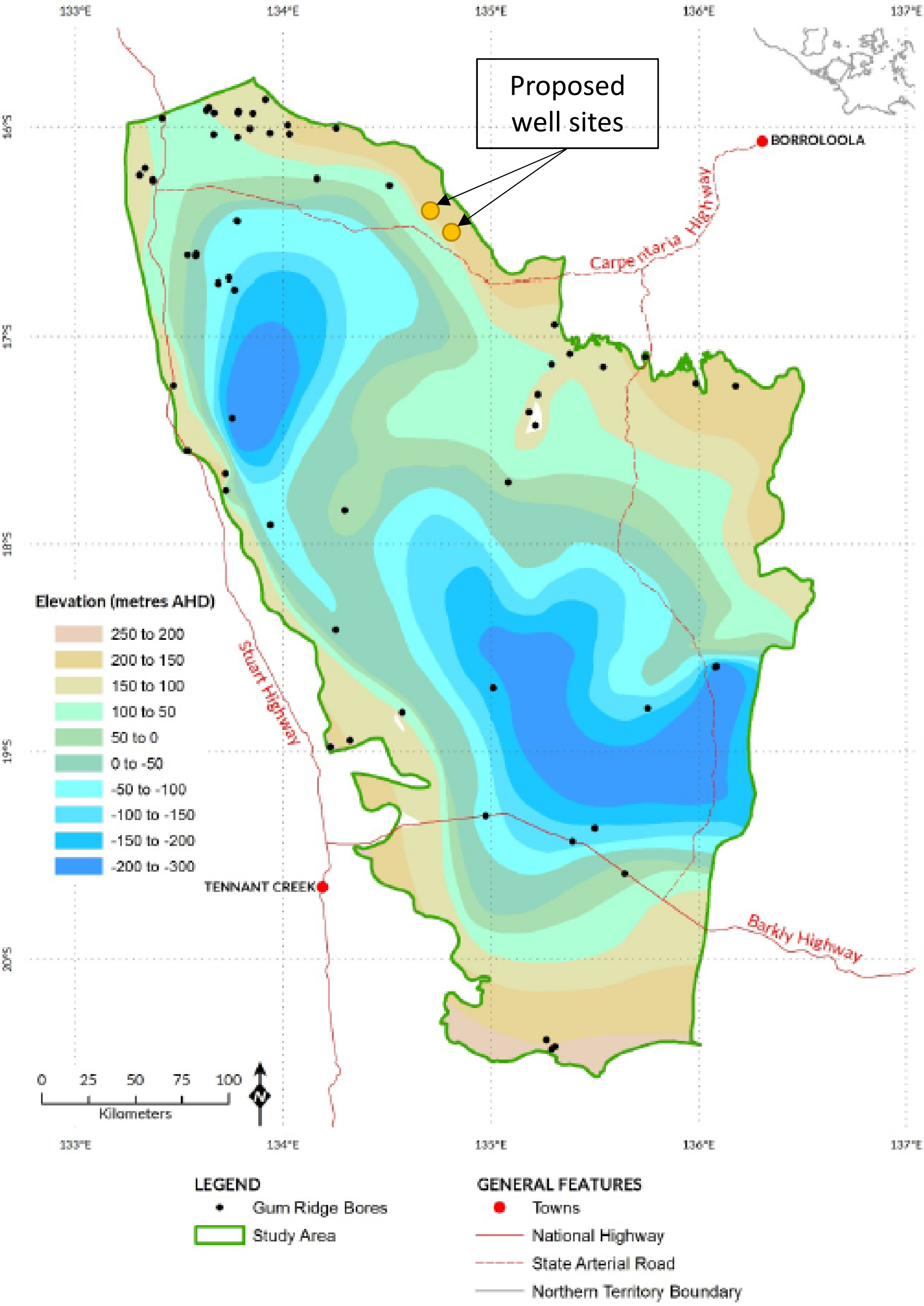


Figure 4-6 Elevation (m AHD) of the base of the Gum Ridge Formation relative to the proposed well sites (adapted from Tickell and Bruwer (2017) *Georgina Basin Groundwater Assessment: Daly Waters to Tennant Creek*)

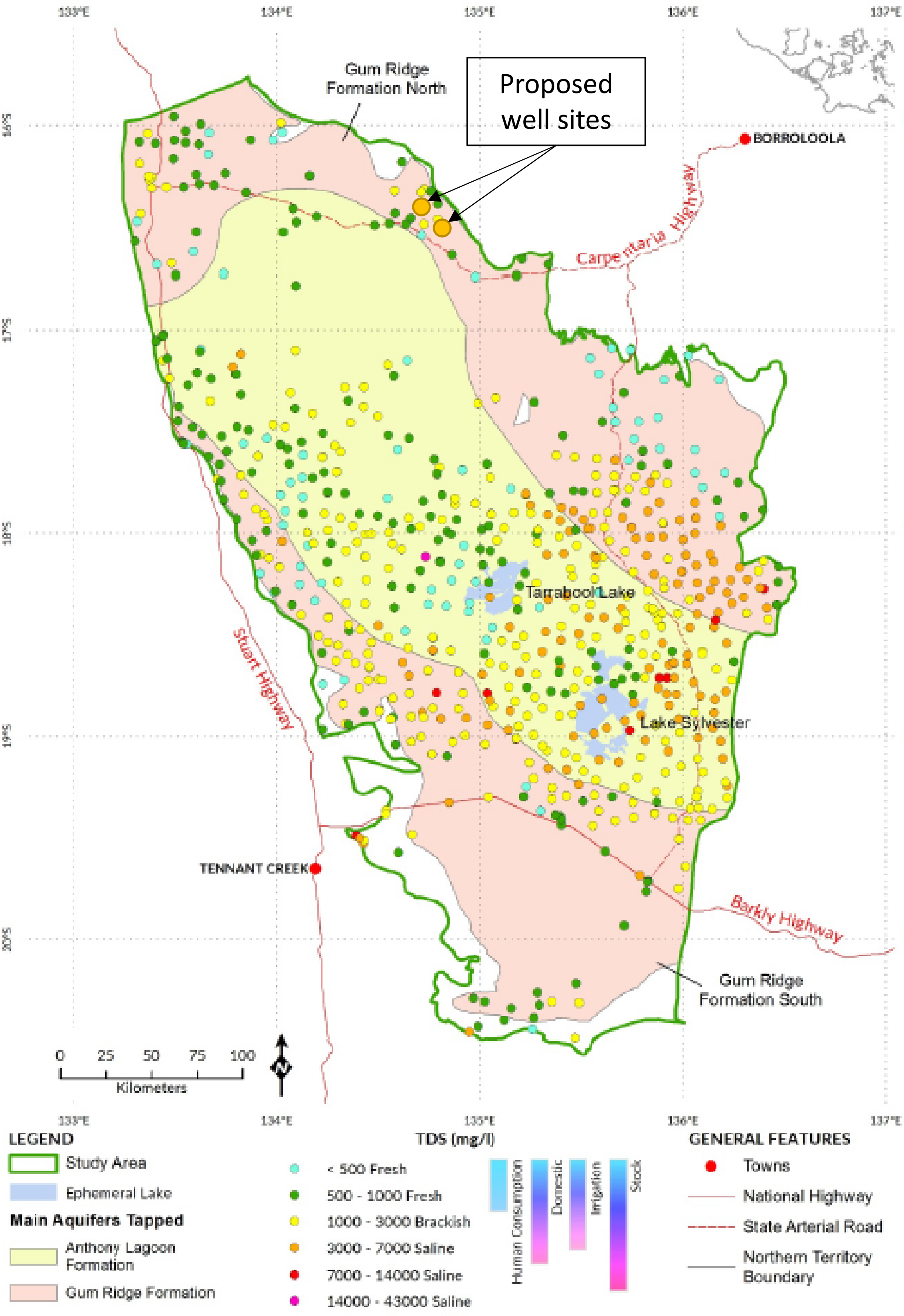


Figure 4-7 Groundwater total dissolved solids (mg/L) relative to the proposed well sites (adapted from Tickell and Bruwer (2017) *Georgina Basin Groundwater Assessment: Daly Waters to Tennant Creek*)

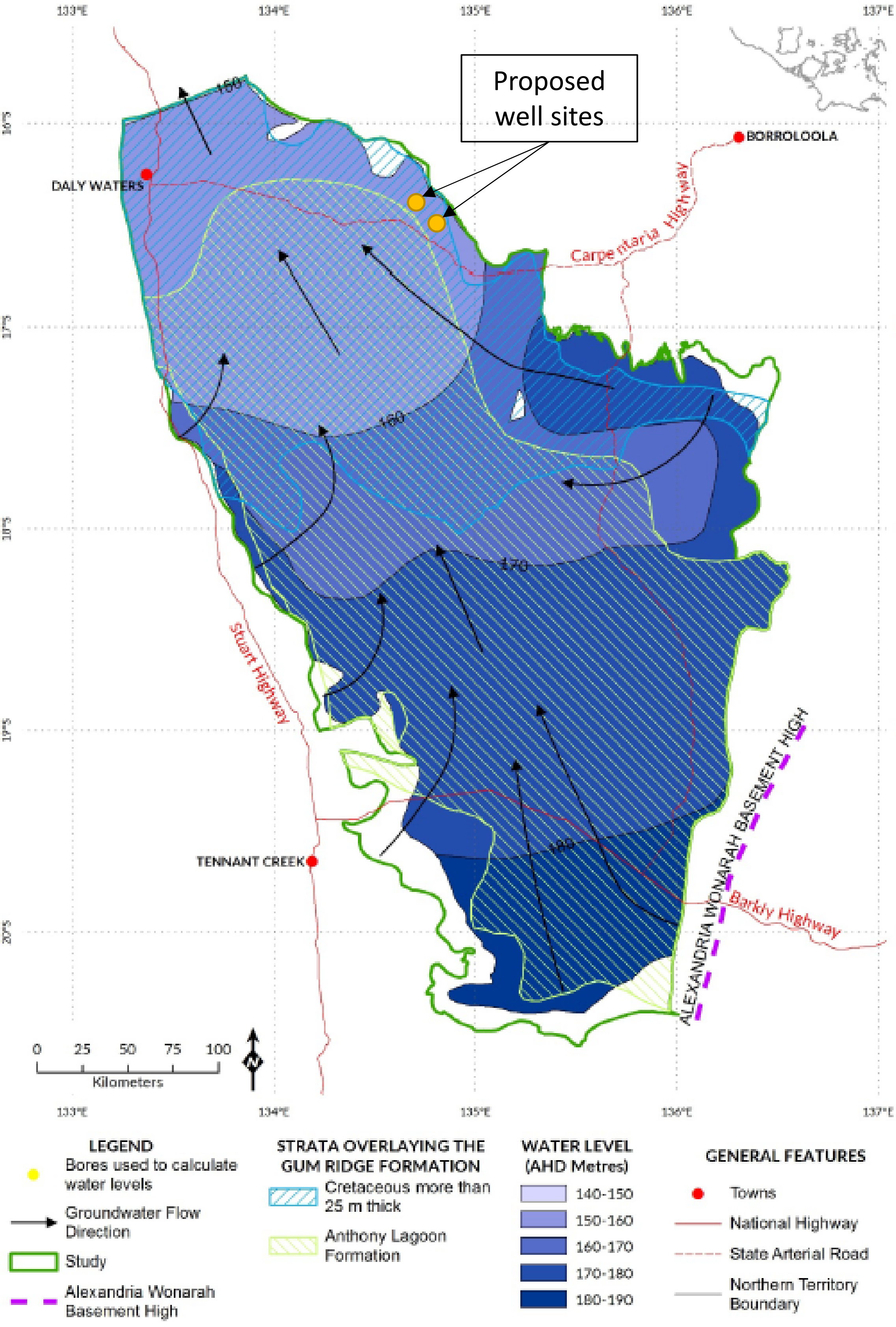


Figure 4-8 Regional groundwater level contours in the Gum Ridge Formation relative to the proposed well sites (adapted from Tickell and Bruwer (2017) *Georgina Basin Groundwater Assessment: Daly Waters to Tennant Creek*)

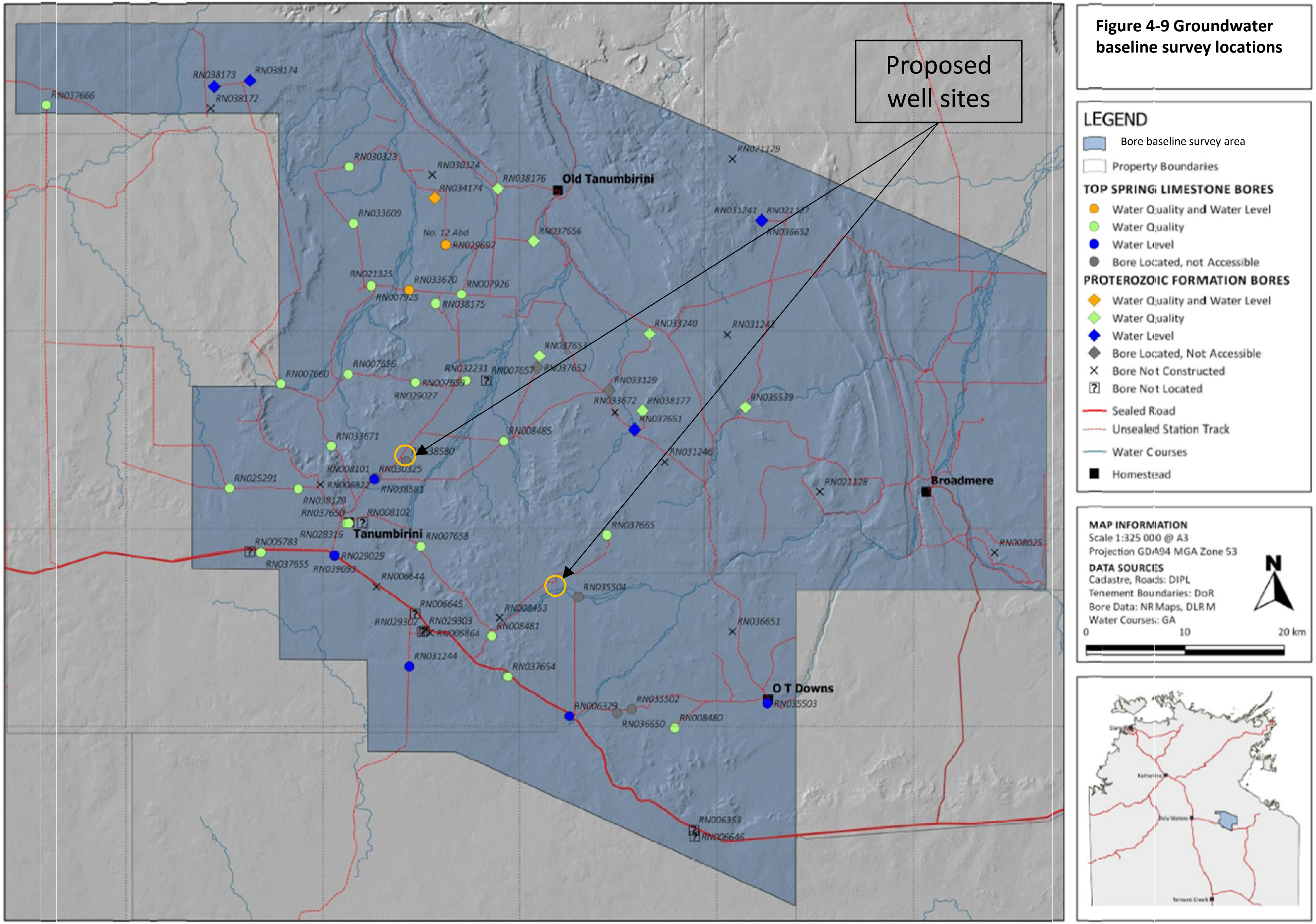


Figure 4-9 Groundwater baseline survey locations

4.1.7 Surface water

The Project Area is located in the headwaters of the Limmen Bight River catchment, which drains north easterly towards the Gulf of Carpentaria as shown in Figure 4-10. Rivers include the Limmen Bight River and its tributary, the Cox River (NR Maps, 2018).

The highest flows for these rivers occur during the wet season, predominantly due to cyclones and monsoonal rainfall. In contrast to these larger rivers, smaller braided streams and drainage lines such as the Tanumbirini Creek and October Creek to the north, and Newcastle Creek to the south are largely ephemeral. Ephemeral rivers and streams are subject to short flow duration and high turbidity.

There is also a range of small wetlands associated with springs, sinkholes and minor depressions in the generally flat landscape. Riparian zones of these rivers and wetlands are generally in fair to good condition, affected mostly by livestock and feral animals and weeds.

4.1.7.1 Flood Modelling

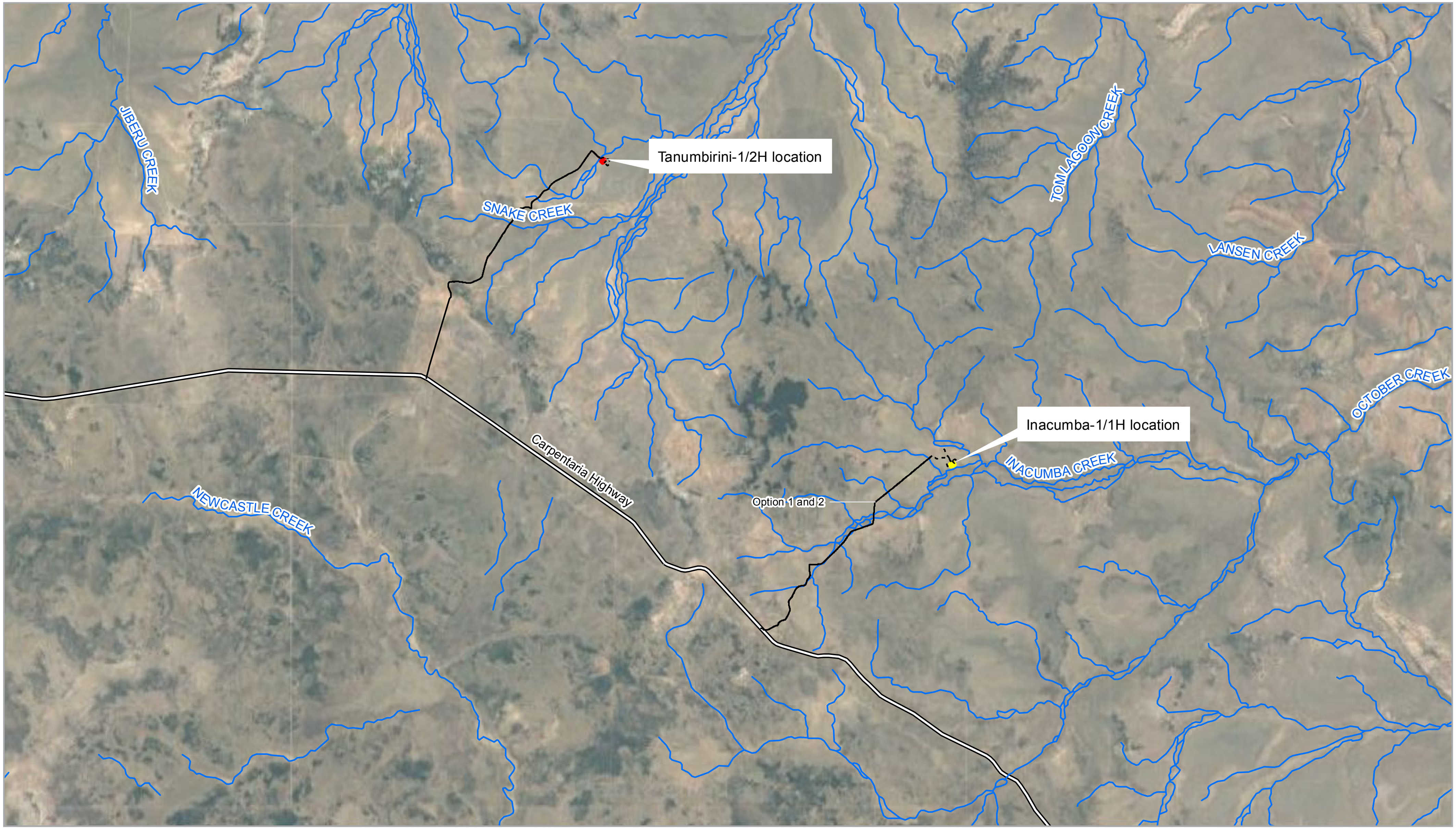
Flood modelling was completed for the Annual Exceedance Probability (AEP) - the probability that a given rainfall total accumulated over a given duration will be exceeded in any one year, of 1 in 10, 1 in 20, 1 in 50 and 1 in 100.

The flood modelling was based on a hydrologically enforced SRTM[1] digital elevation model (vertical accuracy +/- 9.8 m), with design discharge rates based on estimates from the Regional Flood Frequency Estimation (RFFE) model, rational method and regression equations outlined in Weeks (2006). A TUFLOW model was then developed based on the SRTM data, running a steady-state simulation based on peak flow rates from the RFFE model.

The results indicate the lease pad at the Tanumbirini 1/2H location will be subject to minor (~<1m) flooding during a 1 in 10 AEP flood event. That flooding extends to an average depth of 1 to 1.5 m during a 1 in 100 AEP flood event. However the supporting infrastructure areas, including the camp, tank pads and laydown areas in the south east remain unaffected by a 1 in 100 AEP flood event. The Inacumba 1/1H location including the lease pad and the supporting infrastructure areas remains mostly unaffected in a 1 in 100 AEP flood event. Note, the model for Tanumbirini 1/2H was adjusted to consider the elevation of the existing lease pad design (i.e. 2 m above the level of the adjacent creek bed).

The 1 in 100 AEP flood extent at the Tanumbirini 1/2H location and the Inacumba 1/1H location is shown in Figure 4-11 and Figure 4-12 below.

[1] Shuttle Radar Topography Mission (STRM) ustilises synthetic aperture radar and interferometry to collate accurate elevation models.



Legend

- Major Waterways
- Proposed Access Road
- Principal Road
- Inacumba Lease
- Tanumbirini Leases

1:220,000 @ A4

0 2.5 5 7.5 10

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

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Surface Water

FIGURE 4-10

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Print date: 02 Apr 2019 - 14:47

Data source: Google Earth: imagery (Jun 2016, captured Mar 2017 . GA: Roads, Waterways (2015) Santos: Proposed Access Roads, Existing Access Roads, Inacumba and Tanumbirini Lease Pads, (2019) Created by: cmacgregor

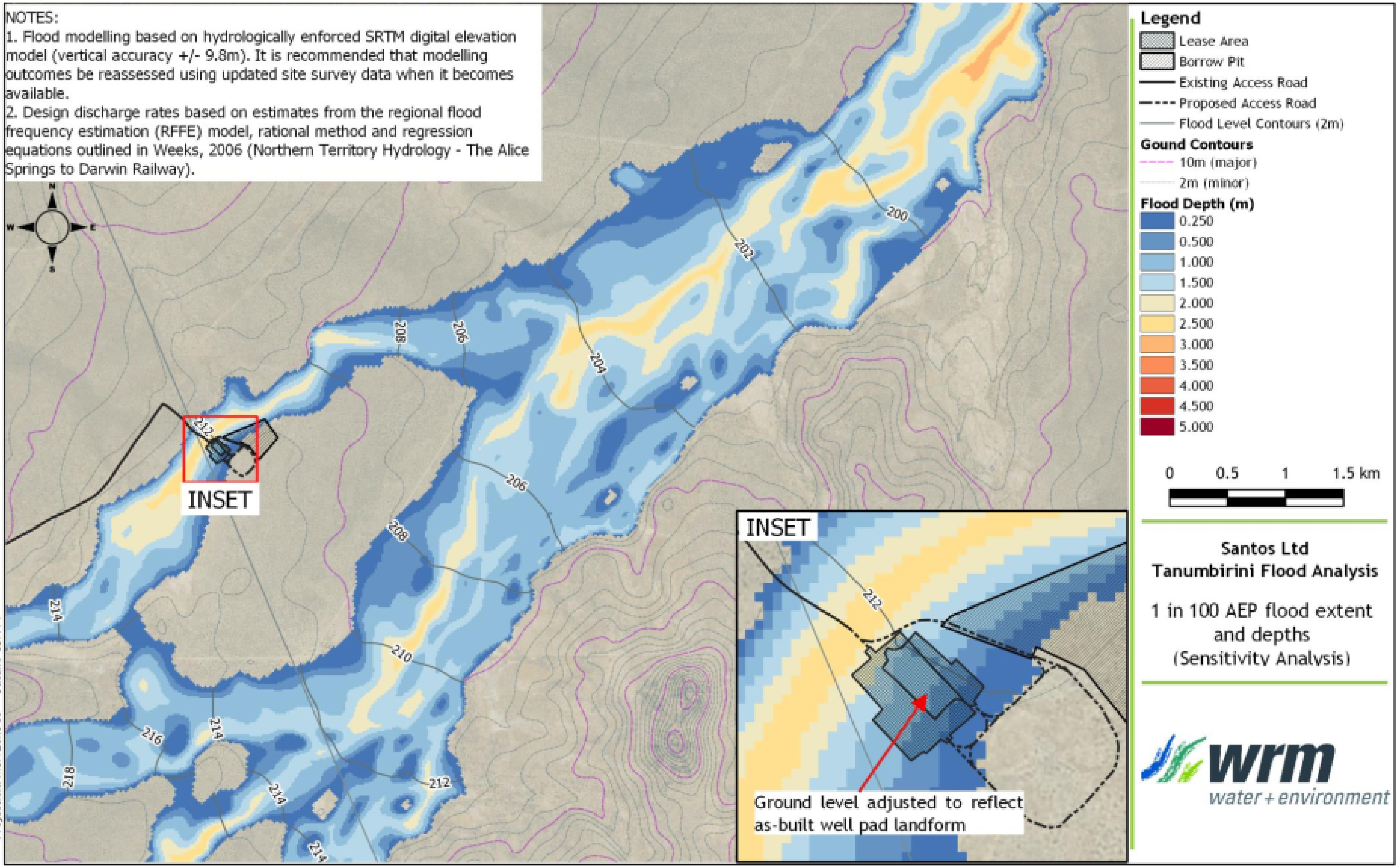


Figure 4-11 The 1 in 100 AEP flood extent at Tanumbirini 1/2H

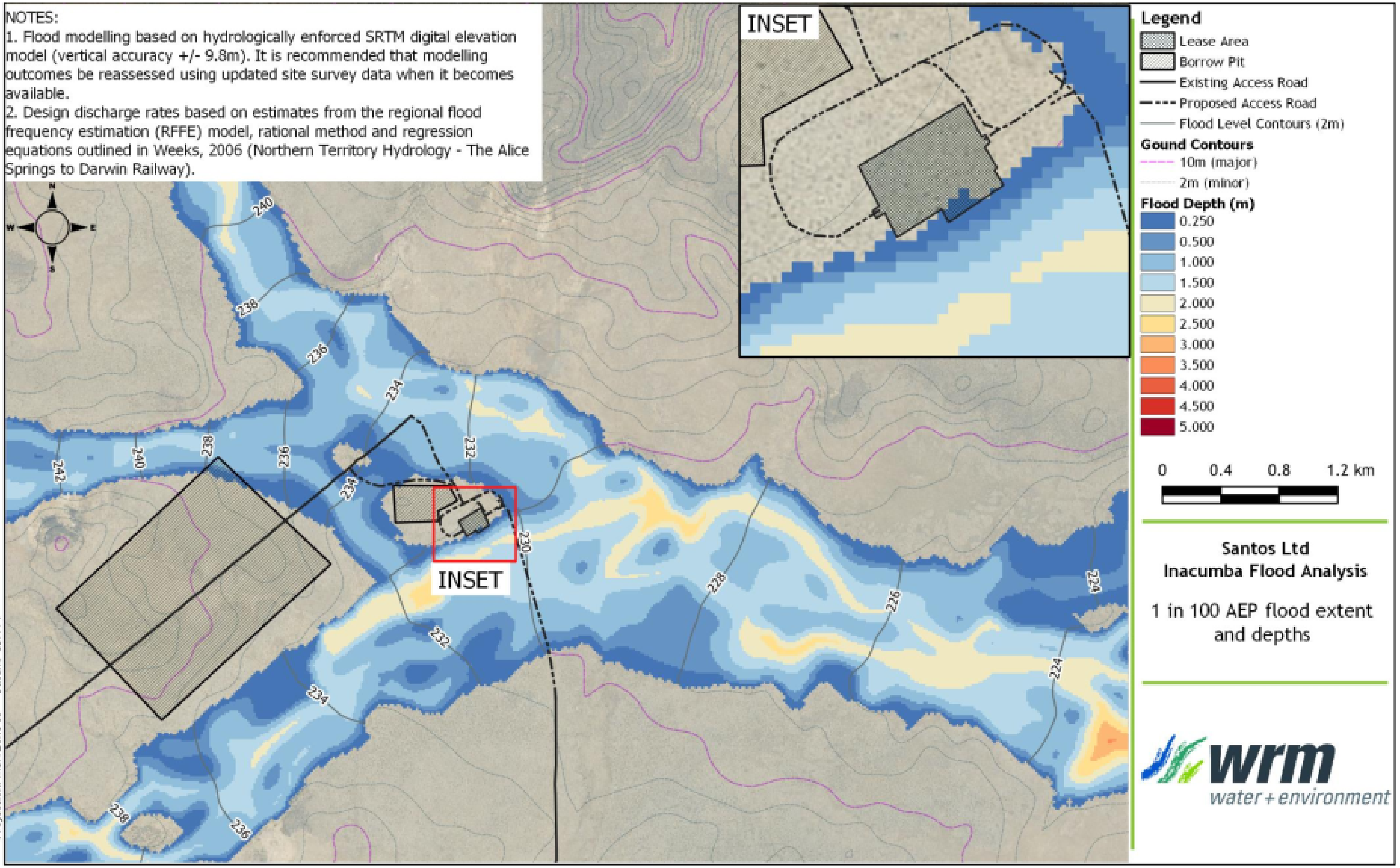


Figure 4-12 The 1 in 100 AEP flood extent at Inacumba 1/1H

4.1.8 Air Quality

Baseline methane monitoring will be conducted to monitor and measure background methane levels and rate of change in methane levels using mobile survey technology. The methane monitoring will be conducted by CSIRO using the methodology established by the Gas Industry Social and Environmental Research Alliance (GISERA). Data collected during this monitoring is available online here: https://gisera.csiro.au/project/baseline-measurement-and-monitoring-of-methane-emissions-in-the-beetaloo-sub-basin/.

