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BEEHIVE 3D MARINE SEISMIC SURVEY

ENVIRONMENT PLAN SUMMARY

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1 *INTRODUCTION*

1.1 *SCOPE OF THIS ENVIRONMENT PLAN*

Finniss Offshore Exploration Pty Ltd (Finniss) is the sole titleholder of exploration permit WA-488-P. Finniss is a wholly owned subsidiary of Melbana Energy Limited (formerly MEO Australia). Pursuant to an Operations Services Agreement dated 21 November 2017 between Finniss, Melbana and Santos Offshore Pty Ltd (Santos), Finniss has engaged Santos to perform certain operational services in connection with the acquisition of 3D seismic survey data over exploration permit WA-488-P, including undertaking the Beehive 3D MSS.

This Environment Plan (EP) has been prepared in accordance with the requirements of the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (OPGGS Act) and associated Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (OPGGS[E]R). It has also been prepared with reference to the Environment Plan Content Requirements Guidance Note (Rev 3, April 2016) produced by the National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA).

1.2 *TITLEHOLDER AND NOMINATED LIAISON PERSON*

Table 1.1 provides details of the WA-488-P permit titleholder and titleholder nominated liaison person.

As per *Section 8.4*, in the event that 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 NOPSEMA and provide the updated details.

Table 1.1 Details of WA-488-P titleholder and nominated liaison person

Titleholder Details	Liaison Person Details
Finniss Offshore Exploration Pty Ltd Level 15, 500 Collins Street Melbourne, VIC, 3000 P: +61(3) 8625 6000 Fax: +61(3) 9614 0660 Email: admin@melbana.com ACN 161 078 253	Andrew White Senior Surveyor, Geophysical Services Santos Limited 60 Flinders Street, Adelaide SA 5000 08 8116 7260 Email: andrew.white@santos.com

2 *ENVIRONMENTAL REQUIREMENTS*

This section provides information on the requirements that apply to the activity and how they apply to the activity. Requirements include relevant laws, codes, other approvals and conditions, standards, agreements, treaties, conventions or practices (in whole or part) that apply to jurisdiction that the activity takes place in.

The Beehive 3D MSS will take place within Commonwealth waters. The impact assessment undertaken and documented in *Section 7* did not identify any impacts or risks to Western Australia (WA) State or Northern Territory (NT) waters.

There are no other approvals and conditions that apply to the survey.

Relevant requirements associated with the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), related policies, guidelines, plans of management, recovery plans, threat abatement plans and other relevant advice issued by the Department of Environment and Energy (DoEE) are detailed in the applicable sections within *Section 5* as part of the description of the existing environment.

Table 2.1 provides a summary of requirements that apply to the activity and are relevant to the activity's environmental management.

Table 2.1 Summary of requirements relevant to the activity and its environmental management

Requirements	Scope	How it Applies to the Activity or Activity's Environmental Management	Administering Authority
Australian Maritime Safety Authority Act 1990	Facilitates international cooperation and mutual assistance in preparing and responding to major oil spill incidents, and encourages countries to develop and maintain an adequate capability to deal with oil pollution emergencies.	In Commonwealth waters AMSA is the Statutory Agencies for vessels and must be notified of all incidents involving a vessel. *Section 8.7 details this requirement.* In Commonwealth waters AMSA is the Control Agency for all ship-sourced marine pollution incidents and will respond in accordance with its Marine Pollution Response Plan. Santos has a MoU with AMSA on Support for Oil Spill Preparedness and Response. *These arrangements are detailed in Section 7.3 of the OPEP.*	Australian Maritime Safety Authority (AMSA)
Biosecurity Act 2015 Biosecurity Regulations 2016	The objects of this Act are: (a) to provide for managing the following: (i) biosecurity risks; (ii) the risk of contagion of a listed human disease; (iii) the risk of listed human diseases entering Australian territory or a part of Australian territory, or emerging, establishing themselves or spreading in Australian territory or a part of Australian territory; (iv) risks related to ballast water; (v) biosecurity emergencies and human biosecurity emergencies; (b) to give effect to Australia's international rights and obligations, including under the International Health Regulations, the SPS Agreement and the Biodiversity Convention.	The Biosecurity Act and regulations apply to 'Australian territory' which is the airspace over and the coastal seas out to 12 nm from the coast line. *Biosecurity risks associated with the survey are detailed in Section 7.10*	Department of Agriculture and Water Resources (DAWR)
Biosecurity Act 2015	Australian Ballast Water Management Requirements (DAWR 2017)	Provides guidance on how vessel operators should manage ballast water when operating within Australian seas in order to comply with the Biosecurity Act. *Section 7.10 details these requirements.*	DAWR

Requirements	Scope	How it Applies to the Activity or Activity's Environmental Management	Administering Authority
Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)	The EPBC Act aims to protect the environment, particularly matters of national environmental significance for which Australia has made international agreements. The Act streamlines national environmental assessment and approval processes, and promotes ecologically sustainable development and conservation of biodiversity. It also provides for a cooperative approach to the management of natural, cultural, social and economic aspects of ecosystems, communities and resources.	Petroleum activities are excluded from within the boundaries of a World Heritage Area (Sub regulation 10A(f). *Section 5.10 details that the survey is not within the boundaries of a World Heritage Area.* The EP must describe matters protected under Part 3 of the EPBC Act and assess any impacts and risks to these. *Section 5 describes matters protected under Part 3 of the EPBC Act.* *Section 7 provides an assessment of any impacts and risks to matters protected under Part 3 of the EPBC Act.*	Department Environment and Energy (DoEE)
EPBC Act	Section 3A of the Act defines the principles of ecological sustainable development. The following principles are principles of ecologically sustainable development : (a) decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations; (b) if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation; (c) the principle of inter-generational equity--that the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations; (d) the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making; (e) improved valuation, pricing and incentive mechanisms should be promoted.	Petroleum activities must be carried out in a manner consistent with the principles of ecological sustainable development set out in Section 3A of the EPBC Act. *Section 6.9 Determination of Impact and Risk Acceptability details that residual risks between 2 and 4 need to show that ALARP is demonstrated and the principles of ecologically sustainable development have been met.*	Department Environment and Energy (DoEE)

Requirements	Scope	How it Applies to the Activity or Activity's Environmental Management	Administering Authority
EPBC Act Policy Statement 2.1 Interaction between offshore seismic exploration and whales	The aim of this Policy Statement is to: 1. provide practical standards to minimise the risk of acoustic injury to whales in the vicinity of seismic survey operations; 2. provide a framework that minimises the risk of biological consequences from acoustic disturbance from seismic survey sources to whales in biologically important habitat areas or during critical behaviours; and 3. provide guidance to both proponents of seismic surveys and operators conducting seismic surveys about their legal responsibilities under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).	The policy statement provides guidance on undertaking seismic activities in Australian waters to limit potential impacts to whales. *Section 7.1 details how the policy statement has been applied to this survey.*	Department Environment and Energy (DoEE)
Environment Protection and Biodiversity Conservation Regulations 