4.2 Natural Environment

A description of the natural environment in the areas surrounding the project are detailed below. In addition, an ecological assessment report of the ecological survey work conducted on Tanumbirini Station between 2017 and 2019 is provided in Appendix D.

4.2.1 Bioregions

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

Tanumbirini Station is located at the junction of two biogeographic regions as well as the headwaters of a number of catchments. As a result, the landscapes reflect to some degree those of the southern Sturt Plateau and Gulf Fall and Upland (upper Roper River) Bioregions, see Figure 4-13.

4.2.1.1 Gulf Fall and Upland Bioregion

The Gulf Fall and Upland Bioregion covers an area of 118,480 km^2 and includes gorges, water holes and dissected sandstone plateaus comprising Proterozoic sandstone outcrops. Vegetation is predominantly eucalypt woodlands over spinifex grasslands. Cattle grazing and mining are the main land uses. Other land uses include Aboriginal land and conservation reserves. Major population centres are Borroloola and Ngukurr (DoEE 2008).

Feral animals, weeds and a broad fire regime are eroding the bioregion however, it is generally in good condition. The bioregion also provides refuge for threatened species including the endangered Carpentaria rock-rat and Gouldian finch (Department of Lands Resource Management 2015).

The riparian zones of water courses are in reasonably good condition however, experience degradation from uncontrolled livestock and feral animals. Other issues localised watercourses face are weed infestations, altered fire regimes and pollution related to mining.

The bioregion is generally in good condition, but is being eroded by continuing increases in the number of feral animals (especially pigs, buffalo, donkeys and cattle) and weeds, and broad-scale changes in fire regime.

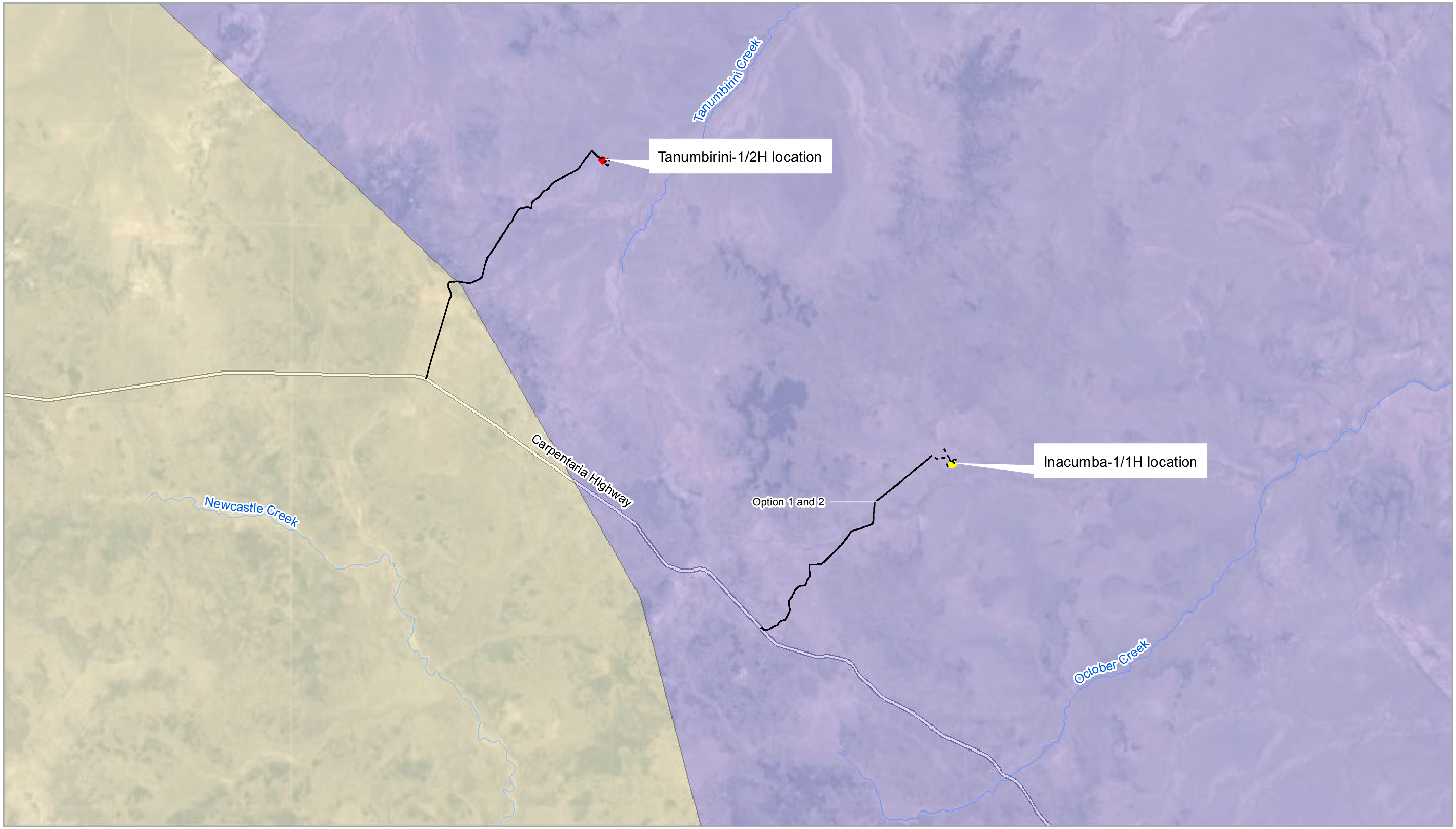
4.2.1.2 Sturt Plateau Bioregion

The Sturt Plateau Bioregion comprises a total area of approximately 98,575 km^2. The topography is characterised by low-lying flat to gently undulating plains. The vegetation is mostly eucalypt open forests and woodlands dominated by bloodwoods. Open areas are dominated by perennial grasses and annual grasses. The main industry use in this region is cattle grazing. The major population centres include Larrimah and Daly Waters (Bastin and Acris, 2008).

The climate in this bioregion is dry but influenced by monsoonal activity. Historically water supply issues have affected this region, but the increase in groundwater information has led to improved success rates for drilling bores and subsequently better land development.

It has been estimated that 77% of the Sturt Plateau bioregion is grazed by stock. There are a number of weeds that are known to occur in this bioregion such as hyptis, prickly acacia, sicklepod and mission grass. The Alice Springs to Darwin railway corridor has provided an avenue for new weeds to invade and spread in the region. Known invasive animals include pigs, dogs, camels, cats and horses (Bastin and Acris, 2008).

The strategic placement of water access points has increased the development of infrastructure, reduced the number and intensity of wildfires and increased the area available for grazing.



Legend

- - - - Proposed Access Road
Principal Road
Inacumba Lease
Tanumbirini Leases

Bioregion Name

Gulf Fall and Uplands
Sturt Plateau

1:220,000 @ A4

0 2.5 5 7.5 10

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

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GHD

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Bioregions

FIGURE 4-13

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Print date: 02 Apr 2019 - 14:48

Data source: Google Earth: imagery (Jun 2016, captured Mar 2017 . GA: BioRegions, Roads, Waterways (2015) Santos: Proposed Access Roads, Existing Access Roads, Inacumba and Tanumbirini Lease Pads, (2019) Created by: cmacgregor

4.2.2 Vegetation

The National Vegetation Information System (NVIS) 2007 Level 2 survey describes the vegetation contained within the EP and surrounding Tanumbirini Station as Tussock grassland, Acacia open forest, and Eucalyptus low woodland (DENR, 2000), as shown Figure 4-16.

The dominant vegetation type in the immediate area of the Tanumbirini Project Area is woodland. The dominant species within the woodland vegetation communities present is dominated by Kullingal *Eucalyptus pruinosa and* variable barked Bloodwood *Corymbia dichrompophloia* with *Melaleuca* spp. with tussock grass understorey.

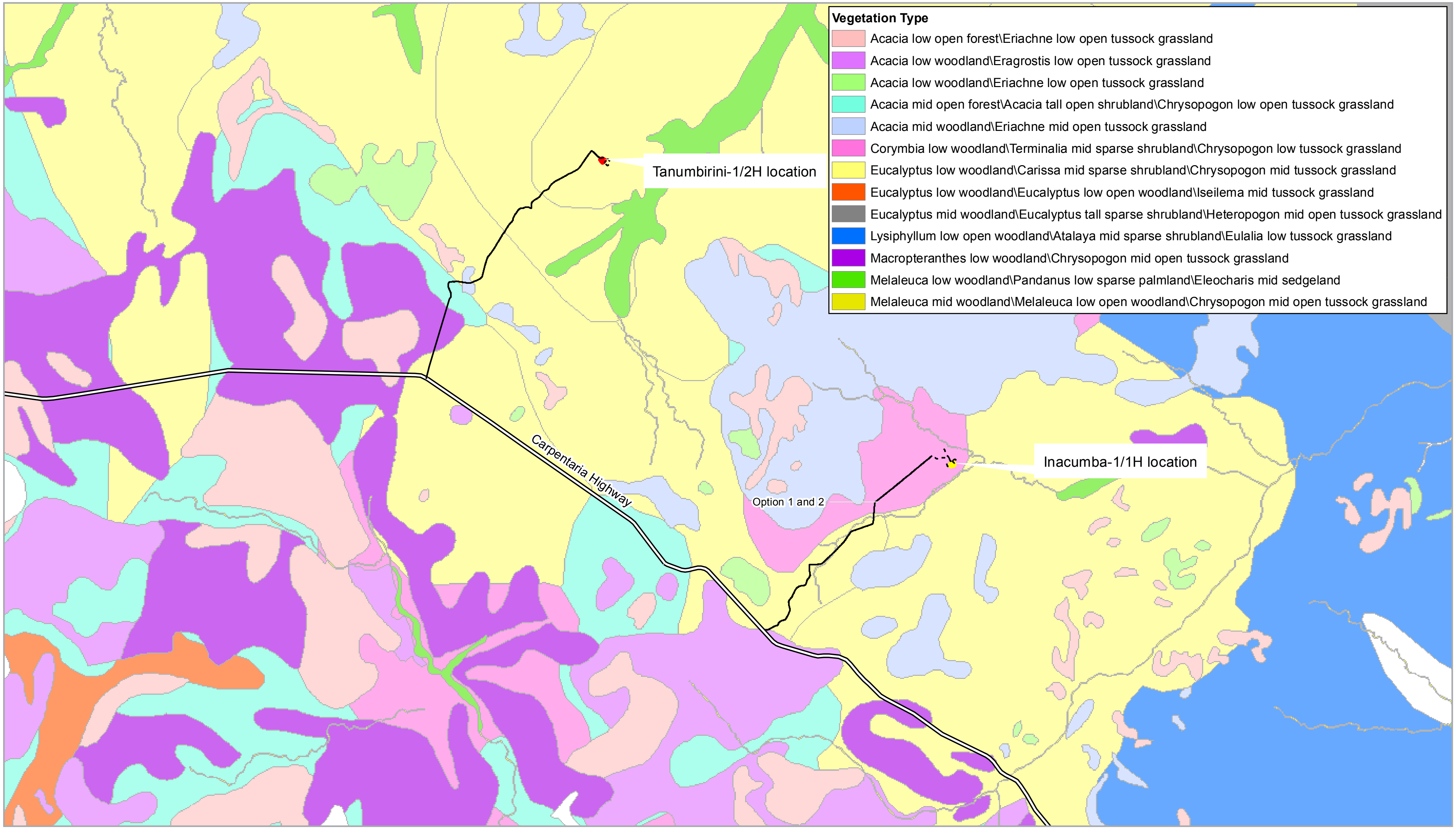
Ecoz undertook a survey of the vegetation in the vicinity of the proposed Tanumbirini 1/2H well location and found vegetation communities within the Project Area are dominated by Eucalyptus and Corymbia species (in the plains and undulating hills), Acacia woodlands/forests, and Melaleuca communities (within drainages lowlands, and depressions), Lancewood (*Acacia shirleyi*) woodland/forests and Bullwaddy (*Macropteranthes kekwickii)* woodlands. Although not indicated on the national vegetation information system (NVIS) mapping, areas of tussock grasslands on lateritic plains or alluvial plains were recorded. These communities were surrounded by either Eucalyptus or Melaleuca woodlands (Aldrick and Wilson 1992, Ecoz 2019).

Vegetation exhibited impacts from cattle. Understorey grass species showed extensive grazing from cattle. Trampling and impacts to the soil surface were also evident.

Eucalyptus woodlands containing *Eucalyptus leucophloia* which occur on rises (particularly within the lateritic plateau land systems) may provide nesting habitat for Gouldian Finch (see Section 4.2). However, none of these habitat areas occur with the Tanumbirini 1/2H or Inacumba 1/1H locations.

Figure 4-14 The Inacumba 1/1H location and the surrounding vegetation

Figure 4-15 Looking west towards the watercourse at the Tanumbirini 1/2H location



Legend

- Existing Access Road
- Proposed Access Road
- Principal Road
- Inacumba Lease
- Tanumbirini Leases

1:220,000 @ A4

0 2.5 5 7.5 10

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

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GHD

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Vegetation Types

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FIGURE 4-16

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Print date: 02 Apr 2019 - 14:47

Data source: NTG - NVIS (2007) . GA: Roads, Waterways (2015) Santos: Proposed Access Roads, Existing Access Roads, Inacumba and Tanumbirini Lease Pads, (2019) Created by: cmacgregor

4.2.3 Listed Threatened Species

A search of the NT Flora and Fauna Atlas (NR Maps, 2018) was completed on 5 December 2018 to determine threatened species records within 10 km of the Project Area, which found records of one reptile (Mertens` Water Monitor) and one mammal (Carpentarian Antechinus).

A search of the PMST database (DoEE 2018) was undertaken on 4 December 2018 to identify MNES likely to occur within 10 km of the Project Area (Appendix B). The PMST Report identified six birds, five mammals and one reptile that are listed threatened species that may occur within 10 km of the Project Area. No listed insects were reported. The results of the PMST Report and NT Fauna Atlas are outlined in

Table 4-6 below and a likelihood assessment has been undertaken, utilising information from desktop and field studies undertaken on EP 161 (Appendix D).

The likelihood assessment was based on habitat requirements, distribution, and the number and dates of proximate records (Ecoz 2017). On-ground habitat assessment was also used to assist the assessment. In this assessment, the likelihood of a species occurring is ranked as none, low, medium, and high. In the context of this report, this means:

- **None** – There is no likelihood of this species occurring within the survey area
- **Low** – The survey area occurs outside of the core distribution for the species and there is no or only marginally suitable habitat. Some vagrant records may exist
- **Medium** – There is suitable habitat within the survey area but records are either old, infrequent or some distance from the project footprint
- **High** – There is suitable habitat within the survey area and records are proximate and recent.

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Table 4-6 Likelihood assessment for potential threatened species

Common Name	Scientific Name	EPBC Status	TPWC Status	Likelihood of occurrence	Distribution and Habitat
Birds					
Australian Painted Snipe	*Rostratula australis*	Endangered	Vulnerable	Low	This species is found in the fringes of permanent and temporary wetlands, swamps and inundated grasslands (Taylor et al. 2013) and is nomadic and scattered across Australia with no predictable occurrence (Rogers 2001). The closest known occurrence is approximately 50 km north-east of the Project Area but the Project Area would provide occasional habitat for this species during periods of inundation.
Crested Shrike-tit	*Falcunculus frontatus whitei*	Vulnerable	-	Medium	Species occurs sparsely across the NT. Populations persist in areas burnt every year and highly grazed, particularly in the Sturt Plateau Bioregion. This is the bioregion containing the Project Area. The Crested shrike-tit inhabits a wide range of forests and woodlands, and are thought to have large home ranges (Woinarski 2004). The Project Area provides potentially suitable habitat for this species.
Curlew Sandpiper	*Calidris ferruginea*	Critically Endangered	Vulnerable	Low	The habitat of this species is coastal and estuarine with tidal mudflats and is rarely found inland (Ecoz 2017). This species has a low likelihood of occurring with the Project Area.
Gouldian Finch	*Erythrura gouldiae*	Endangered	Vulnerable	Medium	Gouldian finches have specific habitat needs including the presence of established hollows for nesting. The preferred tree species for nesting are Snappy Gums *(Eucalyptus Leucophloia)*, which have been identified as occurring within the Project Area. Gouldian Finches feed on the seeds of perennial grasses and require a water source within 2-4 km of their home range (O'Malley 2006). Due to the presence of potential nesting habitat within the study area, it is possible that the Gouldian Finch may occur.
Masked Owl	*Tyto novaehollandiae kimberli*	Vulnerable	Vulnerable	Low	This species is found mainly in Eucalyptus tall open forests (especially those dominated by *Eucalyptus miniata* and *E. tetrodonta*), but also roosts in monsoon rainforests and forages in more open vegetation types, including grasslands (Woinarski and Ward 2012).There is no suitable tall open

Common Name	Scientific Name	EPBC Status	TPWC Status	Likelihood of occurrence	Distribution and Habitat
					Eucalyptus forest for roosting in the Project Area, although the open woodland habitat may provide suitable foraging habitat (Ecoz 2017).
Red Goshawk	*Erythrotriorchis radiatus*	Vulnerable	Vulnerable	Low	The Red Goshawk prefers tall, open Eucalyptus forest and riparian areas and nests in large trees, which occur within 1 km of permanent water (Ecoz, 2017). No nesting habitat of this type was observed within the Project Area (Ecoz, 2017).
Grey Falcon*	*Falco hypoleucos*	-	Vulnerable	Medium	Occurs in areas of lightly-timbered lowland plains, typically on inland drainage systems, where the average annual rainfall is less than 500 mm and the majority of records are from the southern half of the NT. (Ward 2012). The Project Area has a higher rainfall than 500 mm however it was observed 100 km north-west of the Project Area in 2000 (Ecoz 2017). This species may occasionally occur within the study area.
Painted Honeyeater*	*Grantiella picta*	Vulnerable	Vulnerable	Low	The Painted Honeyeater is distributed predominantly in Eastern/South-eastern Australia. There are no known breeding colonies in the NT, and it has been speculated that sightings have been of an occasional bird that has moved west. It is believed that degradation of breeding habitat in Eastern Australia has led to their population to decline nationally, including in the NT (DENR, 2012). It is unlikely that this species occurs within the study area with any regularity.
Mammals					
Bare-rumped Sheath-tailed Ba	*Saccolaimus nudicluniatus*	Vulnerable		Low	The species is predominantly found throughout the monsoonal tropics and the dry open woodlands and grasslands in the Project Area are unlikely to be suitable habitat (Ecoz 2017.)
Carpentarian Antechinus	*Pseudantechinus mimulus*	Vulnerable	-	Low	The species habitat in the NT is sloping sandstone hills with boulders, pavement, outcrops and rocky surface, with open woodland of *Eucalyptus tetrodonta* and E. *aspera*, and a dense understorey and ground cover of *Plectrachne pungens* (DoE 2017a). There is only a small area of rocky outcropping in the Project Area and the Project Area is towards the edge of the species' distribution (Ecoz 2017). Not recorded in the area since 1987.

Common Name	Scientific Name	EPBC Status	TPWC Status	Likelihood of occurrence	Distribution and Habitat
Ghost Bat	*Macroderma gagis*	Vulnerable	-	Low	The species is found from the arid Pilbara (WA) to tropical savannah woodlands and north Qld rainforests and. distribution likely influenced by the availability of suitable caves and mines for roost sites (TSSC 2016). There is no suitable permanent roost sites in the Project Area and no occurrences near the Project Area (Ecoz 2017)
Greater Bilby	*Macrotis lagotis*	Vulnerable	Vulnerable	None	In the NT, the species is found in hummock grasslands on sandy soils with a preference for paleo-drainage lines (Southgate 1990). There is no suitable habitat in the Project Area and the Project Area is outside the historic distributional extent for this species.
Northern Quoll	*Dasyurus hallucatus*	Endangered	Critically Endangered	None	The species is found in rocky sandstone escarpments or coastal Eucalyptus tall open forest, which are not found within the Project Area (Ecoz 2017). The Project Area is outside the distribution of the species.
Pale Field-rat*	*Rattus tunneyi*	-	Vulnerable	Low	The species was found historically in a wide range of habitats, but now occurs primarily in dense vegetation along creeks (Aplin *et al.* 2008). There is no suitable habitat in the Project Area. This species was not found in the PMST database or NT Fauna Atlas but has been identified by DENR as potentially occurring in the Project Area in comments received in the previous EMP submission for EP 161.
Reptiles					
Gulf Snapping Turtle	*Elseya lavarackorum*	Endangered	-	None	This species is found in large rivers and their associated overflow lagoons and deeper permanent pools, which are not present within the Project Area (Ecoz 2017).
Mertens' Water Monitor	*Varanus mertensi*	-	Vulnerable	Medium	This species is found in and around freshwater waterways and associated riparian vegetation (Ward et al 2006). This monitor species has a broad geographic range in the NT. There is a record of this species being recorded within the study area in 1993, therefore there is the potential for this species to continue to persist in the surrounding freshwater waterways and associated riparian vegetation.

Common Name	Scientific Name	EPBC Status	TPWC Status	Likelihood of occurrence	Distribution and Habitat
Mitchell's Water Monitor*	*Varanus mitchelli*	-	Vulnerable	Low	The species is found in semi-aquatic and arboreal habitats, inhabiting the margins or watercourse, swamps and lagoons (Ward 2012). The ephemeral watercourses and limited wetlands in the Project Area are unlikely to provide suitable habitat (Ecoz 2017). This species was not found in the PMST database or NT Fauna Atlas but has been identified by DENR as potentially occurring in the Project Area in comments received in the previous EMP submission for EP161.

4.2.4 Listed Migratory Species

A search of the PMST database (DoEE 2018) was undertaken on 4 December 2018 to identify MNES likely to occur within 10 km of the Project Area (Appendix B). The PMST Report identified 12 birds and one reptile that are listed migratory species which may occur within 10 km of the Project Area. These results are outlined below in

Table 4-6, and a likelihood assessment has been undertaken, utilising information from desktop and field studies undertaken on EP 161 (Appendix D).

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Table 4-7 Likelihood assessment for listed migratory species

Species Name	Scientific Name	Likelihood of occurrence	Comments
Birds			
Fork-tailed Swift	*Apus pacificus*	Medium	The species is almost exclusively aerial and mostly occurs over dry or open habitats, including riparian woodland and tea-tree swamps, low scrub, heathland or saltmarsh (Ecoz 2017). Given the broad distribution and wide ranging nature of the species it is likely to be present within or over the Project Area (Ecoz 2017) depending on climatic conditions.
Red-rumped Swallow	*Cecropis daurica*	Low	The species is vagrant to Australia and the woodland vegetation of the Project Area is unlikely to provide suitable foraging habitat for the species, which forages over wetlands (Ecoz 2017).
Oriental Cuckoo	*Cuculus optatus*	Low	Although the Project Area is within the distribution of this species, the open woodland vegetation and creek line vegetation within the Project Area does not provide suitable habitat for this species (Ecoz 2017).
Barn Swallow	*Hirundo rustica*	Low	The Barn Swallow is found foraging above open vegetated areas including farmland, sports grounds, native grasslands and airstrips as well as over open water such as billabongs, lagoons, creeks and sewage treatment plants (Ecoz 2017). The species is vagrant to the region and has not been found within 200 km of the Project Area (Ecoz 2017) and is therefore unlikely to occur.
Grey Wagtail	*Motacilla cinerea*	Low	The species is a vagrant visitor to Australia and there is only one record from the Roper River, over 150 km from the Project Area. Although the Project Area is south of the known distribution of the species in Australia, the creek areas within the Project Area may provide limited suitable habitat for the species (Ecoz 2017) although given this species is a vagrant visitor, it is unlikely to occur.
Yellow Wagtail	*Motacilla flava*	Low	The vegetation of the Project Area is provides limited suitable open areas for foraging of this species and the Project Area is also south of the known distribution of the species in Australia (Ecoz 2017), indicating the unlikely presence of this species within the Project Area.
Common Sandpiper	*Actitis hypoleucos*	Low	Widespread across coastal regions of the Top End of the Northern Territory, and widespread but scattered inland, mostly north of Tennant Creek (DoE 2017b). If occasionally present, in low numbers only.

Species Name	Scientific Name	Likelihood of occurrence	Comments
Sharp-tailed Sandpiper	*Calidris acuminate*	Low	The species prefers muddy edges of shallow wetlands, with inundated low vegetation (DoE 2017c), therefore the Project Area does not provide suitable habitat
Curlew Sandpiper	*Calidris ferruginea*	Low	The habitat of this species is coastal and estuarine with tidal mudflats and is rarely found inland (Ecoz 2017), therefore unlikely to occur within the Project Area.
Pectoral Sandpiper	*Calidris melanotos*	Low	The species is found in shallow fresh waters, often with low grass or other herbage, flooded pastures, sewage ponds, occasionally tidal areas, saltmarshes. (Ecoz 2017). Given the preference for wetland areas, there is little suitable habitat within the Project Area for this species (Ecoz 2017).
Oriental Pratincole	*Glareola maldivarum*	Low	Oriental Plover is a non-breeding visitor to Australia, where the species occurs in both coastal and inland areas, mostly in northern Australia. It is found on black soil plains in the Northern Territory and Queensland (DoE, 2017d). The Project Area is within the species range and the grasslands (and black soil plains) within the Project Area represent suitable habitat (Ecoz 2017).
Osprey	*Pandion haliaetus*	Low	The Osprey is found primarily along coastal areas of mainland Australia, and inland along major waterways. Due to the lack of a permanent supply of water, the Project Area represents unsuitable habitat for this species. (DENR, 2018)
Painted Snipe	*Rostratula australis*	Low	This species is found in the fringes of permanent and temporary wetlands, swamps and inundated grasslands (Taylor et al. 2013) and is nomadic and scattered across Australia with no predictable occurrence (Rogers 2001). The closest known occurrence is approximately 50 km north-east of the Project Area and the inundated grassland may provide seasonally suitable habitat (Ecoz 2018a).
Reptiles			
Freshwater crocodile	*Crocodylus johnstoni*	Low	The Freshwater Crocodile preferred habitat is in wetland environments upstream from the coast. (DENR, 2018). Ecoz (2017) recorded a number of freshwater crocodiles at Rocky Hole, which is a permanent water hole used for pastoral operations however, it is unlikely that permanent waters exist in the Project Area based on aerial imagery and field survey (Ecoz 2017).

4.2.5 Pest Species and Weeds

Weeds and animal pest species can cause varying degrees of damage to the environment and land management on pastoral lands. The Weeds of National Significance (WoNS) list is compiled by the federal government and provides a national standard for ranking the impact of individual pest weed species. The *Weeds Management Act 2013* (Weeds Act) is the relevant law in the NT which describes the procedures involved with weed control. Under the Weeds Act, weeds can be declared as:

- Class A – To be eradicated
- Class B – Growth and spread to be controlled
- Class C – Not to be introduced into the NT (All declared weeds are automatically a class C weed)

The PMST Report (2018) (Appendix B) identified two species potentially occurring within 10 km of the Project Area:

- Prickly Acacia (*Acacia nilotica* subsp.) which is declared Class A in the NT and a WoNS
- Buffel-grass (*Cenchrus ciliaris*) which is not a declared weed in the NT or a WONS

EcOz undertook a baseline survey for weeds within the Project Area in August and November 2018 during preparation of the Weed Management Plan (EcOz 2019) (Appendix E). No Weeds of National Significance were found within the area. Declared weeds observed in and around the Project Area are listed below in Table 4-8.

Table 4-8 Declared Weeds

Species	NT Declared Class	Weed of National Significance (WoNS)
Hyptis (*Hyptis suaveolens*)	B/C	No
Rubber Bush *(Calotropis procera*)*	B/C	No
Spinyhead sida (*Sida acuta)*	B/C	No
Sicklepod (*Senna obtusifolia*)	B/C	No

Other species of concern that have the potential to become established in the Project Area are outlined below in Table 4-9.

Table 4-9: Weeds with a potential to become established

	Common name	Scientific name	NT Class	WoNS
Katherine region priority weeds	Mesquite	*Prosopis* spp.	A/C	Y
	Prickly acacia	*Vachellia nilotica*	A/C	Y
	Parkinsonia	*Parkinsonia aculeate*	B/C	Y
	Chinee Apple	*Ziziphus Mauritania*	A/C	
	Mimosa	*Mimosa pigra*	A/C	Y
	Bellyache bush	*Jatropha gossypiifolia*	A/C	Y
	Gamba grass	*Andropogon gyanus*	A/C	Y

	Common name	Scientific name	NT Class	WoNS
	Neem	*Azadirachta indica*	B/C	
	Grader grass	*Themeda quadrivalvis*	B/C	Y
	Snake weed	*Stachytarpheta spp.*	B/C	
	Devils claw	*Martynia annua*	A/C	
Other declared weeds	Parthenium	*Parthenium hysterophorus*	A/C	Y
	Starburr	*Acanthospermum hispidum*	B/C	
	Mossman River grass	*Cenchrus achinatus*	B/C	
	Spiny-head sida	*Sida acuta*	B/C	
	Flannel weed	*Sida cordifolia*	B/C	
	Paddy's Lucerne	*Sida rhombifolia*	B/C	
	Caltrop	*Tribulus terrestris*	B/C	
	Noogoora Burr	*Xanthium strumarium*	B/C	
	Khaki weed	*Alternanthera pungens*	B/C	

Weed distribution is often related to environmental disturbances caused by the construction of roads and tracks, cattle grazing and feral animals. Weeds are most prevalent on land under pastoral lease, with infestations generally concentrated around infrastructure such as water points, fence lines and tracks, and along the banks of watercourses where cattle and feral animals tend to congregate.

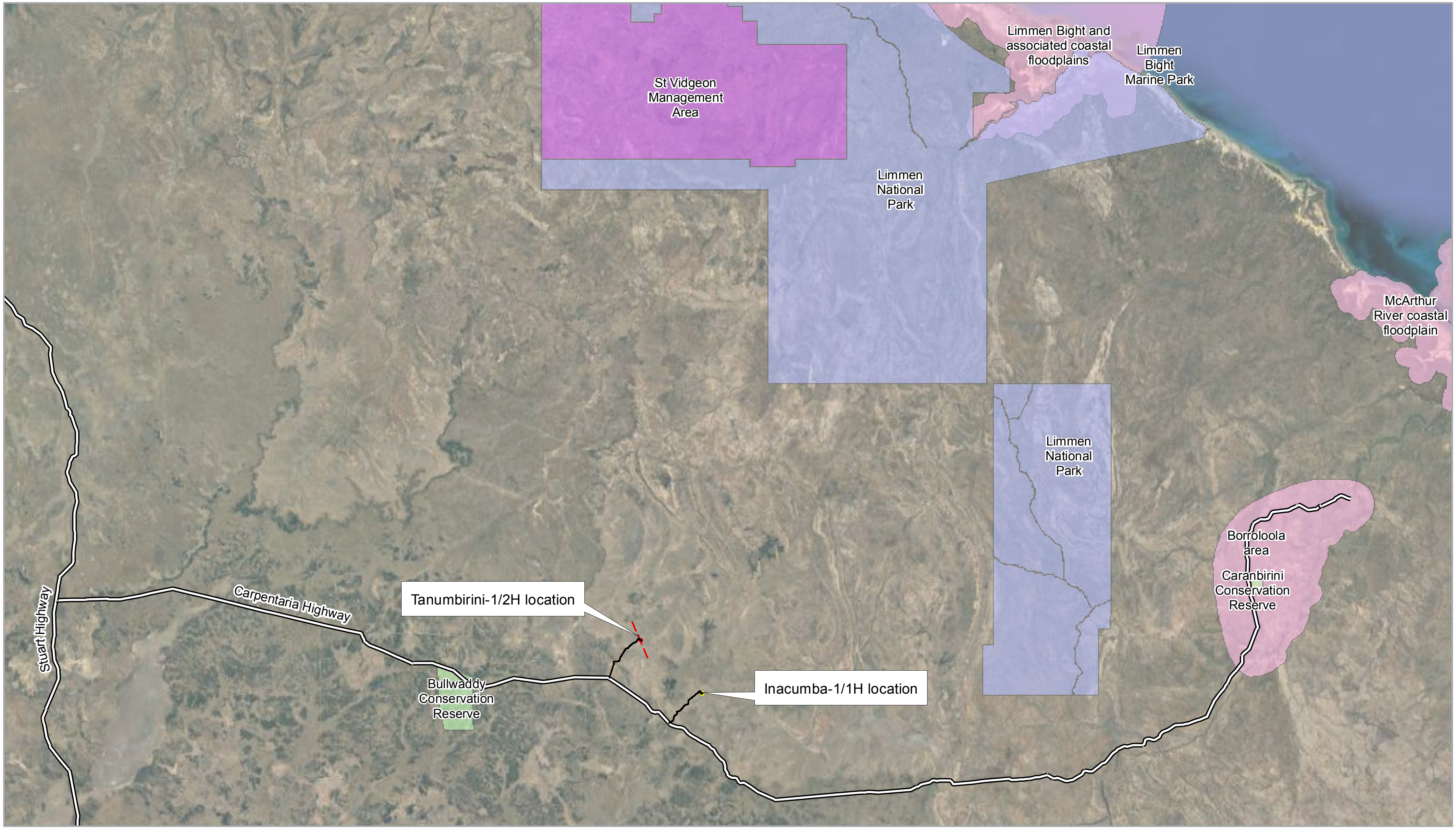
Nine prohibited fauna species were also identified in the PMST report (DoEE 2018) as likely occurring within 10 km of the Project Area (refer Appendix B, C and D). Pest animals identified in the Project Area include cane toads, cattle, sparrows, buffaloes, dogs, donkeys, cats, horses and pigs.

4.2.6 Protected Areas

There are no National Parks or conservation areas or Sites of Conservation significance near the Project Area. (Figure 4-17).

The Bullwaddy Conservation Reserve (NTP 5680) is approximately 40 km southwest of the project area (the area where the activities are occurring) (NTG 2009), and in a different catchment. In addition, there is approximately 18km between Bullwaddy Conservation Reserve (NTP 5680) and the edge of the Exploration Permit (EP) 161. Between EP 161 and Bullwaddy Conservation Reserve is another tenement (EP 76). The reserve is a declared conservation area within the Sturt Plateau bioregion, conserving Acacia woodlands and the unique *Acacia shirleyi* (Lancewood) / *Macropteranthes kekwickii* (bullwaddy) vegetation type.

The Limmen National Park (NTP 1334) is located approximately 80 km downstream of the Project Area (the area where the activities are occurring). It is adjacent to the Limmen Bight and associated coastal floodplains, which is a Site of Conservation Significance. The site is dominated by huge coastal mudflats, which are some of the most extensive in the NT, and mangrove forests associated with the mouth of the Roper River and the large coastal delta system at the mouth of the Limmen River (DNRETAS, 2009))



Legend

- 2D Seismic Line
- Existing Access Road
- Proposed Access Road
- Principal Road
- Inacumba Lease
- Tanumbirini Lease
- Sites of Conservation Siginificance
- Conservation Reserve
- Management Area
- National Park

1:1,125,000 @ A4

0 10 20 30 40

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

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Revision No. **B**
Date **11/04/2019**

Protected and Conservation Areas

FIGURE 4-17

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Print date: 11 Apr 2019 - 10:42

Data source: Google Earth: imagery (Jun 2016, captured Mar 2017 . GA: Roads, Waterways (2015) Santos: Proposed Access Roads, Existing Access Roads, Inacumba and Tanumbirini Lease Pads, (2019) Created by: cmacgregor

4.2.7 Significant vegetation

Significant or sensitive vegetation communities are described in the NT Land Clearing Guidelines (NRETAS 2010). They are vegetation communities that are distinct and limited in extent or support important ecological values and include vine thicket, closed forest or riparian vegetation, mangroves, monsoon vines forest, sand-sheet heath and vegetation containing large trees with hollows suitable for fauna.

Riparian vegetation occurs along freshwater waterways (ephemeral or permanent). It covers a relatively small land area and provides unique habitat features and dry season refuge for a range of native fauna species (DENR 2018). In these areas, maintaining bank stability to reduce erosion is important. An ecological assessment report of the ecological survey work conducted on Tanumbirini Station between 2017 and 2019, including the mapping of significant riparian vegetation is provided in Appendix D.

Riparian vegetation has been observed along the drainage lines adjacent to the Project Area. Ecoz (Appendix D) found that riparian vegetation forms a distinct community along the edge of the drainage lines in the vicinity of the proposed Inacumba 1/1H wells. Ecoz (Appendix D) also surveyed around the Tanumbirini 1/2H wells and found that although the vegetation along the watercourse comprised primarily a narrow strip of sparse *Eucalyptus camaldulensis.* This vegetation is located away from the Tanumbirini 1/2H wells.

4.2.8 Groundwater Dependent Ecosystems

A search of the National Groundwater Dependent ecosystems (GDE) Atlas (BoM 2018b) was conducted on 25 January 2018. The dataset expresses the potential for groundwater interaction/use for river/spring/wetland ecosystems across Australia. It shows the ecosystems that rely on groundwater that has been discharged to the surface, such as baseflow or spring flow.

There are no terrestrial or aquatic GDEs identified within the Project Area (BoM 2018b). The riparian vegetation communities present along the watercourse, particularly those dominated by *Eucalyptus camaldulensis* may rely on rainfall stored in alluvial sediments and therefore may be groundwater dependant.

4.2.9 Fire

Aboriginal people have traditionally used fire as a tool during hunting and gathering. Patch burning shortly after the end of the rainy season has shaped vegetation and faunal patterns across central Australia. The advent of pastoralism brought new approaches regarding fire use resulting in fewer but larger fires initiated later in the dry season.

Fire management or controlled burns within the region are a common occurrence. Controlled burns are undertaken early in the dry season to reduce the possibility of uncontrolled fires and to assist in land management.

The peak fire danger season for the region is during the late dry season. At this time, high fuel loads and dry windy conditions fuel potentially very large bushfires. Periods of increased temperature and reduced rainfall and humidity due to climatic cycles such as El Niño can exacerbate these conditions.

Bullwaddy vegetation communities are very sensitive to frequent and intensive fires (PWCNT 2005). Late season fires also impact pastoralism because the heat of these large wildfires kills the understorey grass species that stock rely on during the lean times before the wet season rains. The NT NRM Report (Appendix C) indicates fire frequency in the immediate vicinity of the Project Area is very low at three or less between 2000 and 2017. Historically, fire around the Tanumbirini Station has not occurred however, increases in frequency to the east, south and west (NTG 2018a). Fire management is discussed in the Fire Management Plan provided in Section 7.2.

4.3 Cultural environment

4.3.1 Historic and Natural Heritage

A search of the PMST database (DoEE 2018) showed no World Heritage Properties or National Heritage Places are registered within 10 km of the Project Area

In addition, a search of the NT Heritage Register (Department of Tourism and Culture 2018) for NT Portion 701 was conducted and no recorded NT heritage items or places are present in the Project Area.

An independent archaeologist was contracted by Santos to undertake a survey of the Project Area to determine the presence of archaeological artefacts or sites of significance within the Project Area. The key finding of the consultant report is that there are no sites of archaeological or heritage significance that will be impacted by the hydraulic fracturing Program.

4.3.2 Northern Land Council

Santos has an executed Exploration Agreement in place with the Northern Land Council (NLC) which has defined processes for community consultation, sacred site surveying, and reporting to AAPA. Community consultations and sacred site avoidance surveys of EP 161 work program areas were completed by NLC and Traditional Owners in 2013, 2014, and 2016 for different proposed work programs (respectively 2D seismic surveying, exploration drilling, and water bore drilling). Any sacred sites or restricted work areas have been identified by these processes; relevant information and conditions are then communicated to Santos as conditions on any granted Authority Certificate from AAPA. The NLC consulted Traditional Owners in relation to the proposed Hydraulic Fracturing Program in early March 2019 (in addition to other relevant work program activity covered under other EMPs), and also facilitated consultation directly with Santos.

4.3.3 AAPA

Areas of significance for sacred sites as defined by the NT Sacred Sites Act, is considered through the process of securing an Authority Certificate from Aboriginal Areas Protection Authority (AAPA). This process aims to prevent damage to, and interference with sacred sites, by identifying and setting out the conditions for entering and working on the land.

In 2014, the Authority issued Authority Certificate C2014/053, indemnifying Santos for the construction of up to three wells and the associated facilities, plus Vertical Source Profiling (VSP) seismic activities within the three areas cleared (including the locations of Tanumbirini-1/2H and Inacumba-1/1H). During a meeting on 1 April 2019 between Santos and the Authority, it was recommended that the proponent seek a variation for C2014/053 to address additional planned works as part of its 2019 work program. Additional works included works associated with hydraulic fracturing. Certificate 2019/043 was subsequently issued on 13 May 2019 and supersedes C2014/053.

The terms of conditions of the AAPA Authority Certificates are incorporated into project planning.

4.4 Socioeconomic Environment

There is a range of current land uses within the area including conservation, tourism, oil and gas exploration and pastoral activities.

The EP-161 lease overlays two Local Government Areas; Barkly Regional Council to the south, and Roper Gulf Regional Council to the north. The Barkly Regional Council covers an area of 323,514 km^2 and has a population of approximately 7,531. The Barkly Regional Council includes the Barkly Tablelands, numerous Aboriginal land trusts and pastoral properties.

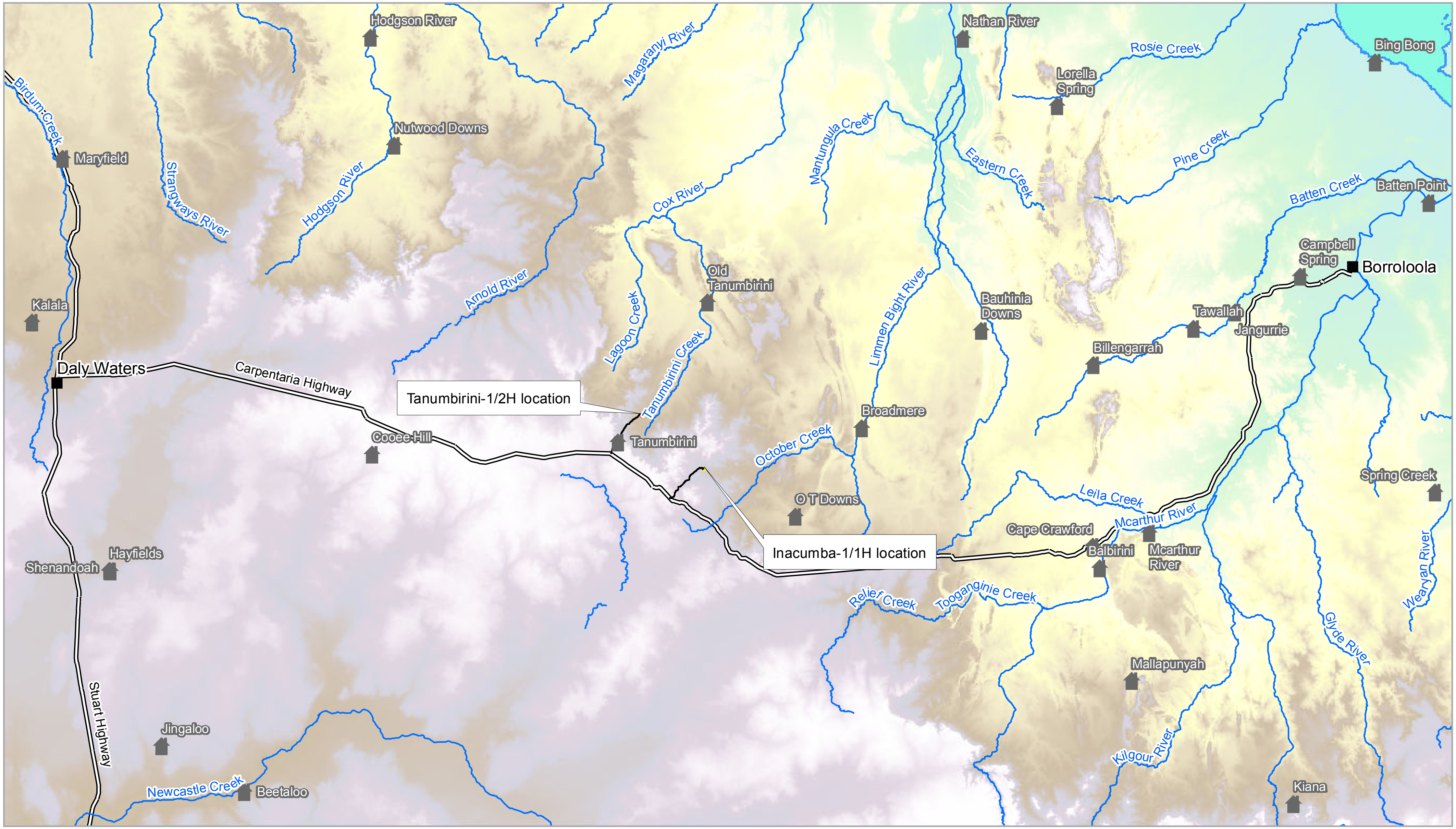
The Roper Gulf Regional Council covers an area of 186,000 km^2 and has a population of approximately 6,121. The Roper Gulf Regional Council includes 16 towns and communities of varying sizes, major roadhouses, 22 outstations and 50 pastoral properties.

The local area remains generally undeveloped in terms of infrastructure and roads. Major infrastructure within EP-161 includes the Carpentaria Highway and the Daly Waters to McArthur River gas pipeline, which run approximately parallel with one another east-west through the southern half of the tenement. The McArthur River Mine is located approximately 100 km east of the Project Area.

The Carpentaria Highway is frequented as a tourist route in the dry season, both as a route to destinations around the Gulf of Carpentaria, and as a link between the NT and Queensland.

4.4.1 Settlements

The closest towns to the Project Area are Daly Waters (approximately 130 km to the west) and Borroloola (approximately 180 km to the east). The closest significant population centre is Katherine located approximately 350 km to the north-west. Pastoral properties and towns in the vicinity of the Project Area are shown in Figure 4-18.



Legend

- Homesteads
- Towns
- Proposed Access Road
- Principal Road
- Inacumba Lease
- Tanumbirini Leases

1:1,250,000 @ A4

0 10 20 30 40

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

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GHD

Santos
McArthur Basin
Environmental Management Plan

Stations and Communities

Project No. **43-22812**
Revision No. **A**
Date **2/04/2019**

FIGURE 4-18

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Print date: 02 Apr 2019 - 16:15

Data source: Google Earth: imagery (Jun 2016, captured Mar 2017 . GA: Roads, Waterways (2015) Santos: Proposed Access Roads, Existing Access Roads, Inacumba and Tanumbirini Lease Pads, (2019) Created by: cmacgregor

4.5 Environmental Values as defined under the Environmental Assessment Act

Although the existing environment and the sensitive environmental values are discussed in detail above, sections 4.1 to 4.4 discusses the Environmental Values as defined under the Environmental Assessment Act and whether they may be affected by the proposed project.

In the existing environment, there can be particular environmental values and sensitivities that should be considered - in particular, the potential for a significant impact on an Environmental Value is the key consideration on whether a proposed activity will require further assessment under the Environmental Assessment Act. The Environmental Factors (as described in (NT EPA 2018)) and corresponding Environmental Values for this proposed project are described in Table 4-10.

Table 4-10 Environmental Values and/or Sensitivities that may be affected by the project

Environmental Factors	Environmental Values and Sensitivities	Summary
Terrestrial Flora and Fauna	Sensitive or significant vegetation	Ecoz (2019) recorded riparian vegetation (a sensitive vegetation type) along the one of the drainage lines to the south of the Inacumba 1-1H location, outside of the project area
	Groundwater dependent ecosystems	There is a low potential for terrestrial GDEs and aquatic GDEs in the Project Area (BoM 2018b).
	Threatened fauna species and their habitat	The PMST and NT database searches identified 12 listed, threatened species have the potential to occur in the Project Area. Of these, the Gouldian Finch, Grey Falcon and Crested Shrike-tit have a medium likelihood of occurrence.
	Listed Migratory Species	The PMST search identified 13 EPBC listed migratory species that were potentially occurring in the Project Area. Of these, the Fork-tailed Swift had a medium likelihood of occurrence.
	Listed threatened flora species and ecological communities	There are no Threatened Ecological Communities (TECs) or threatened flora listed under the EPBC Act and/or TPWC Act known to occur within 10 km of the Project Area.
Terrestrial Environmental Quality	Soils	The Project Area has intact soils within ephemeral creeks and drainage lines maintain the stability of water course and reduce sedimentation when rainfall events occur.
Inland water environmental quality	Groundwater	The Cambrian Limestone Aquifer is a regional scale aquifer that provides groundwater resources for pastoral enterprises, domestic bores at homesteads and town water supplies at a number of small communities across the region. The groundwater resource in this area is understood to connect to the Roper River where groundwater discharge supports aquatic, riparian and floodplain ecosystem function.
	Surface water	There are ephemeral creeks and drainage lines present in the Project Area. In significant rainfall events, these drain into larger rivers eventually in to the Gulf of Carpentaria. 80 km downstream of the Project Area the rivers traverse the Limmen Bight National Park.
Hydrological processes	Supply and quantity of water	Ephemeral creeks adjacent to the Project Areas are located in the headwaters of the Limmen Bight river catchment and feed into the Limmen Bight River during significant rainfall events

Environmental Factors	Environmental Values and Sensitivities	Summary
Social, economic and cultural surroundings	Cultural heritage, sacred sites	An application for an AAPA Authority Certificate was submitted to AAPA in January 2019 (reference 201900379). During a meeting on 1 April 2019 between Santos and the Authority, it was recommended that the proponent seek a variation for C2014/053 to address additional planned works as part of its 2019 work program. Additional works included works associated with hydraulic fracturing. Certificate 2019/043 was subsequently issued on 13 May 2019 and supersedes C2014/053. Archaeological surveying for artefacts or sites of archaeological significance was completed by an independent consultant to support this EMP (report attached in Appendix F)
Human health	People and communities	There are a number of pastoral properties with livestock and infrastructure in the vicinity of the Project Area. The nearest property is Tanumbirini Homestead, located approximately 8.5 km southwest of Tanumbirini 1/2H location.

5.0 Overview of the Environmental Risk Assessment Process

The Regulations operate around the concepts of environmental risks and environmental impacts. Environmental risk is defined as “*the chance of something happening that will have an environmental impact, measured in terms of the environmental consequences and the likelihood of those consequences occurring*”. Environmental impact is defined as “*any adverse change, or potential adverse change, to the environment resulting wholly or partly from a regulated activity*”.

It is acknowledged that environmental risks are inherent in some onshore oil and gas activities, and without control, environmental impacts may arise. As such, the Regulations require detailed assessment, reduction and control of these environmental risks and impacts through the development and implementation of the EMP for the project. This section provides an overview of the environmental risk assessment process.

5.1 Process Overview

The planned and potential interactions between the described activity, the aspects triggered and the described environment represent a source of risk (or impact) which has potential to result in a change to the environment.

An Environmental Risk Assessment (ERA) involves assessment of the likelihood and consequence of these impacts. An EMP must demonstrate that the environmental impacts and environmental risks will be reduced to a level that is ALARP and acceptable.

ALARP essentially involves making a judgement about whether all reasonably practicable measures are in place to control a potential risk or impact considering the level of consequence and cost, time and resources involved to mitigate it.

To determine whether potential environmental risks and inputs are ‘acceptable’ is a matter of judgement that depends on issues such as the nature and scale of impacts and the social or economic benefits. In determining acceptability, the Regulations require consideration of the principles of ESD. In particular, demonstration that the principles of inter-generational equity and the maintenance of biological diversity and ecological processes is required.

To meet the requirements for ERA under the regulations, the principles of the risk management process of AS/NZS ISO 31000:2009 Risk management – principles and guidelines, in addition to HB 203:2006 Environmental risk management - Principles and process have been followed. The summary of this approach is:

1. Identification of environmental aspects
2. Description of the environment that may be affected
3. Identification of the particular values and sensitivities
4. Identification and evaluation of potential environmental impacts
5. Determination of the pre-treatment risk ranking
6. Control measure identification and ALARP decision
7. Determine severity of consequence
8. Determine likelihood
9. Determine residual risk ranking
10. Determination of acceptability

Section 6 Environmental Risk Assessment, details the outcomes of this process.

5.2 Identification of risk events

Santos considered the activities that would be undertaken and identified the potential risk event and associated impact and defined the source of the impact.

5.3 Identification of the Environment that may be affected

Following the identification of potential risk events, the likely extent of each impact is considered and the environment which may be affected determined. The environment which may be affected is categorised by the EPA Factors (NT 2018) described within section 4.5.

5.4 Identification of Particular Values and Sensitivities

Based on Santos' and publicly available information, including field work at both locations, a review of the existing environment (Section 4.0) was undertaken to identify the environmental values and / or sensitivities with the potential to occur within the Project Area. Table 4-10 provides a summary of these values and sensitivities, which were used to inform the risk assessment as they provide the potential worst-case consequence.

5.5 Identification and Evaluation of Potential Environmental Impacts

The known and potential impacts of environmental aspects to the identified environmental receptors were identified. These were evaluated and specifically considered:

- Receptor sensitivity to identified aspect
- Extent and duration of the potential impact.

5.6 Pre-treatment Risk Ranking

Risk is expressed in terms of a combination of the consequence of an impact and the likelihood of the impact occurring (see sections 5.8 and 5.9).

A pre-treatment risk ranking is identified to assist with the determination of the level of controls required to reduce the risk or impact.

5.7 Control Measure Identification and ALARP Decision Framework

Based on the identified impacts, and the ranking of their pre-treatment risk, control measures were identified in accordance with the defined environmental performance outcomes, to eliminate, prevent, reduce or mitigate consequences associated with each of the identified environmental impacts. Control measures were identified through previous surveys, in workshops and through review of best practice techniques across the industry. When determining whether the risk or impact has been reduced to ALARP, it must be asked whether environmental risks can be lowered further without a grossly disproportionate increase in impost.

Santos' approach to this decision is based on the Oil and Gas UK's 'Guidance on Risk Related Decision Making' (Table 5-1). This framework considers impact severity and several guiding factors to achieve ALARP risk demonstration:

- Activity type
- Risk and uncertainty
- Stakeholder influence.

This framework provides appropriate tools, commensurate to the level of uncertainty or novelty associated with the impact or risk (referred to as the Decision Type A, B or C). Decision types and methodologies to establish ALARP are outlined in Figure 5-1.

Table 5-1 ALARP Decision Making based upon Level of Uncertainty

Decision Type	Description	Decision Making Tools
A	Risks classified as a Decision Type A are well-understood and established practice	Good Practice Control Measures are considered to be: Legislation, codes and standards: Identifies the requirements of legislation, codes and standards that are to be complied with for the activity. Good Industry Practice: Identifies further engineering control standards and guidelines that may be applied over and above that required to meet the legislation, codes and standards. Professional Judgement: Uses relevant personnel with the knowledge and experience to identify alternative controls. When formulating control measures for each environmental impact or risk, the 'Hierarchy of Controls' philosophy, which is a system used in the industry to identify effective controls to minimise or eliminate exposure to impacts or risks, is applied.
B	Risks classified as a Decision Type B are typically in areas of increased environmental sensitivity with some stakeholder concerns.	Risk-based tools, such as cost based analysis or modelling: this assesses the results of probabilistic analyses such as modelling, quantitative risk assessment and/or cost benefit analysis to support the selection of control measures identified during the risk assessment process.
C	Risks classified as a Decision Type C will typically involve sufficient complexity, high potential impact, uncertainty or stakeholder interest	Precautionary Approach: OGUK (2014) state that if the assessment, taking account of all available engineering and scientific evidence, is insufficient, inconclusive or uncertain, then a precautionary approach to hazard management is needed. A precautionary approach will mean that uncertain analysis is replaced by conservative assumptions that will result in control measures being more likely to be implemented.

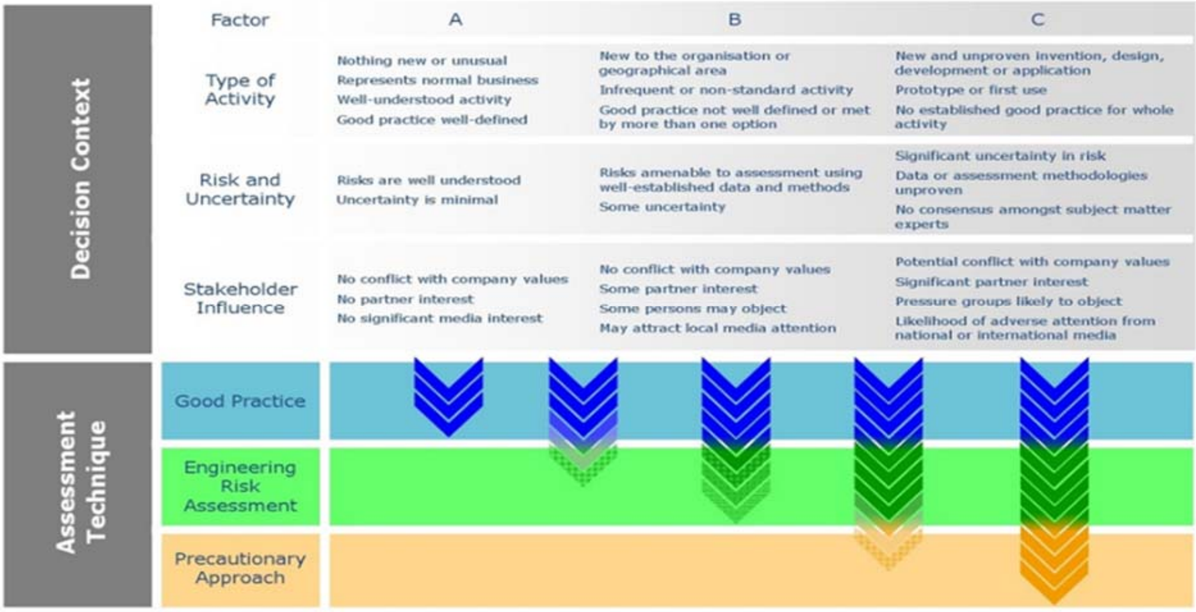

Figure 5-1 Impact and Risk 'Uncertainty" Decision-Making Framework

5.8 Determination of Severity of Consequence

The potential level of impact (consequence) was assessed and assigned in line with potential hazards and receptors, using the 'Santos Environmental Consequence Classification' (Table 5-2) from the Santos Operational Risk Matrix. The consequence level for each hazard is documented in the risk assessment tables in Section 6.0.

Table 5-2 Santos Environmental Consequence Classification

Level	Environment
VI	Regional and long-term impact on an area of significant environmental value. Destruction of an important population of plants and animals with recognised conservation value. Complete remediation impossible.
V	Destruction of an important population of plants or animals or of an area of significant environmental value. Complete remediation not practical or possible.
IV	Extensive and medium term or localised and long-term impact to an area, plants or animals of recognised environmental value. Remediation possible but may be difficult or expensive.
III	Localised and medium term or extensive and short-term impact to areas, plants or animals of significant environmental value. Remediation may be difficult or expensive.
II	Localised and short-term impact to an area, plants or animals of environmental value. Readily treated.
I	Localised and short term environmental or community impact – readily dealt with.

Definitions	
Duration of potential impact	Extent of impact
Short term: Days or weeks	**Localised**: Within the Project Area
Medium Term: Less than 12 months	**Extensive**: Within the permit area
Long Term: Greater than 12 months	**Regional**: Outside of the permit area

5.9 Determination of Likelihood

Likelihood relates to the potential for a consequence to occur. This includes the likelihood of an event occurring and the subsequent potential consequence. This is defined using the Santos Likelihood Descriptors (Table 5-3) from the Santos Operational Risk Matrix.

Table 5-3 Santos Risk Matrix

Level		Criteria
Almost Certain	f	Occurs in almost all circumstances or could occur within days to weeks
Likely	e	Occurs in most circumstances or could occur within weeks to months
Occasional	d	Has occurred before in Santos or could occur within months to years
Possible	c	Has occurred before in the industry or could occur within the next few years
Unlikely	b	Has occurred elsewhere or could occur within decades
Remote	a	Requires exceptional circumstances and is unlikely even in the long term or only occurs as a '100 year event'

5.10 Residual Risk Ranking

Risk is expressed in terms of a combination of the consequence of an impact and the likelihood of the impact occurring. Santos uses a Corporate Risk Matrix (Table 5-4) to plot the consequence and likelihood to determine the level of risk.

Once the level of risk is determined Santos uses a Risk Significance Rating (Table 5-5) to determine the magnitude of the risk and if further action is required to reduce the level of risk using the process described in section 5.10.

Table 5-4 Santos Risk Matrix

	I	II	III	IV	V	VI
f	2	3	4	5	5	5
e	2	3	4	4	5	5
d	2	2	3	4	4	5
c	1	2	2	3	4	5
b	1	1	2	2	3	4
a	1	1	1	2	3	3

Table 5-5 Santos Risk Significance Rating

Risk Level	Mitigation/Investigation Focus (Add additional Business Unit specific requirements where required)
5	Intolerable risk level Following verification of the residual risk at level 5, activity must stop Activity cannot recommence until controls implemented to reduce the residual risk to level 4 or lower Detailed multi-disciplinary incident investigation team Management involvement in the investigation
4	Assess risk to determine ALARP If ALARP, activities related to maintenance of controls/barriers prioritised and managed If not ALARP, improve existing controls and/or implement new controls Detailed multi-disciplinary incident investigation team
3	Assess risk to determine ALARP If ALARP, activities related to maintenance of controls/barriers prioritised and managed If not ALARP, improve existing controls and/or implement new controls Full incident investigations
2	Assess risk to determine ALARP If ALARP, activities related to maintenance of controls/barriers prioritised and managed If not ALARP, improve existing controls and/or implement new controls Incident investigations using simple tools
1	Managed as stipulated by the related work processes No incident investigation required

5.11 Determination of Impact and Risk Acceptability

The model Santos used for determining acceptance of residual risk is detailed in the Santos Residual Risk Acceptance Model in Figure 5-2. In summary:

- A Level 5 residual risk is intolerable and must not be accepted or approved by Management
- A Level 2 – 4 residual risk is acceptable provided that ALARP has been achieved and demonstrated
- A level 1 residual risk is acceptable and it is assumed that ALARP has been achieved

In addition to the requirements detailed above, for the purposes of petroleum activities, impacts and risk to the environment are considered broadly acceptable if:

- The residual risk is determined to be 1 (and ALARP Decision Type A selected and good practice control measures applied), or

- The residual risk is determined between 2 and 4 and ALARP can be demonstrated; and
- The following have been met:
  - Principles of ecologically sustainable development
  - Legal and other requirements
  - Santos policies and standards
  - Stakeholder expectations

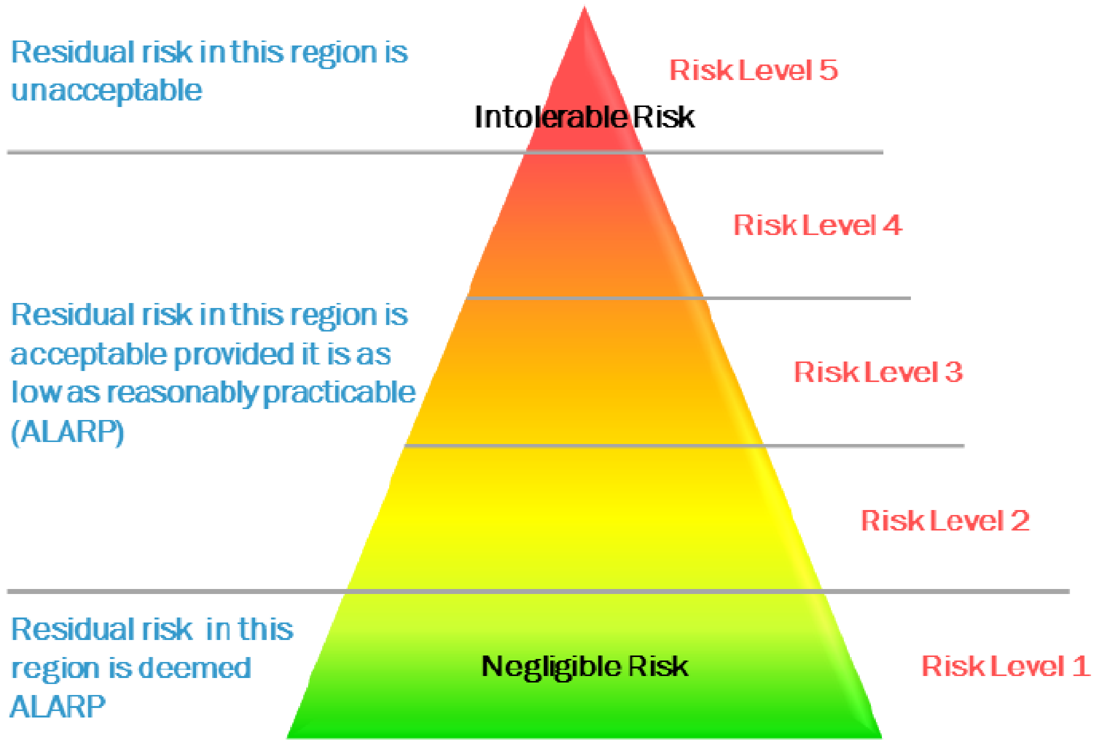

Figure 5-2 Santos Residual Risk Acceptance Model

5.11.1 Risk Determination and the Code

The purpose of the Code is to ensure that petroleum activities are managed according to minimum acceptable standards to ensure that risks are managed to a level that is ALARP and acceptable. The Code of practice is mandatory and will be implemented during all stages of this activity.

The Code identifies industry standards, good and acceptable industry practice and mandatory requirements for the conduct of petroleum activities and will ensure on compliance with their obligations under Northern Territory's petroleum legislation.

6.0 Environmental Risk Assessment

An environmental risk assessment was undertaken for the proposed activities using the methodology outlined in section 5.0 and the results are reported in Table 6-1.

Table 6-1 Risk Assessment for proposed activities

Risk Event	Potential Impact	Relevant Environmental Factor	Risk Source	Initial Risk Ranking*			Mitigation and Management Measures		Residual Risk Ranking*			Effective Controls	Uncertainty Ranking
				L	C	R	EMP Commitments	Relevant Code of Practice	L	C	R		
Physical disturbance including vehicle and plant movements	Disturbance to soil	Terrestrial environmental quality	Vehicles leave the previously constructed roads or work areas	F	I	2	Driving is only permitted on designated access	A.3.1 Site Selection and Planning A.3.4 Erosion and sediment control	C	I	1	Yes	Type A Risk – Risks are well-understood with established management practices (e.g. Land Clearing Guidelines and the ESCP)
Physical disturbance including vehicle and plant movements	Disturbance to Aboriginal archaeological sites	Social, economic and cultural surroundings	Vehicles leave the previously constructed roads or work areas	B	II	1	Archaeological surveys completed by independent consultant(s) prior to activity commencement. Results indicate that no Aboriginal archaeological or historical sites/relics will be encountered or impacted by proposed activities in this portion of EP161 Driving is only permitted on designated access	A.3.1 Site Selection and Planning	A	I	1	Yes	Type A Risk – Risks are well-understood heritage survey complete with avoidance measures in place
Groundwater extraction	Reduction in groundwater quantity	Hydrological processes	Use of groundwater for project activities	B	II	1	Valid water extraction licence in place prior to extraction Compliance with water extraction licence limits and conditions Ensure groundwater extraction is limited to the volumes required by the hydraulic fracture program (See water use estimates in Section 3.10). Bore numbers and estimated extraction volumes will be provided to DPIR and DENR.	A.3.1 Site Selection and Planning B.4.17 Groundwater monitoring	A	II	1	Yes	Type A Risk – Risks are well-understood. The regional understanding of the CLA is sufficient to understand the risks. Groundwater Monitoring has been undertaken and will continue.
Groundwater extraction	Reduction in groundwater available for other users	Social, economic and cultural surroundings	Use of groundwater for project activities	B	IV	2	Valid water extraction licence in place prior to extraction Compliance with water extraction licence limits and conditions Ensure groundwater extraction is limited to the volumes required by the hydraulic fracture program (See water use estimates in Section 3.10). Bore numbers and estimated extraction volumes will be provided to DPIR and DENR.	B.4.17 Groundwater monitoring	A	III	1	Yes	Type A Risk – Risks are well-understood. The regional understanding of the CLA is sufficient to understand the risks. Groundwater Monitoring has been undertaken and will continue.
Creation of dust	Smothering of flora	Terrestrial flora and fauna	Vehicle and plant movements	F	II	3	Driving is only permitted on designated access roads. Speeds on unsealed roads will be limited to a maximum of 60 km/hr. Water trucks will be used, to manage dust emissions from vehicle movement associated with hydraulic fracture activities as appropriate.	A.3.1 Site Selection and Planning A.3.5 Biodiversity protection	B	I	1	Yes	Type A Risk – Risks are well-understood with established and proven management practices.
Creation of dust	Loss of amenity	Social, economic and cultural surroundings	Vehicle and plant movements	F	I	2	Driving is only permitted on designated access roads. Speeds on unsealed roads will be limited to a maximum of 60 km/hr. Water trucks will be used, to manage dust emissions from vehicle movement associated with hydraulic fracture activities as appropriate.	A.3.1 Site Selection and Planning A.3.4 Erosion and sediment control	A	I	1	Yes	Type A Risk – Risks are well-understood with established and proven management practices.
Creation of dust	Public ingesting dust	Human health	Vehicle and plant movements	D	II	2	Driving is only permitted on designated access. Speeds on unsealed roads will be limited to a maximum of 60 km/hr. Water trucks will be used, to manage dust emissions from vehicle movement and hydraulic fracture activities as appropriate.	A.3.1 Site Selection and Planning A.3.4 Erosion and sediment control	B	I	1	Yes	Type A Risk – Risks are well-understood with established and proven management practices.

Risk Event	Potential Impact	Relevant Environmental Factor	Risk Source	Initial Risk Ranking*			Mitigation and Management Measures		Residual Risk Ranking*			Effective Controls	Uncertainty Ranking
				L	C	R	EMP Commitments	Relevant Code of Practice	L	C	R		
Creation of atmospheric emissions	Reduction in air quality	Air quality and greenhouse gas	Vehicle and plant movements	C	II	2	Vehicles and fixed plant maintained as per maintenance schedule.	A.3.1 Site Selection and Planning	B	I	1	Yes	Type A Risk - Risks associated with diesel combustion are well known, both within Australia and Internationally. Methods for estimating emissions are available via the National Pollutant Inventory and NGERS.
Creation of atmospheric emissions	Reduction in air quality	Air quality and greenhouse gas	Fugitive emissions	C	II	2	Wells to be constructed with cement isolation All cement slurries to be laboratory tested for ensure slurry is fit for purpose. Cement placement modelling conducted prior to the job including but not limited to casing standoff, drilling fluid displacement, anticipated job pressures and equivalent circulating densities A geohazard assessment was used to select the well locations to mitigating shallow gas hazards Baseline methane monitoring was completed by CSIRO prior to commencing stimulation as per the Code of Practice for Petroleum activities. Gas detection monitoring will be conducted during all phases of the hydraulic fracturing operations. All wells will be tested every six months for any leaks Emissions will be reported in accordance with the NGERS. The Methane Emissions Management Plan (Appendix J) will be implemented	A.3.1 Site selection and planning D.4.1 Baseline Methane assessment D.5.9.4 Other fugitive emissions D.5.1 Methane Emissions management Plan	B	I	1	Yes	Type A Risk - Risks and impacts associated with fugitive emissions are well known. Emissions during petroleum activities are estimated using the NGERS estimation tools.
Creation of atmospheric emissions	Reduction in air quality	Air quality and greenhouse gas	Production Testing flaring	F	II	3	Gas detection monitoring will be conducted during all phases of the flowback and production testing operations. All flaring will be measured using flow meters compliant with NGERS. Emissions will be reported in accordance with the NGERS. Flaring will be used rather than venting The Methane Emissions Management Plan (Appendix J) will be implemented	D.5.9 Venting and Flaring D.4.1 Baseline Methane assessment D.4.3 Routine periodic atmospheric monitoring programme D.5.1 Methane Emissions management Plan	E	1	2	Yes	Type A Risk - Risks and impacts associated with flaring activities are well understood and proven management practices are established.
Noise and vibration from project activities	Disturbance to native fauna	Terrestrial flora and fauna	Vehicle movements and hydraulic fracture activities	D	II	2	Engines/Machinery will be maintained as per planned maintenance systems. Engines/machinery will have noise suppression devices.	A.3.1 Site selection and planning A.3.3 Noise	C	I	1	Yes	Type A Risk – Risks are well-understood with established and proven management practices.
Noise and vibration from project activities	Disturbance to landholders	Social, economic and cultural surroundings	Vehicle movements and hydraulic fracture activities	D	II	2	Engines/Machinery will be maintained as per planned maintenance systems. Engines/machinery will have noise suppression devices. Wells are located >8km from the Tanumbirini homestead. Hydraulic fracturing activity and majority of vehicle movements will be limited to daylight hours.	A.3.1 Site selection and planning A.3.3 Noise	B	I	1	Yes	Type A Risk – Risks are well-understood with established and proven management practices. Land access agreements are in place and stakeholder engagement is ongoing.

Risk Event	Potential Impact	Relevant Environmental Factor	Risk Source	Initial Risk Ranking*			Mitigation and Management Measures		Residual Risk Ranking*			Effective Controls	Uncertainty Ranking
				L	C	R	EMP Commitments	Relevant Code of Practice	L	C	R		
Light from project activities	Disturbance to native fauna	Terrestrial flora and fauna	Production Testing	F	2	3	Night time operations restricted (e.g. No HFS pumping will occur at night) Lighting required for well operations (e.g. wireline, slickline, coiled tubing, and production testing) may will be limited to direct area immediately around the wellhead location. Lighting would be faced toward the wellhead and work areas to provide adequate lighting for safe operations, without excessive overspill.	D.5.9 Venting and Flaring D.4.1 Baseline Methane assessment D.4.3 Routine periodic atmospheric monitoring programme D.5.1 Emissions management Plan	C	1	1	Yes	Type A Risk – Risks are well-understood with established and proven management practices. Santos has extensive experience in managing disturbance to native fauna.
Light from project activities	Disturbance to native fauna	Terrestrial flora and fauna	Vehicle movements and hydraulic fracture activities at night Lighting from camp.	F	I	2	Task focussed lighting will be used and all boundary lighting for the camp will be positioned to face inwards to provide adequate lighting for safe operations, without excessive overspill. Hydraulic fracturing activity and majority of vehicle movements will be limited to daylight hours. Lighting required for well operations (e.g. wireline, slickline, coiled tubing, and production testing) may will be limited to direct area immediately around the wellhead location. Lighting would be faced toward the wellhead and work areas to provide adequate lighting for safe operations, without excessive overspill.	A.3.1 Site selection and planning 4.3.2 Well pad site selection requirements	B	I	1	Yes	Type A Risk – Risks are well-understood with established and proven management practices. Santos has extensive experience in managing disturbance to native fauna.
Light from project activities	Disturbance to landholders	Social, economic and cultural surroundings	Vehicle movements and hydraulic fracture activities at night, Lighting from camp.	F	I	2	Task focussed lighting will be used and all boundary lighting will be positioned to face inwards to provide adequate lighting for safe operations, without excessive overspill. Wells are located >8km from the Tanumbirini homestead.	A.3.1 Site selection and planning 4.3.2 Well pad site selection requirements	B	I	1	Yes	Type A Risk – Risks are well-understood with established and proven management practices. Land access agreements are in place.
Fauna interaction	Disturbance, injury or death to terrestrial fauna	Terrestrial flora and fauna	Vehicle movements, hydraulic fracture activities, flaring and entrapment	E	I	2	Appropriate separation distances between flares and surrounding vegetation that provides fauna habitat Fauna ladders will be installed at all open pits. Driving is only permitted on designated access roads and seismic lines. Speeds on unsealed roads will be limited, with to a maximum of 60 km/hr. All tank pads are above ground, with steep sides, to prevent ease of animal entry. When significant rainfall events are predicted wastewater will be stored in enclosed tanks. All HFS work tanks are enclosed. Daily checks of tank pads throughout the hydraulic fracturing program. Potential avian wildlife exposure to selected chemical additives and/or flowback assessed (See Appendix A)	A.3.5 Biodiversity protection A.3.8 Containment of contaminants	C	I	1	Yes	Type A Risk – Risks are well-understood with established and proven management practices (e.g. site roads are speed limited). Santos has extensive experience in managing fauna interactions and entrapment.
Fauna interaction	Disturbance, injury or death to livestock	Social, economic and cultural surroundings	Vehicle movements, hydraulic fracture activities, and entrapment.	E	I	2	Relevant landowners and occupiers are notified prior to the commencement of the activity. All gates are left in the condition in which they were found (i.e. open / closed). When necessary, all fences are restored to satisfaction of landowner / managers. Speeds on unsealed roads will be limited to a maximum of 60 km/hr. Pits and dams will be fenced. Daily checks infrastructure throughout the hydraulic fracture program	A.3.5 Biodiversity protection A.3.8 Containment of contaminants	C	I	1	Yes	Type A Risk – Risks are well-understood with established and proven management practices (e.g. site roads are speed limited).

Risk Event	Potential Impact	Relevant Environmental Factor	Risk Source	Initial Risk Ranking*			Mitigation and Management Measures		Residual Risk Ranking*			Effective Controls	Uncertainty Ranking
				L	C	R	EMP Commitments	Relevant Code of Practice	L	C	R		
Introduction of pest species	Loss of native vegetation through competition for resources	Terrestrial flora and fauna	Plant and vehicles carrying weeds from outside the project area. Spread of weeds in project area through vehicle movements.	D	III	3	A Weed Management Plan has been developed for the project (Appendix E). Mitigation measures described in the Weed Management Plan for the project will be implemented.	A.3.6 Weed management A.5.3 Biodiversity protection	B	III	2	Yes	Type A Risk – Risks are well-understood with established and proven management practices. Baseline weed survey complete and DENR approved weed management plans in place.
Introduction of pest species	Loss of pasture species through competition for resources	Social, economic and cultural surroundings	Plant and vehicles carrying weeds from outside the project area. Spread of weeds in project area through vehicle movements.	D	II	2	A Weed Management Plan has been developed for the project (Appendix E). Mitigation measures described in the Weed Management Plan for the project will be implemented.	A.3.6 Weed management	B	II	1	Yes	Type A Risk – Risks are well-understood with established and proven management practices. Baseline weed survey complete and DENR approved weed management plans in place.
Fire	Disturbance or death to terrestrial fauna, loss of terrestrial flora	Terrestrial flora and fauna	Ignition sources from plant and machinery Inappropriate disposal of cigarettes.	C	III	2	Implementation of Fire Management Plan (Section 7.2). Fire-fighting equipment and competent fire-fighting personnel will be available. All vehicles will be equipped with portable fire extinguishers. Machinery and vehicles should be parked in areas of low fire risk. Any petrol motor vehicles or petrol-powered pumps will be fitted with spark arresters. All vehicles will be equipped with operational VHF and / or UHF radio transceivers. Smoking will only be permitted in areas clear of vegetation, and there will be no disposal of butts to land. All personnel will receive information prior to the commencement of the activity relating to: • Provisions of the Emergency Response Plan including procedures during a fire emergency • The operation of firefighting equipment and communications • Restricted smoking requirements Toolbox meetings will be conducted to: • Alert the workforce of the fire risk level for the day • Discuss any fire risk management breaches and remedial actions	A.3.7 Fire management	B	II	1	Yes	Type A Risk - Risks associated with bushfire are well known, with numerous literature and NT Government mapping and management plans in place.

Risk Event	Potential Impact	Relevant Environmental Factor	Risk Source	Initial Risk Ranking*			Mitigation and Management Measures		Residual Risk Ranking*			Effective Controls	Uncertainty Ranking
				L	C	R	EMP Commitments	Relevant Code of Practice	L	C	R		
Fire	Disturbance or death to terrestrial fauna, loss of terrestrial flora	Terrestrial flora and fauna	Production testing, flaring	C	III	2	Implementation of Fire Management Plan (Section 7.2). Firebreaks to be implemented around the lease with minimum setbacks to infrastructure based on flaring design. Flares will be located with at least 30m from vegetation to ensure safe operations during fire danger periods. The fire protection zone surrounding the lease pad and flare will be devoid of trees. Flares and flare stacks must be designed, prepared and operated in accordance with industry standards: ANSI B31.3, NACE MR-01-075, API 521, API 537. All flare pits and flare stacks must be positioned as per hazardous area classification. Flaring to have an appropriate buffer, with proper barriers to prevent access by wildlife. The vertical flare stack will be monitored during flaring. Implementation of the Emergency Response Plan.	D.5.9 Venting and Flaring D.4.1 Baseline Methane assessment D.5.1 Emissions management Plan	B	II	1	Yes	Type A Risk - Risks associated with bushfire are well known, with numerous literature and NT Government mapping and management plans in place.
Fire	Injury or death to livestock, loss of pasture, dwellings and infrastructure	Social, Economic and Cultural Surroundings	Ignition sources from plant and machinery) Inappropriate disposal of cigarettes.	C	III	2	Implementation of Fire Management Plan (Section 7.2). Fire-fighting equipment and competent fire-fighting personnel will be available. All vehicles will be equipped with portable fire extinguishers. Machinery and vehicles should be parked in areas of low fire risk and be free of any combustible material. Any petrol motor vehicles or petrol-powered pumps will be fitted with spark arresters. All vehicles will be equipped with operational VHF and / or UHF radio transceivers. Smoking will only be permitted in areas clear of vegetation, and there will be proper disposal of butts. All personnel will receive information prior to the commencement of the activity relating to: • Provisions of the Emergency Response Plan including procedures during a fire emergency • The operation of firefighting equipment and communications • Restricted smoking requirements Toolbox meetings will be conducted to: • Alert the workforce of the fire risk level for the day • Discuss any fire risk management breaches and remedial actions.	A.3.7 Fire management	B	II	1	Yes	Type A Risk - Risks associated with bushfire are well known, with numerous literature and NT Government mapping and management plans in place.

Risk Event	Potential Impact	Relevant Environmental Factor	Risk Source	Initial Risk Ranking*			Mitigation and Management Measures		Residual Risk Ranking*			Effective Controls	Uncertainty Ranking
				L	C	R	EMP Commitments	Relevant Code of Practice	L	C	R		
Fire	Injury or death to livestock, loss of pasture, dwellings and infrastructure	Social, Economic and Cultural Surroundings	Production testing, flaring	C	III	2	Implementation of Fire Management Plan (Section 7.2). Firebreaks to be implemented around the lease with minimum setbacks to infrastructure based on flaring design. Flares will be located with at least 30m from vegetation to ensure safe operations during fire danger periods. The fire protection zone surrounding the lease pad and flare will be devoid of trees. Flares and flare stacks must be designed, prepared and operated in accordance with industry standards: ANSI B31.3, NACE MR-01-075, API 521, API 537. All flare pits and flare stacks must be positioned as per hazardous area classification. Flaring to have an appropriate buffer, with proper barriers to prevent access by livestock. The vertical flare stack will be monitored during flaring. Implementation of the Emergency Response Plan.	A.3.7 Fire management D.5.9 Venting and Flaring	B	II	1	Yes	Type A Risk - Risks associated with bushfire are well known, with numerous literature and NT Government mapping and management plans in place.
Disturbance to landholder/public	Disturbance to landholders activities	Social, Economic and Cultural Surroundings	Vehicle and plant movements throughout the project area	D	II	2	Relevant landowners and occupiers are notified prior to activity of preparation of camp sites and undertaking of operations. Inductions for all employees and contractors cover pastoral, conservation, legislation and infrastructure issues. System is in place for logging public/landholder complaints to ensure that issues are addressed. Damage to station tracks and fences is reported and restored to satisfaction of landowner / managers. All gates are left in the condition in which they were found (i.e. open / closed). Speeds on unsealed roads will be limited to a maximum of 60 km/hr.	A.3.1 Site selection and planning 4.3.2 Well pad site selection requirements	B	I	1	Yes	Type A Risk – Risks are well-understood with established and proven management practices. Land access agreements are in place and stakeholder engagement is ongoing.
Chemical spills and leaks associated with chemical and fuel storage and handling	Localised contamination of soil	Terrestrial Environmental Quality	Inappropriate storage or handling of hazardous substances, including stimulation fluid and flowback fluid wastewater. Poor refuelling or fuel transfer practices	D	III	3	Implementation of the Wastewater Management Plan (Appendix G). Implementation of the Spill Management Plan (Appendix H). When significant rainfall events are predicted wastewater will only be stored in enclosed tanks.. All HFS work tanks are enclosed. Bunded containment for storage of liquid hydraulic fracturing materials. Spill containment for storage of liquid hydraulic fracture chemicals Spill management kits located onsite for response to any small scale spills Use of drip trays for transfers. Any spills contained and remediated. Fuel and other lubricants will be appropriately stored and managed, in accordance with industry standards. Pre-spud checks / Pre-job checks when transferring fluids Appropriate bunding in use for storage of chemicals and where required adherence to standards Hydraulic fracture fluid system mixed into small volumes as needed, contained and monitored in engineered fluid storage tanks. A WOMP will be developed to cover well activities. The Project will not commence until a WOMP has been approved. Comprehensive spill modelling has been conducted (Attachment B, Appendix A). Chemical Risk Assessment of all chemical used in the proposed HFS (Appendix A).	A.3.8 Containment of contaminants B.4.16 Site material and fluid management C.4.2 Management of Produced water and Flowback Fluid C.7.2 Spill management plan	B	III	2	Yes	Type A Risk – Risks are well-understood with established and proven management practices. Comprehensive spill modelling completed. Santos has extensive experience in drilling conventional and unconventional petroleum wells in the NT and across Australia and this experience includes managing storage and handling of hazardous substances.

Risk Event	Potential Impact	Relevant Environmental Factor	Risk Source	Initial Risk Ranking*			Mitigation and Management Measures		Residual Risk Ranking*			Effective Controls	Uncertainty Ranking
				L	C	R	EMP Commitments	Relevant Code of Practice	L	C	R		
Chemical spills and leaks associated with chemical and fuel storage and handling	Reduction in surface and groundwater water quality	Inland Water Environmental Quality	Inappropriate storage or handling of hazardous substances, including stimulation fluid and flowback fluid wastewater. Poor refuelling or fuel transfer practices	D	III	3	Implementation of the Wastewater Management Plan (Appendix G). Implementation of the Spill Management Plan (Appendix H). When significant rainfall events are predicted wastewater will only be stored in enclosed tanks.. All HFS work tanks are enclosed. Installation of blow-out prevention equipment systems. Bunded containment for storage of hydraulic fluid. Spill containment for storage of liquid hydraulic fracture chemicals. Spill management kits located onsite for response to any small scale spills. Use of drip trays for transfers. Any spills contained and remediated. Fuel and other lubricants will be appropriately stored and managed, in accordance with industry standards. Appropriate bunding in use for storage of chemicals and flowback fluid and where required adherence to standards. Hydraulic fracture fluid system mixed into small volumes as needed, contained and monitored in engineered fluid storage tanks. There is only one mix tank used during fracturing operations, and this tank is instrumented with tank levels and constantly supervised. There are work tanks with fresh water that do not have tank levels, but have constant supervision by personnel during fracturing operations. Freeboard design of engineered storage tanks allows for ease of control of flowback fluids without risk of overfilling. Comprehensive spill modelling has been conducted (Attachment B, Appendix A). Chemical Risk Assessment of all chemical used in the proposed HFS (Appendix A).	A.3.8 Containment of contaminants B.4.16 Site material and fluid management C.3 Well site water management C.4.2 Management of Produced water and Flowback Fluid C.7.2 Spill management plan	B	II	2	Yes	Type A Risk – Risks are well-understood with established and proven management practices. Comprehensive spill modelling completed. Santos has extensive experience in drilling conventional and unconventional petroleum wells in the NT and across Australia and this experience includes managing storage and handling of hazardous substances including fuels.

Risk Event	Potential Impact	Relevant Environmental Factor	Risk Source	Initial Risk Ranking*			Mitigation and Management Measures		Residual Risk Ranking*			Effective Controls	Uncertainty Ranking
				L	C	R	EMP Commitments	Relevant Code of Practice	L	C	R		
Loss of stimulation fluid, flowback fluid recovery	Reduction in groundwater and surface water quality	Inland Water Environmental Quality	Cross-flow during hydraulic fracture stimulation, Faults or major structures enables cross-flow.	C	IV	3	Installation of blow-out prevention equipment systems. A geohazard assessment has been performed to mitigate for subsurface hazards such abnormal pressure zones, shallow gas, lost circulation and potential zones of instability. Hydraulic fracture diagnostics including chemical tracers, surface tiltmeter and micro seismic monitoring is used to determine the spatial extent and orientation of the induced fracture. Distance of target shale formation (Velkerri formation) from nearest high quality aquifer (Cambrian Limestone aquifer) is over 2000 m. Drilling of wells off-structures using seismic data for control. Wells are located away from major faults and structures based on seismic data control; further seismic data acquisition planned where "dip" and "strike" line control is not available. Ground water monitoring bores installed on location prior to hydraulic fracture operations. Baseline monitoring conducted six months prior to and post hydraulic fracture operations. Shallow aquifers isolated behind cemented concentric casing strings. Cemented casing, following the Code of Practice requirements, will prevent aquifer cross-flow once well is constructed and passes well acceptance criteria. Specifically the casing is designed to: • Maintain hole stability and withstand all planned life cycle well loading conditions without loss of well integrity • Ensure the establishment of the well barriers required at various stages of the well life. • Ensure equivalent circulating density in the next hole section does not exceed the fracture propagation pressure while maintaining the required static overbalance. • Ensure the formation strength at the previous casing shoe or at a deeper zone will not be exceeded whilst circulating out a gas influx taken from the bottom of the open hole with the anticipated fluid weight and 0.5 ppg (60 g/l) kick intensity over prognoses formation pressure. Code of Practice: Onshore Petroleum Activities (the code) will be implemented. The code includes requirements for well operations and wastewater management. Chemical Risk Assessment of all chemical used in the proposed HFS (Appendix A) A WOMP will be developed to cover well activities. The Project will not commence until a WOMP has been approved.	B.4.1 Well Integrity management B.4.2 Aquifer protection B.4.3 Well design and well barriers B.4.6 Casing and tubing B.4.7 Primary cementing B.4.9 Well control B.4.13 Hydraulic stimulation and flowback operations B.4.17 Groundwater monitoring C.4.2 Management of Produced water and Flowback Fluid C.7.2 Spill management plan	B	II	2	Yes	Type A Risk – Risks are well known and have been extensively assessed through the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report. In addition the CSIRO regional baseline monitoring program is underway and the knowledge of the regional aquifers is well established. Chemical risk assessment and ecotox assessment conducted Santos has extensive experience in drilling conventional and unconventional petroleum wells in the NT and across Australia. Control and monitoring bores as per Preliminary Guidelines: Groundwater Monitoring bores for Exploration Petroleum Wells in the Beetaloo Sub-Basin

Risk Event	Potential Impact	Relevant Environmental Factor	Risk Source	Initial Risk Ranking*			Mitigation and Management Measures		Residual Risk Ranking*			Effective Controls	Uncertainty Ranking
				L	C	R	EMP Commitments	Relevant Code of Practice	L	C	R		
Loss of stimulation fluid, flowback fluid recovery	Impacts to groundwater dependant ecosystems	Terrestrial Flora and Fauna	Cross-flow during hydraulic fracture stimulation, Faults or major structures enables cross-flow.	C	IV	3	Installation of blow-out prevention equipment systems. A geohazard assessment has been performed to mitigate for subsurface hazards such abnormal pressure zones, shallow gas, lost circulation and potential zones of instability. Hydraulic fracture diagnostics including chemical tracers, surface tiltmeter and micro seismic monitoring is used to determine the spatial extent and orientation of the induced fracture. Distance of target shale formation (Velkerri formation) from nearest high quality aquifer (Cambrian Limestone aquifer) is over 2000 m. Drilling of wells off-structures using seismic data for control. Wells are located away from major faults and structures based on seismic data control; further seismic data acquisition planned where “dip” and “strike” line control is not available. Ground water monitoring bores installed on location prior to hydraulic fracture operations. Baseline monitoring conducted six months prior to hydraulic fracture operations. Shallow aquifers isolated behind cemented concentric casing strings. Cemented casing, following the Code of Practice requirements, will prevent aquifer cross-flow once well is constructed and passes well acceptance criteria. Code of Practice: Onshore Petroleum Activities (the code) will be implemented. The code includes requirements for well operations and wastewater management. Chemical Risk Assessment of all chemical used in the proposed HFS (Appendix A) A WOMP will be developed to cover well activities. The Project will not commence until a WOMP has been approved.	B.4.1 Well Integrity management B.4.2 Aquifer protection B.4.3 Well design and well barriers B.4.6 Casing and tubing B.4.7 Primary cementing B.4.9 Well control B.4.13 Hydraulic stimulation and flowback operations B.4.17 Groundwater monitoring C.4.2 Management of Produced water and Flowback Fluid C.7.2 Spill management plan	B	II	2	Yes	Type A Risk – Risks are well known and have been extensively assessed through the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report. In addition the CSIRO regional baseline monitoring program is underway and the knowledge of the regional aquifers is well established. Chemical risk assessment and ecotox assessment conducted Santos has extensive experience in drilling conventional and unconventional petroleum wells in the NT and across Australia. Control and monitoring bores as per Preliminary Guidelines: Groundwater Monitoring bores for Exploration Petroleum Wells in the Beetaloo Sub-Basin
Transport of chemicals and wastewater on unsealed roads during the wet season	Localised contamination of soil	Terrestrial environmental quality	Transport vehicle accident due to weather Transport vehicle stuck due to mechanical or weather events	C	2	2	A risk assessment of road conditions for heavy vehicle transport will be conducted prior to mobilisation on unsealed roads using detailed weather forecasting. Road conditions for heavy vehicle transport will be assessed prior to mobilisation on unsealed roads. If the conditions are assessed to be unsuitable for heavy vehicle transport, there will be no transport of chemicals or wastewater. Transport of wastewater will only occur in double lined enclosed tanks to minimise the risk of spills. In the event of a truck being stuck due to mechanical or weather reason, transfer or recovery will only occur once safe and the risk of spills are ALARP. Only licenced waste transporters to be used to transport listed wastes. The proposed activity has a Land Access and Compensation Agreement in place with the landholder which includes “make good” provisions in the event of damage to roads and other infrastructure on the property as a result of the activity.	A.3.8 Containment of contaminants	A	2	1	Yes	Type A Risk – Risks are well-understood with established management practices. Rainfall data and the use of enclosed tanks for transport.

Risk Event	Potential Impact	Relevant Environmental Factor	Risk Source	Initial Risk Ranking*			Mitigation and Management Measures		Residual Risk Ranking*			Effective Controls	Uncertainty Ranking
				L	C	R	EMP Commitments	Relevant Code of Practice	L	C	R		
Transport of chemicals and wastewater on unsealed roads during the wet season	Reduction in surface and groundwater water quality	Inland Water Environmental Quality	Transport vehicle accident due to weather Transport vehicle stuck due to mechanical or weather events	C	2	2	A risk assessment of road conditions for heavy vehicle transport will be conducted prior to mobilisation on unsealed roads using detailed weather forecasting. Road conditions for heavy vehicle transport will be assessed prior to mobilisation on unsealed roads. If the conditions are assessed to be unsuitable for heavy vehicle transport, there will be no transport of chemicals or wastewater. Transport of wastewater will only occur in double lined enclosed tanks to minimise the risk of spills. In the event of a truck being stuck due to mechanical or weather reason, transfer or recovery will only occur once safe and the risk of spills are ALARP. Only licenced waste transporters to be used to transport listed wastes. The proposed activity has a Land Access and Compensation Agreement in place with the landholder which includes "make good" provisions in the event of damage to roads and other infrastructure on the property as a result of the activity.	A.3.8 Containment of contaminants	A	2	1	Yes	Type A Risk – Risks are well-understood with established management practices. Rainfall data and the use of enclosed tanks for transport.
Waste	Fauna attracted to waste	Terrestrial flora and fauna	Waste stored inappropriately attracting native fauna	F	II	2	Waste will be segregated and stored on site and all putrescible waste material will be held in fauna proof containers. Only waste from approved wastewater systems and grey water will be disposed of to land. Licenced waste contractor will be used for any offsite transfer or disposal.	C.7.1 Wastewater management plan	B	I	1	Yes	Type A Risk – Risks are well-understood with established and proven management practices. Santos has extensive experience in managing wastes to avoid attracting native fauna.
Waste	Reduction in surface water and groundwater quality	Inland Water Environmental Quality	Overflow of fluid storage tanks Leaching from storage tanks	D	III	3	Implementation of the Wastewater Management Plan (Appendix G). Implementation of the Spill Management Plan (Appendix H). Daily monitoring of weather and for predicted significant rainfall events will be undertaken. For produced water and flowback fluid treatment processes occurring outside of enclosed tanks A minimum of 1.5m freeboard will be maintained in all tanks/ponds that contain flowback fluid throughout the wet season. All produced water and flowback fluid must be held in above-ground enclosed tanks at all times Stored volume and available freeboard for all produced water and flowback fluid storage facilities must be monitored at least weekly Flowback fluid tank levels and flowlines will be monitored during and after high rainfall events. Flowback fluid tanks and will be appropriately designed and constructed with an impermeable containment barrier. Flowback fluid tank design includes, double lined tanks, leak detection systems, Tank pad will be bunded Bunded tank pad will accommodate the volume of the largest tank Tank storage volumes monitored for loss of containment	A.3.8 Containment of contaminants B.4.16 Site material and fluids management C.4.2 Management of produced water and flowback fluid C.7.2 Spill management plan C.7.1 Wastewater management plan	B	II	2	Yes	Type A Risk – Risks are well known and have been extensively assessed through the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report. Comprehensive spill modelling completed. Chemical risk assessment and ecotox assessment conducted Santos has extensive experience in drilling conventional and unconventional petroleum wells in the NT and across Australia including the management of fluids.

Risk Event	Potential Impact	Relevant Environmental Factor	Risk Source	Initial Risk Ranking*			Mitigation and Management Measures		Residual Risk Ranking*			Effective Controls	Uncertainty Ranking
				L	C	R	EMP Commitments	Relevant Code of Practice	L	C	R		
Waste	Impact to soil quality	Terrestrial Environmental Quality	Overflow of fluid storage tanks Leaching from storage tanks Flowline failure	D	II	2	Storage tanks are designed and operated to prevent overtopping due to rainfall and designed with enough freeboard to accommodate total rainfall anticipated. Wastewater management contractor is required to have a Journey Management Plan All wastes to be transported in accordance with the NT Waste Management and Pollution Control Act All dangerous goods to be transported in accordance with the NT Dangerous Goods Act and Australian Dangerous Goods Code. Code of Practice: Onshore Petroleum Activities (the code) will be implemented. The code includes requirements for well operations and wastewater management. Implementation of an approved Spill Management Plan and Wastewater Management Plan, as defined by the code. A WOMP will be developed to cover well activities. The Project will not commence until a WOMP has been approved.	C.6.1 Water and Wastewater tracking and reporting C.7.2 Spill management plan	C	II	2	Yes	Type A Risk – Risks are well known and have been extensively assessed through the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) Final Report. Comprehensive spill modelling completed. Chemical risk assessment and ecotox assessment conducted Santos has extensive experience in drilling conventional and unconventional petroleum wells in the NT and across Australia including the management of fluids.

6.1 Discussion on ALARP, acceptability and ESD

As discussed in section 5.7, Santos uses a model to determine acceptance of residual risk is detailed in the Santos Residual Risk Acceptance Model. In summary:

- A Level 5 residual risk is intolerable and must not be accepted or approved by Management.
- A Level 2 – 4 residual risk is acceptable provided that ALARP has been achieved and demonstrated.
- A level 1 residual risk is acceptable and it is assumed that ALARP has been achieved.

In addition to the requirements detailed above, for the purposes of petroleum activities, impacts and risk to the environment are considered broadly acceptable if:

- The residual risk is determined to be 1 (and ALARP Decision Type A selected and good practice control measures applied), or
- The residual risk is determined between 2 and 4 and ALARP can be demonstrated; and
- The following have been met:
    - Principles of ESD
    - Legal and other requirements
    - Santos policies and standards
    - Stakeholder expectations.

All the residual risks in the risk assessment in Table 6-1 are between 1 and 2, which means that they are acceptable, ALARP and have considered ESD.

In the risk assessment, all risks have been considered a decision 'Type A', meaning that they are well understood and that are established practices in place to manage these risks.

Activities conducted under this EMP will be done in compliance with the Code of Practice: Petroleum Activities in the Northern Territory. This ensures that that petroleum activities are managed to ensure that risks are managed to a level that is as low as reasonably practical (ALARP) and acceptable.

6.2 Referrals to DoEE and NT EPA

6.2.1 Significant Impact test for EPBC listed species

As discussed in section 2.6, referral of the project to the Department of Environment and Energy is required if the proposed action will have, or is likely to have a significant impact on MNES. Gouldian Finch, Grey Falcon and Crested Shrike-tit were identified as having a medium chance of occurring within the Project Area. However, the proposed Hydraulic Fracturing Program will not directly impact habitat for these species and significant impact to these species or their habitat as a result of project activities is considered remote. The project will not be referred to the Department of Environment and Energy. The proposed action will not have a significant impact on any MNES

6.2.2 Significant impact test for Environmental Assessments Act

As discussed in section 2.6.2, petroleum activities that could reasonably be considered to be capable of having a significant effect on the environment are referred to the NT EPA. Using the guideline 'Referring a proposal to the NT EPA: A guide for proponents and referral agencies' (NT EPA 2018), a detailed review of and assessment against each prescribed Environmental Objectives for each

Environmental Factor was conducted in relation to the proposed Hydraulic Fracturing Program and is included in Table 6-2. The results of the assessment in in Table 6-2 clearly demonstrate that the proposed petroleum activities that could not reasonably be considered to be capable of having a significant effect on the environment.

Table 6-2 Assessment against the Environmental Assessments Act's Environmental Objectives and Environmental Factor

Theme	Environmental Factor	Environmental Objective	Relevance to the application
Land	Terrestrial Flora and Fauna	Protect NT's flora and fauna so that biological diversity and ecological integrity are maintained.	The proposed activities occur within previously cleared areas devoid of vegetation and fauna habitat features. The proposed activities are unlikely to result in impacts to vegetation or native fauna. The mitigation measures outlined in Table 6-1 will be implemented to manage these risk to a level that is ALARP and acceptable. Accordingly, biological diversity and ecological integrity will be maintained and there would be no potential for a significant effect on biological diversity and ecological integrity because of the proposed activities.
Land	Terrestrial Environmental Quality	Maintain the quality of the land and soils so that environmental values are protected.	In the unlikely event that a release occurs, the proposed activities are likely to result in only minor localised impacts to the land (see Appendix A). The mitigation measures outlined in Table 6-1 will be implemented to manage these risk to a level that is ALARP and acceptable. Accordingly, biological diversity and ecological integrity will be maintained and there would be no potential for a significant effect to land and soils because of the proposed activities.
Land	Landforms	Conserve the variety and integrity of distinctive physical landforms so that environmental values are protected.	The landforms within EP 161 include gorges, water holes and dissected sandstone plateaus (within the Gulf Falls and Uplands Bioregion) and flat to gently undulating plains with little local relief (within the Sturt Plateau Bioregion), as outlined in Section 4.3.1.The Project Area is located in areas of previous disturbance that are devoid of outstanding landforms. No major civil works are proposed, therefore there is be no potential for a significant effect on landforms.
Water	Aquatic Ecosystems	Protect aquatic ecosystems to maintain the biological diversity of flora and fauna and the ecological functions they perform.	It is unlikely aquatic ecosystems will be impacted by the purposed activities, given that no sensitive vegetation will be disturbed and there is a lack of permanent surface waters and aquatic GDEs in the Project Area. Furthermore, the spill modelling in Appendix A and the mitigation measures outlined Table 6-1, will be employed to ensure that potential risks and impacts are managed and further mitigated. Accordingly, there would be no potential for a significant effect on aquatic ecosystems.

Theme	Environmental Factor	Environmental Objective	Relevance to the application
Water	Water Environmental Quality	Maintain the quality of groundwater and surface water so that environmental values including ecological health, land uses, and the welfare and amenity of people are protected.	The proposed activities have the unlikely potential to result in localised and short-term disturbance to inland water quality through unplanned erosion and spills at the surface or potential cross-flow of hydraulic fracturing fluids and/or unconnected aquifers. Given the lack of permanent surface waters and the chemical risk assessment in Appendix A, it is unlikely the inland water quality will be impacted. In addition, the mitigation measures outlined in Table 6-1, The Wastewater Management Plan and Spill Management Plan will be implemented to manage any potential risks. Accordingly, there would be no potential for a significant effect on the quality of groundwater and surface water.
Water	Hydrological Processes	Maintain the hydrological regimes of groundwater and surface water so that environmental values are protected.	It is unlikely hydrological regimes of groundwater or surface waters will be altered by the proposed activities. The area of planned disturbance is small, minimal volumes of groundwater are required. A valid water extraction licence is in place and groundwater extraction associated with the project is regulated and reported on. Furthermore, the control measures outlined in Table 6-1 will be implemented to ensure that these potential risks and impacts are managed and further mitigated. Accordingly, there would be no potential for a significant effect on hydrological regimes of groundwater and surface water.
Air	Air Quality and Greenhouse Gases	Maintain air quality and minimise emissions and their impact so that environmental values are protected.	The proposed activities have the potential to result in localised, short-term minor impacts to air quality through planned atmospheric emissions. The mitigation measures outlined in Table 6-1 will be implemented to manage these risks. Given this, and the relatively small nature of operations, there would be no potential for significant effect to air quality and greenhouse gases.
People and Communities	Social, Economic and Cultural Surroundings	Protect the rich social, economic, cultural and heritage values of the Northern Territory.	The proposed activities have the unlikely potential to result in disturbance to culturally sensitive sites and/landholders through lighting, weeds, fire, planned physical disturbance, and unplanned stakeholder interactions. The control mitigation measures outlined in Table 6-1 will be implemented to manage these risks, such as the areas proposed to be disturbed have been surveyed for sacred sites and cultural heritage significance and AAPA certificate C2019/043 issued on 13 May 2019, superseding C2014/053, is in place. Given this, and the relatively small nature of operations and proposed actual ground disturbance, the proposed activities will maintain the social, economic, cultural and heritage values of the Northern Territory.

Theme	Environmental Factor	Environmental Objective	Relevance to the application
People and Communities	Human Health	Ensure that the risks to human health are identified, understood and adequately avoided and/or mitigated.	The tiered chemical risk assessment in Appendix A demonstrates that the risks to human health associated with the project are identified, understood and adequately avoided. The mitigation measures outlined in Table 6-1 will be implemented to manage this risk. Accordingly, there would be no potential for significant effect to human health.

7.0 Management and Monitoring Plans

7.1 Weed Management Plan

A project specific weed management plan must be developed as part Fof the EMP which meets the requirements of the *NT Weed Management Planning Guide: Onshore Petroleum Projects* (DENR 2019). The Weed Management Plan for the 2019 Hydraulic Fracturing Program is provided in Appendix E.

7.2 Fire Management Plan

7.2.1 Baseline Fire Information

Baseline fire information has been provided by Infonet and the Northern Territory Fire History Report available from NRM InfoNet.

7.2.1.1 Fire Frequency

The Fire History Report indicates fire frequency in the immediate vicinity of the Project Area and within Tanumbirini Station is very low at three or less between 2000 and 2018. Fire frequency increases to the east, south and west and less so to the north (NTG 2019). The number of years burnt between 2000 and 2018 at the Tanumbirini 1/2H location and the Inacumba 1/1H location is shown in Figure 7-1.

The location immediately surrounding the Tanumbirini 1/2H location appears to have been burnt zero or one time between 2000 and 2018. The Inacumba 1/1H location appears to have been burnt three or four times between 2000 and 2018

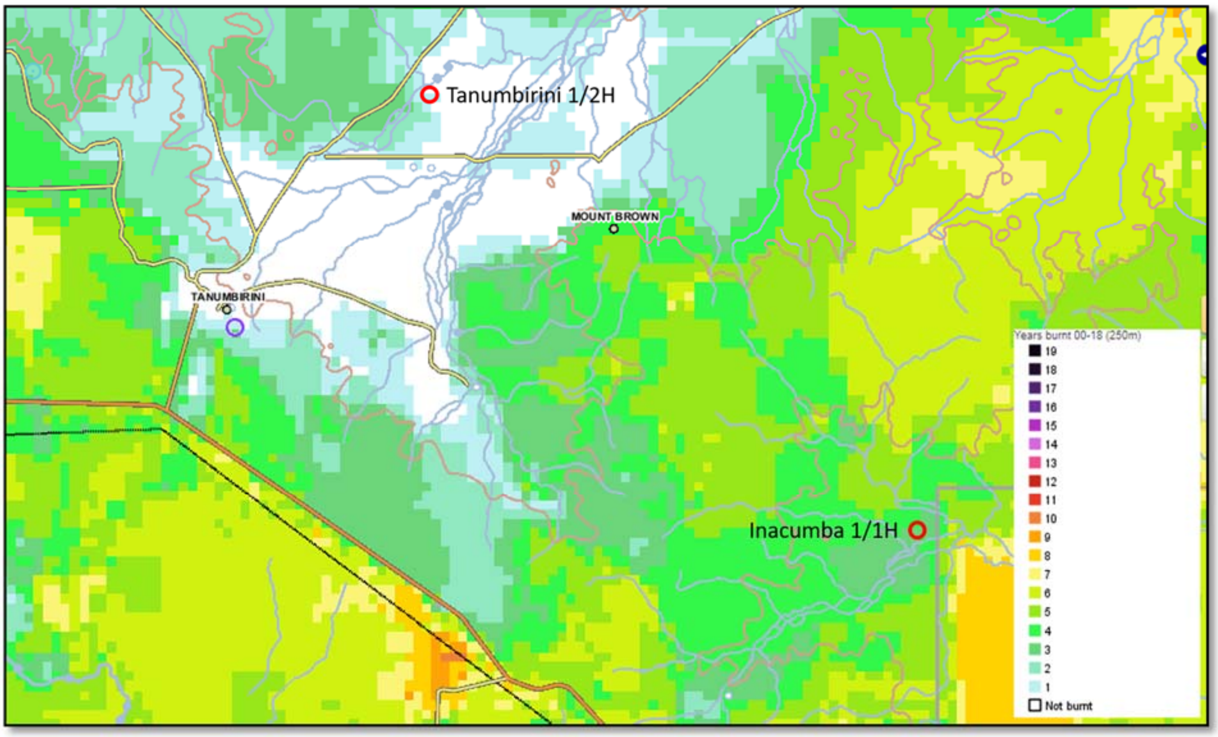

Figure 7-1 Fire frequency between 2000 and 2018 at Tanumbirini 1/2H and Inacumba 1/1H

7.2.1.2 Last Burn

Generally the most recent fires have occurred west and east of Tanumbirini 1/2H and Inacumba 1/1H respectively. In 2012 much of the area in the vicinity of the project was subject to fire (NTG 2018). The number of years burnt between 2000 and 2018 at the Tanumbirini 1/2H location and the Inacumba 1/1H location is shown in Figure 7-2.

The Tanumbirini 1/2H location was last burnt in 2006. The Inacumba 1/1H location, and much of the area that surrounds this location, was last burnt in 2012.

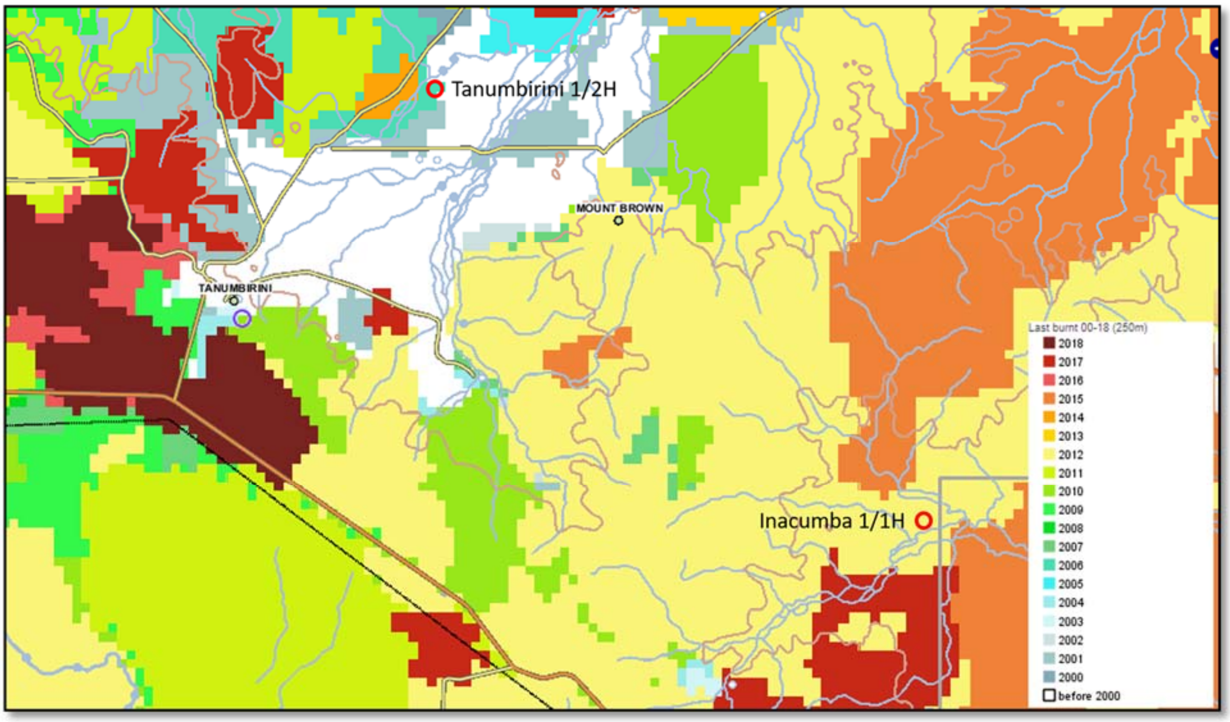

Figure 7-2: The year of last burn between 2000 and 2018 at Tanumbirini 1/2H and the Inacumba 1/1H

7.2.2 Fire management

Under the Bushfires Management Act 2016 a permit to burn (or flare) is required during fire danger periods. During fire ban periods, flaring is not permitted.

7.2.2.1 Fire Management Objectives

The fire management objectives of this Fire Management Plan are:

- accept surrounding landholder fire management objectives
- exclude fire from site area by putting in fuel reduced buffers (but not using fire to reduce fuel)
- responding with direct action (with or without pastoralist assistance) when infrastructure threatened
- reducing probability of ignition on or around site.

7.2.2.2 Impacts of the proposed activities on the existing fire management

The proposed activities will be located on existing cleared infrastructure. The small size of the project area will ensure that there will be no impacts on existing fire management.

7.2.2.3 Coordination with the landholder and other land users

The proposed development will require a Land Access and Compensation Agreement with the landholder/s. Through this process Santos will ensure that the project does not affect the landholder's fire management obligations and strategies.

The project lies within the Savanna Fire Management Zone in the Northern Territory. The Savanna Regional Bushfires Management Plan 2018 has been developed to support community wide fire management within the Savanna Fire Management Zone in line with the *Bushfires Management Act 2016*.

The proposed activities do not include the use of fire and fire exclusion from the lease pads is proposed. Outside of the lease pads there will be no impact on fire management. This is consistent with the Savanna Regional Bushfires Management Plan 2018 and the Fire management objectives for petroleum exploration.

7.2.2.4 Fire Mitigation Measures

The central piece of fire mitigation for the project is the implementation of a Fire control zone surrounding the Inacumba 1/1H location and the Tanumbirini 1/2H location (See EMP Figure 3.2 and Figure 3.3). This fire control zone has been established. The objectives of the fire control zones are:

- Protecting assets (resources, materials and equipment) by removing fuel in their vicinity may be done using other means
- Manage fire to maintain safety of employees and visitors to site in regards to removing vegetation and managing bushfire hazards involved in machinery used.
- Neighbours - Unplanned Fires during exploration have the ability to quickly impact on neighbouring properties where grass is a major asset to their livelihoods.
- Firebreaks - Installation of firebreaks to allow for management to ensure fire does not enter lease or possible exit lease impacting on neighbours.

The fire control zones will be cleared of vegetation and maintained to ensure no fire encroachment during project activities.

The access roads to the Inacumba 1/1H location and the Tanumbirini 1/2H locations will also serve as the fire access tracks. These will be upgraded in places and maintained to ensure ongoing access to land to allow for exploration work to be undertaken and to allow landholder to access to the areas.

Communication of fire alerts will include:

- All personnel will receive information prior to the commencement of the activity relating to:
  - Provisions of the Emergency Response Plan including procedures during a fire emergency
  - The operation of firefighting equipment and communications
  - Restricted smoking requirements
- Toolbox meetings will be conducted to:
  - Alert the workforce of the fire risk level for the day '
  - Discuss any fire risk management breaches and remedial actions.

All project infrastructure will be designed and constructed to mitigate risks of ignition. Project specific requirement to mitigate risk of ignition include:

- Fire-fighting equipment and competent fire-fighting personnel will be available.
- All vehicles will be equipped with portable fire extinguishers.
- Machinery and vehicles should be parked in areas of low fire risk and be free of any combustible material.
- Any petrol motor vehicles or petrol-powered pumps will be fitted with spark arresters.
- All vehicles will be equipped with operational VHF and / or UHF radio transceivers.
- Smoking will only be permitted in areas clear of vegetation, and there will be no disposal of butts.

7.2.3 Annual Fire Mapping

The proposed works are expected to commence in 2019 and finalise early 2020. If during the proposed exploration works a fire has occurred in and around the project area, Santos will map the extent of the fire, in consultation with the landholder and provide the information to DENR.

7.3 Rehabilitation Management Plan

Santos may request approval to undertake additional exploration activities following the completion of the activities covered under this EMP (which would require further EMP and other regulatory approvals and are not covered by this EMP). The wells proposed as part of this EMP are part of an exploration program with uncertainty on reservoir outcome. The timing of rehabilitation activities for activities included in this EMP will depend on exploration outcomes and the potential for reservoir development and production.

7.3.1 Scope

Rehabilitation of access tracks and lease pads will are not included in the scope of this EMP. Unless the landholder requests infrastructure to remain in place, the reprofiling of access tracks and lease pads utilised under this EMP will be done as part of the Civils and Seismic EMP.

7.3.2 Progressive rehabilitation

Progressive rehabilitation of significantly disturbed land which is not required for the ongoing conduct of the petroleum activities or future activities, will commence as soon as practicable, but not longer than 12 months following the cessation of the activity.

As discussed above the wells proposed as part of this EMP are part of an exploration program with uncertainty on reservoir outcome. The timing of progressive rehabilitation a will depend on exploration outcomes and the potential for reservoir development and production.

7.3.3 Final land use

Unless the landholder requests infrastructure to remain in place all surface infrastructure will be removed and rehabilitated. Rehabilitation activities will only allow a landholder to acquire certain infrastructure types. If the landholder does requests infrastructure to remain in place, the proposed infrastructure must be signed off with both the Pastoral Land Board and DPIR. Otherwise, the following activities will be undertaken:

- Removal of fencing
- Removal of drilling and HFS infrastructure such
- Water bore holding ponds to be drained of liquids
- Flowback fluid tanks will be emptied for offsite disposal by licenced waste company
- Lightly scarifying or rolling all disturbed areas to break up consolidated surfaces

- Spreading of stockpiled topsoil material and trees, shrubs and grasses across the lease pad and areas not needed for future monitoring and maintenance.
- Ripping and spreading of stockpiled vegetation to promote revegetation
- Removal of fencing and well site infrastructure.
- Any reusable materials and pumps to be delivered to the landholder.
- Repair or reinstate any landholder infrastructure damaged due to project activities.

7.3.4 Rehabilitation goals

Given the rehabilitation efforts associated with this EMP as related to hydraulic fracturing activities, rehabilitation goals are limited to:

- Removal of all rubbish and waste
- Removal of above ground infrastructure so that in the event the civils works rehabilitation such as the reprofiling of access tracks and lease pads can occur unimpeded.
- Provide that the drilling sites are reshaped (if required) to a stable landform to ensure the lease pad is safe and stable.

Following completion of the rehabilitation works final photo point revisit and any required additional rehabilitation, Santos will submit the final Environmental Reports to DPIR and DENR along with the application to release the long-term Rehabilitation Security. In accordance with the Environmental Closeout Procedures for Petroleum Activities (DPIR 2016), the final rehabilitation assessment and endorsement will be conducted by an appropriately qualified third party.

7.3.5 Environmental Outcomes and Performance Standards

The specific rehabilitation requirements for the Hydraulic Fracturing Program are limited as most of the surface rehabilitation requirements are provided for in the approved Civils and Seismic EMP. The specific environmental outcomes and performance standards required for the rehabilitation requirements of the Hydraulic Fracturing Program are provided in Table 7-1.

Table 7-1 Environmental Outcomes, Performance Standard, Monitoring and Reporting

Environmental Outcomes	Performance Standard	Monitoring	Reporting
Complete Remediation of the lease pads.	Removal of all surface infrastructure including tanks and tank pad liners	Visual inspection/photo points at the completion of the project	Final Rehabilitation report / Security bond release

7.3.6 Monitoring and maintenance program

Photo points will be established at the wellsite. Each photo point is geo-referenced and is captured digitally to ensure consistency. By establishing photo points, it provides a balanced representation of the ground condition and various landform and vegetation types encountered and enables rehabilitation success to be effectively monitored.

The process is repeated after the Hydraulic Fracturing Program is completed (i.e. post well completion). The revisit intervals are generally immediately after rehabilitation works have been completed post decommissioning, following the first wet season, one year after rehabilitation works, and three years after rehabilitation; although the return period is determined by weather/road conditions and current activity in the region. Revisits may also be targeted, with emphasis on sensitive areas and areas potentially subject to erosion such that environmental impact of re-accessing remote locations is minimised in consultation with, and on the advice of, an independent environmental consultant.

If during any monitoring events (weed monitoring, rehabilitation monitoring, groundwater monitoring etc.) contamination is detected, an incident will be logged and remediation will commence immediately.

7.4 Site Groundwater Monitoring Plan

Groundwater monitoring for exploration petroleum wells will be undertake in accordance with the *Preliminary Guideline: Groundwater Monitoring Bores for Exploration Petroleum Wells in the Beetaloo Sub-basin* (Department of Environment and Natural Resources, November 2018) (the Guideline). It should be noted that the monitoring plan may be updated to align with any revisions to the *Preliminary Guideline: Groundwater Monitoring Bores for Exploration Petroleum Wells in the Beetaloo Sub-basin* as updated from time to time or an alternative process agreed with DENR.

7.4.1 Aquifers to be monitored

The Guideline states that groundwater monitoring at well sites in the Beetaloo Sub-Basin is required for aquifers in the Antony Lagoon and Gum Ridge Formations (or equivalents) where they are present below the water table. Neither formation is considered an aquifer where it lies above the water table.

The interpreted hydro-stratigraphy at the location of each the proposed well sites is summarised in Table 7-2. Down-hole gamma logs were provided to DENR Water Assessment Branch as they became available post-drilling but prior to the completion of the holes as monitoring bores. The interpretation of these logs confirmed that the Anthony Lagoon Formation was not encountered or was not an aquifer at the monitoring well locations. Therefore monitoring of the Gum Ridge Formation of the Cambrian Limestone aquifer is required in accordance with the Guideline.

Table 7-2 Stratigraphy encountered at the proposed well sites.

Well / Multi-well pad	Tanumbirini 1/2H	Inacumba 1/1H
Observed water table	59.6 mbgl	73.43 mbgl
Top Anthony Lagoon Formation	45.0 mbgl	Not present
Top Gum Ridge Formation	57.0 mbgl	56.0 mbgl
Top Bukalara Sandstone	188.0 mbgl	102.5 mbgl

7.4.2 Location and timing requirements

The Guideline states that two types of monitoring bores are required. Control monitoring bores (CMBs) and impact monitoring bores (IMBs). In accordance with the Guideline, both need to be screened near the top, middle and bottom of the Gum Ridge Formation.

Tanumbirini 1/2H is a multiple well pad, and so the location of the impact monitoring bore has been located 20m down-gradient of the Tanumbiribi 2H well head. This was confirmed by DENR as the most preferable location.

Table 7-3 shows the monitoring bore type requirements and Figure 7-3 shows the potentiometric surface in the Gum Ridge Formation across the project area. This shows that the flow directions are toward a bearing of 275-285 degrees and 305-315 degrees for the Tanumbirini 1/2H well and the Inacumba 1/1H well, respectively.

Table 7-3 Monitoring bore type requirements

Monitoring bore array type	Location	When required
Control monitoring bore	Within 100m up-gradient of the well pad	6 months prior to drilling
Impact monitoring bore	Within 20m down-gradient of the petroleum well. Where multiple exploration wells on a well pad are proposed then a single array, 20m downgradient of the well head series.	At completion of the well drilling and prior to hydraulic fracturing of the well

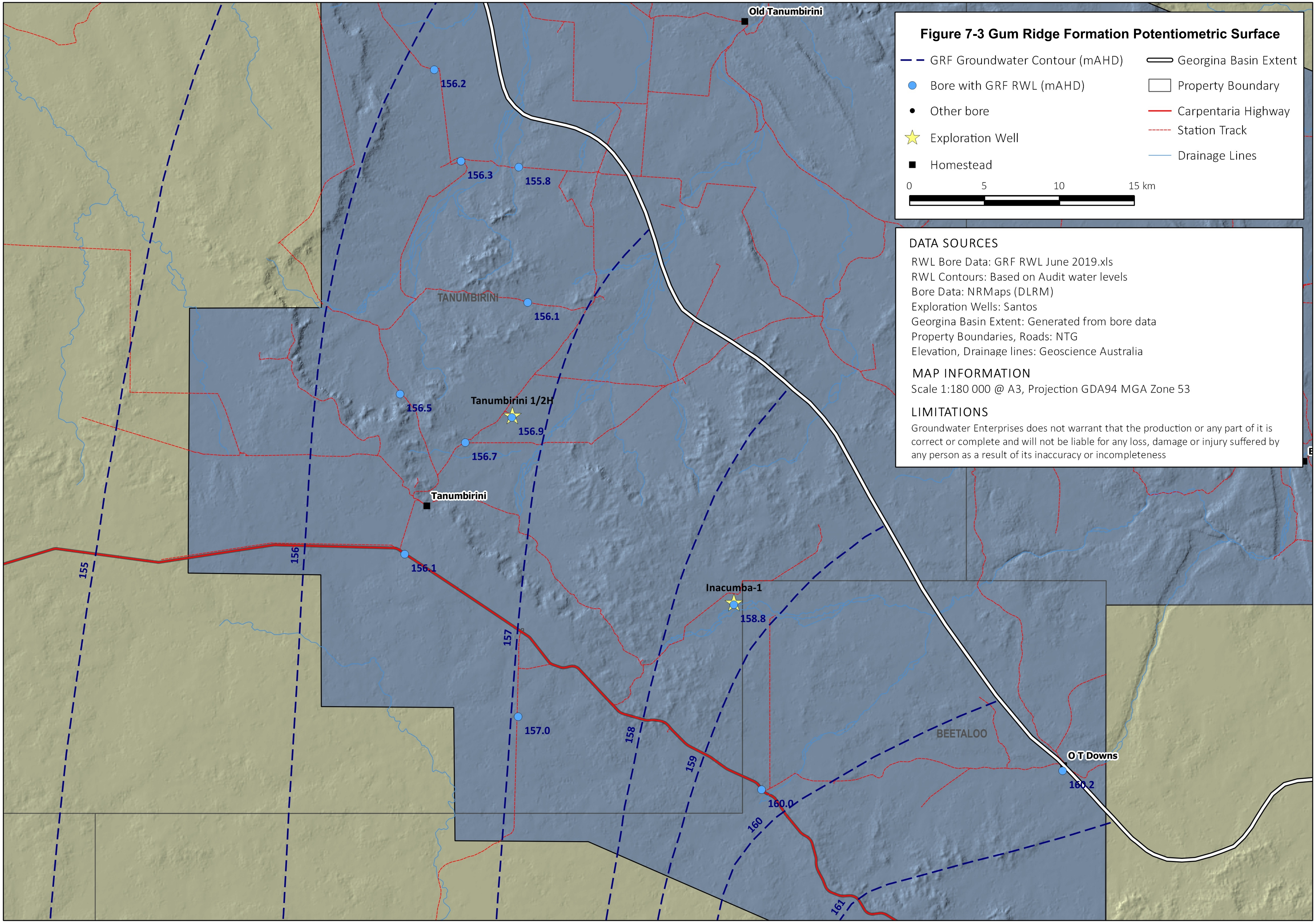
Figure 7-3 Gum Ridge Formation Potentiometric Surface
GRF Groundwater Contour (mAHD)
Bore with GRF RWL (mAHD)
Other bore
Exploration Well
Homestead
Georgina Basin Extent
Property Boundary
Carpentaria Highway
Station Track
Drainage Lines
0
5
10
15 km
DATA SOURCES
RWL Bore Data: GRF RWL June 2019.xls
RWL Contours: Based on Audit water levels
Bore Data: NRMaps (DLRM)
Exploration Wells: Santos
Georgina Basin Extent: Generated from bore data
Property Boundaries, Roads: NTG
Elevation, Drainage lines: Geoscience Australia
MAP INFORMATION
Scale 1:180 000 @ A3, Projection GDA94 MGA Zone 53
LIMITATIONS
Groundwater Enterprises does not warrant that the production or any part of it is correct or complete and will not be liable for any loss, damage or injury suffered by any person as a result of its inaccuracy or incompleteness
Old Tanumbirini
TANUMBIRINI
Tanumbirini 1/2H
Tanumbirini
Inacumba-1
BEETALOO
O T Downs
156.2
156.3
155.8
156.1
156.5
156.9
156.7
156.1
158.8
157.0
160.0
160.2
155
156
157
158
159
160
161

7.4.3 Monitoring bore design

Table 7-4 provides a summary of the well pad monitoring bore details.

Table 7-4 Well Pad Monitoring Bore Summary

Well site or multi-well pad	Bore ID	Purpose	Date spudded	Easting	Northing	SWL (mbgl)	Effective inlet top (mbgl)	Effective inlet bottom (mbgl)
Tanumbirini 1/2H	RN040930	CMB	30-11-18*	468346	8186790	59.6	5.8	184.4
Tanumbirini 1/2H	RN040936	IMB	22-07-19	468331	8186846	57.6	46	182
Inacumba 1/1H	RN040931	CMB	14-12-18**	483196	8173849	73.43	5.8	98.0
Inacumba 1/1H	RN040935	IMB	15-07-19	483176	8173860	74.3	5.8	100.0

* Well remediated on 9-7-2019
** Well remediated on 28-6-2019

7.4.4 Sampling frequency

The Guideline requires that Control Monitoring Bore (CMBS) is established in time to allow at least six months of sampling prior to the drilling of the gas well, and that sampling should encompass the likely major extent of natural variation between late dry season and late wet season periods. At least 7 samples will be taken from each Control Monitoring Bore prior to stimulating the well.

Santos has installed CMBs at both the Tanumbiribi 1/2H and Inacumba 1 well sites. Details relating to the CMBs and monitoring / frequencies are presented in Table 7-5.

Table 7-5 Expected sampling frequency / number of samples for Control Monitoring Bores

Bore ID	Dec 2018	July 2019	Aug 2019	Sept 2019	Oct 2019	Nov 2019	Dec 2019 onward
RN040930	1	3	4	4	4	2	Monthly*
RN040931	1	2	4	4	4	2	Monthly*

* Where access is feasible (e.g. not constrained by wet weather road conditions)

The Guideline requires that Impact Monitoring Bores (IMBs) be installed and sampled prior to stimulating the well. Santos has installed IMBs at both the Tanumbiribi 1/2H and Inacumba 1/1H well sites (refer to Table 7-4).

In accordance with the Guideline, sampling shall be undertaken at least once prior to well stimulating the well. Groundwater sampling from all CMBs and IMBs will continue on a monthly basis, where access is feasible (e.g. not constrained by wet weather road conditions) for at least three years after stimulating the well had commenced, or as otherwise advised.

7.4.5 Sampling methodology

Samples will generally be taken in accordance with protocols detailed in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality field sampling program.

Sampling procedures will include the following components:

1. Sampling must be undertaken by suitably qualified and trained personnel
2. Water quality samples will be collected only after at least three times the volume of water stored in the bore and discharge piping has been purged and the field water quality parameters (e.g. E.C.) have stabilised. The purge volume will be recorded. Alternatively low flow monitoring techniques will be utilised.
3. Water quality samples will have a unique identification number that can be cross-referenced to the monitoring location and time of sampling.
4. Sample preservation measures are to be documented and comply with analytical laboratory requirements and relevant standards (e.g. AS/NZS 5667.1:1998).
5. Chain of custody (CoC) procedures will be followed in accordance with section 3.7 of Monitoring and Sampling Manual 2009 —Environmental Protection (Water) Policy 2009 (Department of Environment and Heritage Protection, 2013).
6. Sample analysis will be undertaken by a laboratory that is NATA approved for that analysis

A survey benchmark relative to Australian Height Datum (AHD) has been established at each bore, comprising the top of casing of each bore, accurate to ±10 cm, to accurately determine depth to water table during each sampling event.

Field readings for sampling events will comprise pH, electrical conductivity, temperature, standing water level (pre-purge water level) and purge volume.

7.4.6 Laboratory testing

The Analytical Suite to be assessed is listed below in Table 7-6. A review of the suite of analytes to be tested may be requested of and approved by DENR once a stable baseline has been established for the monitoring bores.

7.4.7 In-situ loggers

Logger devices will be installed into each bore. The loggers will measure groundwater pressure (which may be converted to a water level), electrical conductivity and temperature. Loggers will be manually downloaded at least once a month where access is feasible (e.g. not constrained by wet weather road conditions).

7.4.8 Data management and reporting

Laboratory reports will be provided to the regulator as soon as practicable after each sampling event and report prepared and issued by the laboratory.

Monitored data shall be submitted in accordance with the *Preliminary Guideline: Groundwater Monitoring Bores for Exploration Petroleum Wells in the Beetaloo Sub-basin* as updated from time to time or an alternative process agreed with DENR.

Table 7-6 Laboratory Analytes, Units and Limit of Reporting

Category	Parameter	Reporting Units	Limit of reporting (<LOR)
	Electrical Conductivity @ 25°C	mS/cm	1
	Total Dissolved Solids @180°C	mg/L	10
	Suspended Solids	mg/L	5
	Total Alkalinity as CaCO3	mg/L	1
	Other radionuclides and gross alpha, beta, and gamma radiation	Bq/L	0.05-0.1
Anions	Chloride	mg/L	1
	Fluoride	mg/L	0.1
	Sulfate as SO4 2-	mg/L	1
	Nitrite as N	mg/L	0.01
	Nitrate as N	mg/L	0.01
Cations and metals	Calcium	mg/L	1
	Chromium (T, D)	mg/L	0.001
	Copper (T, D)	mg/L	0.001
	Iron (T, D)	mg/L	0.05
	Lead (T, D)	mg/L	0.001
	Magnesium	mg/L	1
	Manganese (T, D)	mg/L	0.001
	Mercury (T, D)	mg/L	0.0001
	Potassium	mg/L	1
	Silver (T, D)	mg/L	0.001
	Arsenic (T, D)	mg/L	0.001
	Barium (T, D)	mg/L	0.001
	Boron (T, D)	mg/L	0.001
	Cadmium (T, D)	mg/L	0.0001
	Lithium (T, D)	mg/L	0.001
	Selenium (T, D)	mg/L	0.001
	Reactive Silica	mg/L	0.001
	Strontium (T, D)	mg/L	0.001
	Sodium	mg/L	1
	Zinc (T, D)	mg/L	0.001
Petroleum	Benzene	mg/L	0.001
	Toluene	mg/L	0.001
	Ethylbenzene	mg/L	0.001
	M and p Xylene	mg/L	0.001
	o Xylene	mg/L	0.001

Category	Parameter	Reporting Units	Limit of reporting (<LOR)
	Total Xylenes	mg/L	0.002
	TRH C_6 - C_{10}	mg/L	0.02
	TRH C_6 - C_{10} less BTEX	mg/L	0.02
	TRH >C_{10} - C_{16}	mg/L	0.02
	TRH >C_{10} - C_{16} less Napthalene	mg/L	0.02
	TRH >C_{16} - C_{34}	mg/L	0.01
	TRH >C_{34} - C_{40}	mg/L	0.01
	Total TRH C_6 - C_{40}	mg/L	0.01
	3-Methylcholanthrene	mg/L	0.001
	7, 12- Dimethylbenz(a)anthracene	mg/L	0.001
	Acenaphthene	mg/L	0.001
	Acenaphthylene	mg/L	0.001
	Anthracene	mg/L	0.001
	Benzo (a) pyrene	mg/L	0.001
	Benzo (b) fluoranthene	mg/L	0.001
	Benzo (ghi) perylene	mg/L	0.001
	Benzo (k) fluoranthene	mg/L	0.001
	Benzo (a) anthracene	mg/L	0.001
	Chrysene	mg/L	0.001
	Dibenz (ah) anthracene	mg/L	0.001
	Fluoranthene	mg/L	0.001
	Fluorene	mg/L	0.001
	Indeno (1,2,3-cd) pyrene	mg/L	0.001
	Napthalene	mg/L	0.001
	Phenanthrene	mg/L	0.001
	Pyrene	mg/L	0.001
	Total PAH	mg/L	0.001
	Dissolved Methane, Ethane, Propane	µg/L	1

7.5 Wastewater Management Plan

A Wastewater Management Plan (WWMP) for the 2019/2020 HFS Program is provided in Appendix G.

7.6 Spill Management Plan

A Spill Management Plan (SMP) for the 2019/2020 HFS Program is provided in Appendix H.

7.7 Methane Emissions Management Plan

A Methane Emissions Management Plan (MEMP) for the 2019/2020 HFS Program is provided in Appendix J.

8.0 Implementation Strategy

The Implementation Strategy described in this section is a summary of the Santos systems, practices and procedures in place to manage the environmental risks of the Hydraulic Fracturing Program. The strategy aims to ensure that the control measures, environmental performance outcomes and standards, detailed in Section 7, are implemented and monitored to ensure environmental impacts and risks are continually identified and reduced to a level that is ALARP and acceptable.

8.1 Environmental Outcomes, Performance Standards and Measurement Criteria

Santos is committed to ensuring that its activities are undertaken in a manner that is environmentally responsible through setting Environmental Outcomes (EO) and Environmental Performance Standards.

Under the Regulations, an EMP must include EO's that address the risks identified in section 6.0. The EO's must address the legislative and other controls that manage the environmental aspects of the activity.

For each EO, there must be at least one related EPS, that either reduces the likelihood of the risk or impact occurring, or reducing the impact or consequence of the risk. The EPS intend to validate the controls that have been implemented to manage the environmental risks. An EPS will relate to the quality of the control in place, including people, systems, equipment and procedures.

For each EO and its relevant EPS, specifically related measurable criteria should be included to measure the performance against the EO and EPS. These Measurement Criteria (MC) must enable a determination to be made on whether the EOs and EPS are being consistently met. The EO, EPS and MC for the Hydraulic Fracturing Program are described in Table 8-1

Table 8-1 Environmental Outcomes, Environmental Performance Standards and Measurement Criteria

Environmental Value	Risk Sources	Environmental Outcome	Environmental Performance Standard	Measurement Criteria
Terrestrial Flora and fauna	Vehicle and plant movements generating dust and depositing on flora	There are no long term impacts on terrestrial flora and fauna as a result of vehicle and plant movements generating dust.	Vehicle speeds do not exceed 60km/hr on unsealed roads. Dust control measures implemented when required due to atmospheric conditions.	Site induction records show all personnel have completed site inductions in accordance with section 7 of this Environmental Management Plan. IVMS records show speed limits adhered to and managed. Records show when and where water trucks have been used for dust control including weather condition observations.
Terrestrial Flora and fauna	Vehicle and plant movements generating noise and vibration and disturbing wildlife	There are no long term impacts on terrestrial flora and fauna as a result of Noise generation and vibration.	Engines/machinery maintained in accordance with manufacturers specifications and frequencies as detailed in the Santos maintenance system. Engines/machinery fitted with noise suppression devices. Wells are located >8km from the Tanumbirini homestead.	Records demonstrate engines and machinery have been maintained in accordance with required maintenance schedule and have been fitted with noise suppression devices.
Terrestrial Flora and fauna	Vehicle movement, project activities and camps generating light and disturbing wildlife	There are no long term impacts on terrestrial flora and fauna as a result of light emissions	Task focused lighting employed (only used as required). All camp boundary lighting positioned inwards. Night time operations restricted (e.g. No HFS pumping will occur at night)	Audit records of lighting at the camp show inward-facing lights that are adequate for safe operations. IVMS data shows that night driving have been avoided or restricted

Environmental Value	Risk Sources	Environmental Outcome	Environmental Performance Standard	Measurement Criteria
Terrestrial Flora and fauna	Disturbance, injury or death to terrestrial fauna due to vehicle movements, project activities and entrapment in open treatment ponds or tanks	No impacts to fauna as a result of vehicle movements. All ponds will be fenced at all times Fauna escapes provided in open treatment ponds.	No off-road driving. Vehicle speeds do not exceed 60km/hr on unsealed roads. Storage tanks and treatment ponds will be fenced. All open treatment ponds have fauna escapes provided. DTriving is only permitted on designated access roads and seismic lines.	Records of Santos Field Environmental Checklists demonstrates that activities are being undertaken in accordance with the Environmental Performance Standards. Daily inspection records show fences are intact and no fauna entrapment. Site induction records shows all personnel have completed site inductions in accordance with section 7 of this Environmental Management Plan.
Terrestrial Flora and fauna	Plant and vehicles distributing weeds from outside or within the project area	No introduction of new species of weeds or plant pathogens as a result of project activities. No increase in abundance of existing weed species as a result of project activities.	Compliance with DENR approved weed management plan.	Audit records show weed management plan requirements are being employed correctly. Audit of weed hygiene declaration forms Results of weed monitoring (post wet season) demonstrates that there has been no weed incursions as a results of project activities.

Environmental Value	Risk Sources	Environmental Outcome	Environmental Performance Standard	Measurement Criteria
Terrestrial Flora and fauna	Ignition sources from plant and machinery causing fire.	No fires as a result of ignition sources from plant and machinery	SDS available and appropriate fire-fighting equipment next to flammable material stores. Vehicles will have portable fire extinguishers and operational VHF or UHF radio transceivers. Petrol motor vehicles and petrol powered pumps will have spark arresters. Staff trained in use of fire-fighting equipment. Fire-fighting equipment available and serviced as per manufacturer's specifications. All staff inducted to this EMP.	Training records verify that operations personnel participate in regular fire and emergency drills. Site induction records shows all personnel have completed site inductions in accordance with section 8 of this Environmental Management Plan. Weekly checklist records demonstrate firefighting equipment and procedures are in place and serviced as per manufacturers specifications. Record audits shows toolbox meeting discussions of fire risk levels, fire risk management and remedial actions.
Terrestrial Flora and fauna	Ignition sources from flaring and production testing.	No fires as a result of flaring and production testing.	Firebreaks to be implemented around the lease. Flaring to have an appropriate buffer, with proper barriers to prevent access by livestock. Implementation of Fire Management Plan (Section 7.2). Implementation of the Emergency Response Plan.	Training records verify that operations personnel participate in regular fire and emergency drills. Records fire incidents and completed remediation in the Santos Incident Management System.
Terrestrial Flora and fauna	Waste stored inappropriately attracting fauna	No fauna congregating at waste storage areas.	All waste segregated and stored Appropriately in accordance with this EMP. Routine inspections of waste storage areas to ensure all waste are in the appropriate place. Only waste from approved wastewater systems and grey water disposed of to land. Licenced waste contractor used for any offsite transfer or disposal.	Weekly inspection records show waste receptacles are fauna proof. Waste records confirm storage and disposal of waste on and off site comply with this EMP.

Environmental Value	Risk Sources	Environmental Outcome	Environmental Performance Standard	Measurement Criteria
Terrestrial Environmental Quality	Vehicles leave the previously constructed roads or work areas	No disturbance outside designated areas	No off-road driving.	Site induction records shows all personnel have completed site inductions in accordance with section 7 of this Environmental Management Plan.
Terrestrial Environmental Quality	Inappropriate storage or handling of hazardous substances. Poor refuelling or fuel transfer practices result in spills or leaks	No spills of hazardous substances or fuels.	Secondary spill containment employed for storage of liquid chemicals and hydraulic fluid. Spill kits, spill containment, and appropriate bunding in all relevant areas. All spills and leaks are remediated as soon as possible. Fuel and other lubricants will be appropriately stored and managed, in accordance with industry standards. Compliance with the Spill Management Plan (Appendix H).	Weekly inspection checklists confirm all hazardous materials and stored and managed in accordance with the Environmental Performance Standards, the Code of practice and the WOMP. Records of spills and completed remediation in the Santos Incident Management System.
Terrestrial Environmental Quality	Inappropriate storage or handling of hazardous substances, including stimulation fluid and flowback fluid wastewater.	No overflowing tanks or treatment ponds.	Daily monitoring of weather and for predicted significant rainfall events will be undertaken. For produced water and flowback fluid treatment processes occurring outside of enclosed tanks A minimum of 1.5m freeboard will be maintained in all tanks/ponds that contain flowback fluid throughout the wet season.. Hydraulic fracture fluid system mixed into small volumes as needed, contained and monitored in engineered fluid storage tanks. All wastewater will be stored in enclosed tanks. All HFS work/mixing tanks are enclosed. Bunded containment for storage of liquid hydraulic fracturing materials. Implementation of the Wastewater Management Plan (Appendix G). Implementation of the Spill Management Plan (Appendix H).	Daily inspection records, tank level, structural integrity of storage tanks, flowlines inspected. Records of spills and completed remediation in the Santos Incident Management System.

Environmental Value	Risk Sources	Environmental Outcome	Environmental Performance Standard	Measurement Criteria
Terrestrial Environmental Quality	Transport vehicle accident due to weather	No long-term impacts to soil quality along transport route	All wastes to be transported in accordance with the NT Waste Management and Pollution Control Act All dangerous goods to be transported in accordance with the NT Dangerous Goods Act and Australian Dangerous Goods Code.	Wastewater management contractor is required to have a Journey Management Plan Records of spills and completed remediation in the Santos Incident Management System.
Inland Environmental Water Quality	Cross-flow during hydraulic fracture stimulation Faults or major structures enables cross-flow	No reduction in groundwater and surface water quality recorded.	A WOMP will be developed to cover well activities. The Project will not commence until a WOMP has been approved. Shallow aquifers are isolated behind cemented concentric casing strings. Cemented casing design criteria utilised following the Code of Practice requirements, will prevent aquifer cross-flow once well is constructed and passes well acceptance criteria. Installation of blow-out prevention equipment systems.	Ground water monitoring bores installed on location prior to hydraulic fracture operations. Baseline monitoring conducted six months prior to hydraulic fracture operations. Groundwater monitoring will occur in accordance with the *Preliminary Guideline: Groundwater Monitoring Bores for Exploration Petroleum Wells in the Beetaloo Sub-Basin* as updated from time to time or an alternative process agreed with DENR

Environmental Value	Risk Sources	Environmental Outcome	Environmental Performance Standard	Measurement Criteria
Inland Environmental Water Quality	Inappropriate storage or handling of hazardous substances, including stimulation fluid and flowback fluid wastewater. Poor refuelling or fuel transfer practices	The supply and quantity of water in surface water and groundwater features not impacted from project activities.	Daily monitoring of weather and for predicted significant rainfall events will be undertaken. For produced water and flowback fluid treatment processes occurring outside of enclosed tanks A minimum of 1.5m freeboard will be maintained in all tanks/ponds that contain flowback fluid throughout the wet season Spill containment employed for storage of liquid chemicals and hydraulic fluid. Spill kits, spill containment, and appropriate bunding in all relevant areas. All spills and leaks are remediated as soon as possible. Fuel and other lubricants will be appropriately stored and managed, in accordance with industry standards. Compliance with the Spill Management Plan (Appendix H).	Weekly inspection checklists confirm all hazardous materials and stored and managed in accordance with the Environmental Performance Standards, the Code of practice and the WOMP. Records of spills and completed remediation in the Santos Incident Management System.
Inland Environmental Water Quality	Transport vehicle accident due to weather	No long-term impacts to surface and groundwater water quality along transport route.	All wastes to be transported in accordance with the NT Waste Management and Pollution Control Act. All dangerous goods to be transported in accordance with the NT Dangerous Goods Act and Australian Dangerous Goods Code.	Licenced waste transporters used to transport listed wastes – waste transfer records retained and reported. Records of spills and completed remediation in the Santos Incident Management System.
Hydrological processes	Project groundwater extraction results in the reduction in groundwater quantity	No long-term impacts to groundwater resources in the area.	Compliance with groundwater extraction licence approval conditions (i.e. volume limits will not be exceeded).	Groundwater extraction volumes at the end of the project provided to DPIR and DENR. Regular testing of groundwater quality, extraction volumes and static water level recorded. Groundwater monitoring results show that water availability is unchanged.

Environmental Value	Risk Sources	Environmental Outcome	Environmental Performance Standard	Measurement Criteria
Air Quality and Greenhouse Gasses	Vehicle and plant emissions result in a reduction in air quality	No impact to air quality due to increased inefficient vehicle and plant emissions.	Vehicles and fixed plant maintained as per in accordance with manufacturers specifications and frequencies. Vehicles compliant with Northern Territory Motor Vehicle registry regulation and work health and safety regulations.	Audit records demonstrate engines and machinery have been maintained in accordance with required maintenance schedule.
Air Quality and Greenhouse Gasses	Project activities results in fugitive emissions	No impact to air quality due flaring and loss of fugitive emissions.	Gas detection monitoring will be conducted during all phases of the hydraulic fracturing operations. All wells will be tested every six months for any leaks Flaring will be used rather than venting The Methane Emissions Management Plan (Appendix J) will be implemented	All flaring will be measured using flow meters compliant with NGERS. Emissions will be reported in accordance with the NGERS. Baseline methane monitoring was completed by CSIRO prior to commencing stimulation as per the Code of Practice for Petroleum activities.
Social, Economic and Cultural Surroundings	Creation of dust results in loss of amenity	No public nuisance/visual amenity impacts from dust generated by project activities.	Driving is only permitted on designated access roads Speeds on unsealed roads will be limited to a maximum of 60 km/hr. No dust nuisance to users of adjacent land. Amicable resolution of complaints. No off-road driving. Vehicle speeds do not exceed 60km/hr on unsealed roads.	Site induction records show all personnel have completed site inductions in accordance with section 7 of this Environmental Management Plan. IVMS records show speed limits adhered to. Any off-road or night driving has been reported to the supervisor and investigated. Stakeholder engagement records demonstrate all reasonable dust complaints received were resolved; or if unable to be resolved, dust monitoring demonstrates dust emissions comply with the relevant legislation.

Environmental Value	Risk Sources	Environmental Outcome	Environmental Performance Standard	Measurement Criteria
Social, Economic and Cultural Surroundings	Noise from vehicle movements and project activities results in noise disturbance to landholders	No noise complaints	Vehicle speeds do not exceed 60km/hr on unsealed roads. Active stakeholder engagement and complaints management. Night time operations restricted (e.g. No HFS pumping will occur at night)	Stakeholder engagement records show active consultation with surrounding stakeholders on any potential noise increase and results of these consultations.
Social, Economic and Cultural Surroundings	Vehicle movements, project activities, and entrapment in open ponds results in disturbance, injury or death to livestock	No disturbance, injury or death to livestock from vehicle movements No entrapment of livestock in open ponds.	Vehicle speeds do not exceed 60km/hr on unsealed roads. No livestock access to ponds and tanks. Gates left in the condition in which they were found. Routine daily inspection ponds and tanks to ensure no trapped livestock.	Santos Field Environmental Checklist records demonstrates activities are being undertaken in accordance with the Environmental Performance Standards. Daily inspection records shows fences are intact and no livestock entrapment. Site induction records show all personnel have completed site inductions in accordance with section 7 of this Environmental Management Plan. Stakeholder engagement records demonstrate active stakeholder engagement (i.e. notification prior to the commencement of activities).

Environmental Value	Risk Sources	Environmental Outcome	Environmental Performance Standard	Measurement Criteria
Social, Economic and Cultural Surroundings	Vehicle and plant movements throughout the project area results in disturbance to landholders	No complaints from landholders. Amicable resolution of complaints.	Night time operations restricted (e.g. No HFS pumping will occur at night) All gates are left in the condition in which they were found (i.e. open / closed). Damage to station tracks and fences is reported and restored to satisfaction of landowner / managers.	Site induction records show all personnel have completed site inductions in accordance with section 7 of this Environmental Management Plan. Stakeholder engagement records demonstrate all reasonable disturbance complaints received were resolved; or if unable to be resolved, dust monitoring demonstrates dust emissions comply with the relevant legislation.
Human Health	Public ingesting dust causing health concerns	No public health concerns resulting from ingesting dust.	Water trucks will be used, to manage dust emissions from vehicle movement and hydraulic fracture activities as appropriate. No off-road driving. Vehicle speeds do not exceed 60km/hr on unsealed roads. Dust control measures implemented.	Site induction records show all personnel have completed site inductions in accordance with section 7 of this Environmental Management Plan. IVMS records show speed limits adhered to. Any off-road or night driving has been reported to the supervisor and investigated. All personnel have completed site inductions in accordance with section 7 of this Environmental Management Plan.

8.2 Santos EHS Management System

Santos manages the environmental impacts and risks of its activities through the implementation of the Santos Management System (SMS). The SMS provides a formal and consistent framework for all activities of Santos employees and contractors. The Santos SMS Framework is provided in Table 8-2.

The framework for the SMS includes:

- Constitution, Board Charters, Delegation of Authority - define the purpose and authorities of the Santos Limited Board, Board Committees and senior staff.
- Code of Conduct and Policies – outline the key requirements and behaviours expected of anyone who works for Santos. The Policies are set and approved by the Board.
- Management Standards - prescribe the minimum performance requirements and expectations in relation to the way we work at Santos (the ‘What’).
- Processes, procedures and tools - support implementation of the Management Standards and Policy requirements by providing detail of ‘How’ to achieve performance requirements.

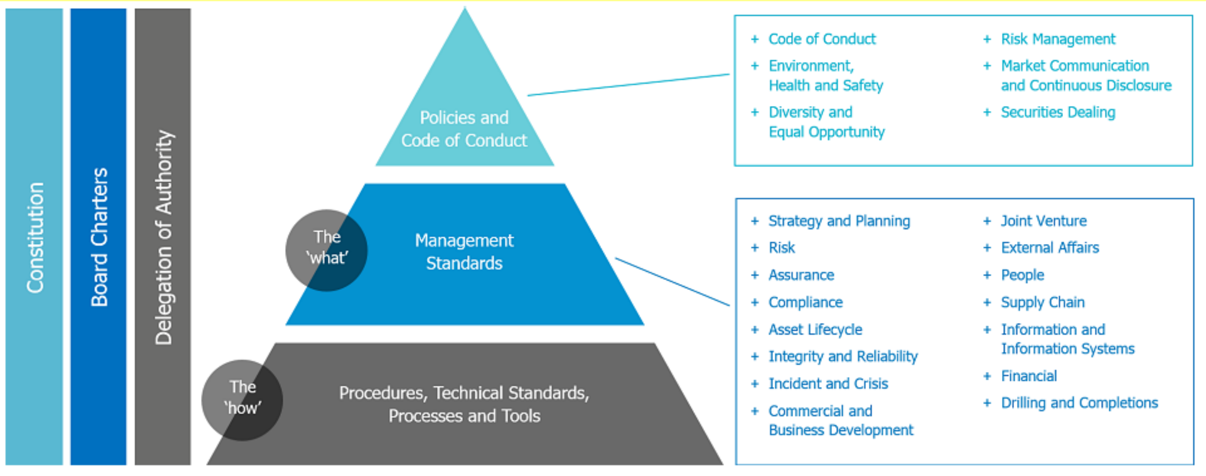

Table 8-2 Santos Management System Framework

8.3 Roles and Responsibilities

Key roles and environmental responsibilities for the activity are detailed in Table 8-3 and will be communicated to these positions prior to the activity commencing and when any changes are made to these positions.

Table 8-3 Key Personnel Roles and Responsibilities

Role	Responsibilities
Santos Field Drilling Supervisor	To supervise drilling and HFS completions engineering, planning, designing, contracting and supporting operations within Santos, ensuring compliance with SMS. To develop an environment that promotes innovation, collaboration and engineering excellence and manages engineering risk. Ensure adequate resources are in place to meet the requirements within the EMP. Undertake daily checklist as described in Table 6-1 Ensure incidents and non-conformances are managed as per Section 8.8 and 8.9.4 respectively. Report environmental incidents to the Exploration Manager and ensure reporting (Table 8-4) and investigations undertaken. Ensure records and documents are managed so they are available and retrievable (Section 8.9.1). Ensure non-conformances identified are communicated, raised in EHS Toolbox and corrective actions completed (Section 8.9.4).
NT Exploration Manager	Notify DPIR of a change in titleholder, a change in the titleholder's nominated liaison person or a change in the contact details for either (Section 8.6). Ensure overall compliance with the EMP. Ensure compliance with SMS including the EHS Policy. Ensure relevant environmental legislative requirements, performance outcomes, performance standards, measurement criteria and requirements in the implementation strategy in this EMP are: Communicated to the activity key personnel Audited to inform the EMP Performance Report. Ensure the EMP Performance Report is prepared and submitted to DPIR (Section 8.10).
Santos Land Access Adviser	Undertake consultation with relevant persons throughout project planning and implementation. Document consultation with relevant persons. Ensure any commitments to relevant persons are undertaken.
Santos Environment Lead	Identify and communicate relevant environmental legislative requirements, Performance Outcomes, Environmental Performance Standards, Measurement Criteria and requirements in the implementation strategy in this EMP to the NT Exploration Manager and Santos Drilling Field Supervisor. Develop the environmental component of the activity induction (Section 8.4). Assess any environmentally relevant changes (Section 8.6). Review any non-conformances relevant to Environment Performance to ensure corrective actions are appropriate to prevent recurrence (Section 8.9.4). Prepare and submit the Environmental Performance Report quarterly (unless otherwise determined by the Minister) to DPIR within 15 days of the quarter finishing (Section 8.10).

8.4 Training and Competencies

Santos staff and contractors undertaking work in the field are required to undertake a two-stage induction process. The general Onshore EHS Induction focuses on hazard identification and sets Santos' expectations for Environment, Health and Safety management for workers at Santos' onshore operational sites.

The general Onshore EHS Induction is supported by an activity specific induction. All field personnel will be required to complete the activity specific induction that will cover the requirements in this EMP. At a minimum, the induction will cover:

- Activity description
- Environmental

- Environmental impacts and risks, and associated controls to be implemented including cultural heritage
- Management of change process
- Roles and responsibilities
- Incident and non-conformance reporting and management

Key roles for the activity, as detailed in Table 8-3, will be specifically briefed on their roles and responsibilities for this project in addition to the inductions.

Competency of contractors is assessed as part of the contracting qualification and via the prestart audit.

Competencies assessed during the contracting process includes;

- Maturity of EHS systems
- EHS Performance
- Internal training and auditing processes
- Existing procedures and training
    - Weed identification and management
    - Refuelling procedures
    - Procedures for clearing
    - Hazardous material and waste management procedures
    - Incident notification and management processes.

8.5 Santos Drilling and Completions

The objective of Santos Drilling and Completions (D&C) is to be a leader in D&C operations, delivering injury free operations that are fit for purpose, upholding health and safety standards for our personnel and the community and minimising environmental impacts. The Santos Policies and Management Standards provide clear direction for the way of working in Santos D&C. The D&C Management Process Description, the D&C Management Process Workflow and the D&C Technical Standards are the governing documents used to meet the performance requirements of the D&C Management Standard.

Santos D&C Managers are responsible for ensuring D&C team members are selected, trained, developed and evaluated periodically to ensure they attain and maintain the level of competency required for the position they hold.

The D&C workflow provides a structured planning process that is divided into five phases. Key aspects of the workflow are governance and assurance which are provided by the assurance review system. This is a complimentary process to the overarching asset lifecycle framework, where projects contain a D&C component, some of the D&C materials and review outcomes may be used as inputs to the asset lifecycle framework.

Santos is responsible for the well design and planning, including preparing and obtaining approval from the authorities for operations programs. In addition, Santos provides well construction materials and a number of third party and support services which have a direct impact on the day-to-day management of EHS on the rig and on the management of incident response. Assurance is provided by the appointment of Competent Personnel and the development of a number procedures and plans aimed at delivering a high standard of environmental and safety performance. These include the Emergency Response Plan and the Well Operations Management Plan (WOMP) will be developed prior to the commencement of drilling activities in 2019:

8.5.1 Emergency Response Plan

The Emergency Response Plan (Appendix K) for the activity will be prepared by the contractors and will be provide to DPIR and made available upon request. If the Emergency Response Plan is updated, a revised version will be provided to DENR.

The emergency response arrangements within the Emergency Response Plan will be exercised early in the campaign to ensure that personnel are familiar with the plan and the type of emergencies to which it applies and that there will be a rapid and effective response in the event of a real emergency occurring. Following the exercise, lessons will be captured and the plan updated if required.

Other triggers for revising or updating the Emergency Response Plan may include:

- New information becomes available following an incident, near miss or hazard
- Learnings from an exercise or drill
- Change in contractor undertaking the work
- Organisational changes
- Changes to government agency contact details or portfolios

8.5.2 Well Operations Management Plan

Well Operations Management Plan (WOMP) will be submitted to the regulator for approval prior to spud of the first well activity to which the plan would apply. The WOMP will provide details on:

- Description of the well and well activities
- Well integrity risk management process
- Design, construction, operations and management of wells
- Performance outcomes
- Well lifecycle control measures
- Performance standards for control measures
- Performance objectives measurement criteria
- Monitoring, audit and well integrity assurance
- Well Abandonment and suspension considerations
- Responsibilities and competencies of contractors service providers
- Source control and blowout contingency measures

A copy of the approved WOMP will be provided to DENR post approval by the regulator.

8.6 Notice of Commencement

Santos will notify the Minister and the Tanumbirini station owner of the proposed date of commencement of construction, drilling or seismic surveys through the submission of a letter.

8.7 Management of Change

The SMS establishes the processes required to ensure that when changes are made to a project, control systems, an organisational structure or to personnel, the EHS risks and other impacts of such changes are identified and appropriately managed.

The SMS requires that all environmentally relevant changes must obtain environmental approval (internal i.e. within Santos and/or external i.e. regulatory) prior to undertaking any activity.

Environmentally relevant changes include:

a) New activities, assets, equipment, processes or procedures proposed to be undertaken or implemented that have potential to impact on the environment and have not been:
   - Assessed for environmental impact previously, in accordance with the requirements of the standard; and
   - Authorised in the existing management plans, procedures, work instructions, or maintenance plans.

b) Proposed changes to activities, assets, equipment, processes or procedures that have potential to impact the environment or interface with an environmental receptor.

c) Changes to requirements of an existing external approval (e.g. changes to conditions of environmental licence).

d) New information or changes of information from research, stakeholders, legal and other requirements, and any other sources used to inform the EMP.

Where an environmentally relevant change is identified, the Management of Change (MoC) is assessed by an Environmental Adviser and if required appropriate technical and/or legal advice is sought. The MoC assessment is made against the approved EMP to ensure that impacts and risks from the change can be managed to ALARP and acceptable levels.

In the event that the proposed change is a significant modification or new stage of activity, introduces a significant new environmental impact or risk, results in a significant increase to an existing environmental impact or risk, or, as a cumulative effect results in an increase in environmental impact or risk, this EMP will be revised and submitted for re-assessment and acceptance by the regulator.

Table 1-1 details the permit titleholder, activity nominated liaison person and contact details for both. A change in any of these details are required to be notified to DENR and DPIR.

8.8 Incident Reporting

Incidents that impact on the environment or have the potential to impact on the environment (near-miss) are to be reported and entered into the EHS Toolbox Incident Management System (IMS).

Table 8-4 details the external incident notification, reporting requirements and timeframes for environmental incidents associated with the activity.

Table 8-4 Incident Reporting Requirements

Requirements	How and by when
Petroleum (Environment) Regulations	
Revision of an EMP	
A revision of an EMP is required if there has been a new environmental impact or an increase in an in an existing environmental impact or environmental risk, not provided for in the current plan for the activity the interest holder must submit to the Minister, for approval.	A proposed revision of the current plan must be provided no later than 30 days after the new environmental impact or environmental risk has occurred.
An interest holder for a current plan must submit to the Minister, for approval, at the end of each period of 5 years.	The proposed revision of the current must be submitted at least 90 days before the end of each period of 5 years.
Modification of an EMP	
If an interest holder for a current plan proposes to modify the regulated activity to which the plan relates in a manner that will not require a revision of the plan, must give the Minister a notice that specifies details of the proposed modification.	Before the interest holder modifies the regulated activity, the holder must give the Minister a notice that specifies details of the proposed modification.
If there is a change in the existing environment that is described in a current plan and the change will not require a revision of the plan, the interest holder for the current plan must give the Minister a notice that specifies details of the change	the interest holder for the current plan must give the Minister a notice within 30 days after the change occurs,
Recordable Incident Reporting	
A recordable incident is a breach of an Environmental Objective or Environmental Performance Standard in the Environment Management Plan that applies to the activity; and is not a reportable incident.	Unless otherwise advised by the minster an Environmental Performance Report will be provided quarterly.

Requirements	How and by when
The recordable incident report must contain: (i) a record of all recordable incidents that occurred during the reporting period; and (ii) all material facts and circumstances concerning the recordable incidents that the operator knows or is able, by reasonable search or enquiry, to find out; and (iii) any action taken to avoid or mitigate any adverse environment impacts of the recordable incidents; and (iv) the corrective action that has been taken, or is proposed to be taken, to prevent similar recordable incidents	
Reportable Incident Reporting	
A reportable incident is an incident relating to the activity that has caused, or has the potential to cause material or serious environmental harm as defined under the Petroleum Act. Based on the Santos Risk Matrix this is an incident that has an actual or potential consequence ≥ III.	
The **initial verbal report** will include as much preliminary information as is available about the incident (e.g. interest holder, location, type of incident, affected stakeholders, initial assessment of environmental harm and initial response).	The initial verbal report will be made as soon practicable but no later than 2 hours after the incident first occurred or when Santos became aware of the reportable incident to the DPIR Operations Team Emergency Number (**1300 935 250**) or in writing.
The initial written report will include: a) The results of any assessment or investigation of the conditions or circumstances that caused or contributed to the occurrence of the reportable incident, including an assessment of the effectiveness of the designs, equipment, procedures and management systems that were in place to prevent the occurrence of an incident of that nature; b) the nature and extent of the material environmental harm or serious environmental harm that the incident caused or had the potential to cause; c) any actions taken, or proposed to be taken, to clean up or rehabilitate an area affected by the incident; any actions taken, or proposed to be taken, to prevent a recurrence of an incident of a similar nature.	The initial written report will be provided as soon as practicable but not later than 3 days after the reportable incident first occurs.

Requirements	How and by when
Interim reports will include: a) The results of any assessment or investigation of the conditions or circumstances that caused or contributed to the occurrence of the reportable incident, including an assessment of the effectiveness of the designs, equipment, procedures and management systems that were in place to prevent the occurrence of an incident of that nature; b) the nature and extent of the material environmental harm or serious environmental harm that the incident caused or had the potential to cause; c) any actions taken, or proposed to be taken, to clean up or rehabilitate an area affected by the incident; any other matters relevant to the reportable incident.	Interim reports to be provided as agreed with the Minister or at intervals of 90 days, starting on the day the initial report was given.
The **final reportable incident report** must include a root cause analysis of the reportable incident.	The final report to be provided to the Minister as soon as practicable but no later than 30 days after the clean up or rehabilitation of the area affected by the reportable incident is completed.
Flowback fluid reporting	
Santos will give the Minister a report about flowback fluid. The report must contain the following information: a) the identity of any chemical or NORM found in the flowback fluid; b) the concentration of any chemical or NORM found in the flowback fluid; c) details regarding how any chemical or NORM has been or will be managed; d) details regarding how any chemical or NORM has been or will be transported; Part 3A Reporting requirements for hydraulic fracturing Petroleum (Environment) Regulations 2016 28 e) details regarding how any chemical or NORM has been or will be treated; f) details regarding any action proposed to be taken to prevent any chemical or NORM spill; g) details of the emergency contingency plan included in the environment management plan to which the activity relates; the requirements in relation to the management of any chemical or NORM of the prescribed chemical legislation.	Within 6 months of the flowback occurring
Waste Management and Pollution Control Act	

Requirements	How and by when
Duty to notify of incidents causing or threatening to cause pollution. Where an incident occurs in the conduct of an activity and the incident causes, or is threatening or may threaten to cause, pollution resulting in material environmental harm or serious environmental harm. A notification is required to specify a) the incident causing or threatening to cause pollution; b) the place where the incident occurred; c) the date and time of the incident; d) how the pollution has occurred, is occurring or may occur; e) the attempts made to prevent, reduce, control, rectify or clean up the pollution or resultant environmental harm caused or threatening to be caused by the incident; and the identity of the person notifying.	The proponent must notify the NT EPA as soon as practicable after (and in any case within 24 hours) first becoming aware of the incident or the time they ought reasonable be expected to become aware of the incident.
Heritage Act	
When a proponent discovers a place or object that is known to be Aboriginal or Macassan archaeological place or object, they must provide • a description of the place or object; • its location; • the person's name and address; if known by the person –the name and address of the owner or occupier of the place or place where the object is located.	The proponent must provide the CEO a written report as soon as practicable but within seven days of discovery..
Work Health and Safety (National Uniform Legislation) Act	
A person who conducts a business or undertaking must ensure that the regulator is notified immediately after becoming aware that a notifiable incident arising out of the conduct of the business or undertaking has occurred. notifiable incident means: (a) the death of a person; or (b) a serious injury or illness of a person; or (c) a dangerous incident	Any person who conducts a business or undertaking

8.9 Environmental Performance Monitoring and Reporting

8.9.1 Monitoring

Santos will undertake a suite of monitoring to implement this management plan and to deliver on the obligations described in Table 8-1. A summary of the key monitoring requirements is listed below in

Table 8-5 Environmental Monitoring

Monitoring program	Frequency	Requirement Source	Reporting
Weed Monitoring	Ongoing during civil and seismic program Annual to coincide with the end of the wet season	Weed Management Plan The Code	Annual Report

Monitoring program	Frequency	Requirement Source	Reporting
Ecological Monitoring	Ongoing in accordance with the WWMP	The code	Annual Report
Groundwater Monitoring	Ongoing in accordance with the groundwater monitoring plan	Northern Territory Government guidelines for groundwater monitoring for petroleum operations The Code	Annual Report Quarterly laboratory reporting to DENR for publication on DENR website
Weather Monitoring	Daily forecast provided by the Bureau of Meteorology	The Code	Notification triggers dependant on forecast
Wastewater Storage Tank Monitoring	Ongoing in accordance with the WWMP	The Code	Reporting in accordance with Table 8-4 and the WWMP.
Methane Monitoring	Ongoing in accordance with the Methane Monitoring Plan	The Code	Annually NGRS reporting and Leak reporting in accordance with the Methane Emissions Management Plan
Flowback Monitoring	Ongoing in accordance with the WWMP	The Code Petroleum (Environment) Regulations	Reporting in accordance with Table 8-4 and the WWMP.
Rehabilitation Monitoring	Photo points established and revisited.	Rehabilitation Management Plan The Code	Environment Reports submitted to DENR and DPIR

8.9.2 Record Management

Key records for management relating to the activity include:

- Weed washdown records
- Induction records
- Weekly checklists
- Training records
- Photopoint records
- Records of monitoring program
- Records related to audits / inspections
- Records relating to investigation of incidents and non-compliances.

8.9.3 Records will be managed in accordance with Regulation 36 of the Petroleum (Environment) Regulations 2016. Audit

To ensure that the EMP requirements have been effectively implemented and that the Environmental Outcomes and Environmental Performance Standards have been met, a daily checklist will be completed on site by the Santos NT Projects Drilling Supervisor. The checklist will ensure compliance with mitigation and management measures detailed in Table 6-1.

Audit / review findings including actions are communicated to the Santos and Contractor Project Managers and Santos Field Representative. Actions are agreed with all parties and assigned an actioner and required completion date. The audit and actions are recorded in the Santos EHS Toolbox Audit & Compliance Manager which notifies the actioner and their manager when actions are due. If actions are not closed within the due date the system has a hierarchy notification system based on the number of days an action is overdue as to the level of manager who receive notification of the overdue action.

8.9.4 Management of Non-Conformances

For the activity, a non-conformance is classed as:

- A breach of an Environmental Outcome or Environmental Performance Standard (Section 7). This triggers the requirement to report as a "recordable incident" as per Section 8.7.
- Failure to implement a requirement in the implementation strategy.

Non-conformances are identified via:

- Audits and inspections
- Incident reporting and investigations

Where a non-conformance is identified, actions are implemented to correct the non-conformance and prevent reoccurrence.

To ensure that non-conformances lead to learning and improvements for the activity and on a company-wide basis, non-conformance are:

- Communicated to the NT Exploration Manager via Santos EHS Toolbox (see below), daily and weekly meetings and the appropriate reports (i.e. audit, performance, incident investigation) to ensure personnel are made aware of non-conformances and corrective actions to help prevent recurrence of similar incidents.
- Communicated to operational personnel at daily pre-start meetings via the Santos Drilling Field Supervisor to ensure personnel are made aware of non-conformances and corrective actions to help prevent recurrence of similar incidents.
- Communicated internally within Santos as per the Santos Internal Incident Notification Guide and where there are lessons learnt that are applicable to other areas of the business a Flash Notification is issued.
- Recorded in Santos EHS Toolbox and actions tracked to completion.
- Reviewed by the actioner's manager prior to being closed to ensure actions are completed and implemented.

8.10 Routine Reporting

As detailed in Table 8-4, Santos will submit an Environmental Performance Report quarterly (unless otherwise advised by the Minister) to DENR (unless otherwise agreed by the Minister) which provides information where there has been a breach of an Environmental Objective or Environmental Performance Standards detailed in this Environment Management Plan. The Environmental Performance Report will include actions taken to avoid or mitigate any adverse environment impacts of the recordable incidents and the corrective action proposed or undertaken to prevent similar recordable incidents. The quarterly report (including "nil" incidents) will be provided to DENR as required under Part 3, Division 1, Regulation 35 of the Petroleum (Environment) Regulations.

In addition, Santos will give the Minister a report about flowback fluid within 6 months of the flowback occurring. See Table 8-4 for more information.

9.0 Stakeholder Engagement

Santos is committed to upholding its long-held reputation as a trusted Australian energy company.

Santos seeks to establish and maintain enduring and mutually beneficial relationships with the communities of which it is a part; ensuring that Santos' activities generate positive economic and social benefits for and in partnership with these communities.

The Santos Management System (SMS) details the requirements for appropriate communication and consultation mechanisms to achieve the above objectives. The standard includes requirements to establish and maintain communication links with employees, contractors and external stakeholders, including local communities, government agencies and other organisations. Reporting and notification of EHS incidents to the appropriate government agency occurs as required. The SMS will be employed throughout this project.

9.1 Stakeholder Identification

Stakeholder identification was conducted prior to commencing drilling works at Tanumbirini 1 in 2014. The relevant stakeholder groups were identified and engaged such that they could be informed of the proposed activities and the associated risks, build an understanding as to why and how Santos operations and have any objections or claims considered and addressed. A key component of the engagement process was face-to-face briefing sessions with key stakeholders one-on-one and at local community events. Key relevant stakeholder groups include community, landholders, traditional owners and aboriginal peoples, and the Northern Territory Government departments. A list of the relevant stakeholders identified as well as contact details are provided in Appendix I.

9.2 Stakeholder Engagement Activities

Santos has continued to engage with these key stakeholders on an ongoing basis since initial identification, specifically with regard to this project and development in the Northern Territory generally. This includes providing information, presentations and mapping to key stakeholders. Government and industry stakeholders are updated through regularly scheduled industry and governmental joint meetings and one off conferences. Santos' industry and government engagement includes:

NT Resources Week South East Asia Australia Onshore Conference (SEAAOC) in September 2018. SEAAOC is Northern Australia's largest and longest established petroleum conference and brings together major players involved within Australasia's oil, gas and petroleum industries. During SEAAOC, Kevin Gallagher (Managing Director and CEO) gave a keynote speech. Other Santos delegates included:

- Bill Ovenden (Executive Vice President, Exploration and New Ventures)
- Tracey Winters (Head of Government and Public Affairs).

A meeting to discuss the 2019 work program and approvals including the scope of this EMP was completed on 31 January 2019. Meeting involved staff from Department of Chief Minister, Department of Trade Business and Innovation, DPIR, DENR and AAPA.

A meeting to discuss 2019 program and approvals including the scope of this EMP was conducted on 6 December 2018 with staff from DPIR and DENR.

A meeting to discuss 2019 program and approvals including the scope of this EMP was conducted on 5 December 2018 with the Board of the EPA.

Ongoing discussions and weed management planning has been conducted with Tahnee Hill – Regional Weed Officer (Onshore Shale Gas Development) – DENR. This consultation has included a site visit in August 2018, review, and approval of weed management plans and procedures.

In addition, Santos was actively engaged with the Hydraulic Fracturing Inquiry and its subsequent implementation process – providing detailed information to the Inquiry drawing from our existing knowledge of the Beetaloo region, the initial exploration activities that have occurred there and our extensive experience in gas exploration. Santos engages regularly with officials of the departments of Chief Minister, Primary Industries and Resources, and Environment and Natural Resources to advance the implementation of the 135 recommendations of the Pepper Inquiry.

Santos has agreed to support and contribute to the funding of the CSIRO led Gas Industry Social and Environmental Research Alliance (GISERA) to undertake research in the Beetaloo area. We have provided DENR with access to our existing groundwater monitoring data and data collected by CSIRO on our behalf over recent years, and have facilitated initial survey work by CSIRO for methane and in collaboration with DENR for weed monitoring. Santos is committed to the timely release of information from these research processes to ensure that all stakeholders are fully informed about the true state of the environment in the exploration area, and any impacts should they occur.

Engagement with the NLC, AAPA and Traditional Owners occurred throughout 2018 and are continuing in 2019. Formal engagements included:

- Meeting with AAPA on the northern and southern scope of Beetaloo work program, including the scope of this EMP, was conducted on 31 January 2019. ** Names Redacted **

- Presentation to Northern Land Council on the 2019 work program was conducted on 1 February 2019. Specifically this presentation identified 2019 activities in EP 161, which include the scope of this EMP. Discussions focused on timeline, agreement commitments including clearance, consent and community consultation meetings. ** Names Redacted **

- Meeting with NLC to discuss future clearance requirements and resourcing on 2 April 2019
- Discussion with AAPA to discuss Authority Certificate application reference 201900379 and the 2019 proposed work program on 1 and 2 April 2019

Other stakeholder engagement has involved engagement with landholders/managers and the Northern Land Council as documented in Appendix I. Appendix I details the information that has been provided to these key stakeholders, including the type of information and date of engagement. Landholders have been consulted on the proposed activities and have been directly involved in an on-ground inspection of proposed infrastructure locations. Land Access and Compensation Agreements (LACA) have been progressed and all LACAs will put be in place during the EMP assessment period and prior to Approval.

9.3 Ongoing Consultation

Prior to any land access a notice of entry is issued to the landholder. Santos will not access any person's land without prior consent in the form of a written agreement and in accordance with relevant policies and guidelines. Where stakeholders have requested or Santos believes it would be beneficial to engage with stakeholders on an ongoing basis during the activity, communications will continue until the activity has concluded.

Stakeholder engagement throughout 2019 and 2020 will be comprehensive. Prior to the 2019 program Santos commits to further engagement with:

- Northern Land Council
- Tanumbirini Station Manager
- Owners of Tanumbirini Station
- Local business (e.g. Hi-Way Inn, Daly Waters Pub, Borroloola Hotel Motel, Savannah Way Motel)
- Roper Gulf Regional Council and Barkly Regional Council
- Traditional Owners
- Annual Geosciences Exploration Seminar (AGES); Alice Springs in March
- Northern Territory Government Departments

9.4 Specific Stakeholder Engagement

Consultation with consideration to environmental impacts associated with Santos' activities on Tanumbirini Station has been undertaken with both the owners representatives based in London and also the station manager. The station manager has been consulted and involved in the scouting/scoping process for all proposed disturbance areas, the local knowledge that the station manager has been beneficial from both a property and Santos perspective. During the negotiation of the LACA with the Tanumbirini Station owners representatives a number of matters related to environmental management and potential environmental impacts were discussed with the both parties agreeing these matters were considered appropriately in the LACA.

From previous Santos operations on Tanumbirni Station, the property owners are aware of Santos' methodology in minimising environmental impacts, as the station manager is involved in the scouting/scoping process he has input into how and what occurs on the property. This oversight from the station manager will continue during all Santos operations on the property for the term of the LACA.

During Santos operations on Tanumbirini Station a Land Access Field Supervisor is present and is accommodated at the Tanumbirini homestead, this allows for open dialogue around both station operations and Santos operations to ensure that potential impacts are avoided. Significant time was also spent during LACA negotiations with the owners representative to ensure that they are comfortable that their rights and activities are adequately considered.
he Station Manager has been involved in all of the scouting/scoping of work so all activities have been covered off from an environmental consideration viewpoint with Mick, they also have explicit coverage in the LACA for environmental impacts associated with our activities on the property.

Detailed engagement records for stakeholder engagement with landholders/managers and the Northern Land Council is documented in Appendix I.

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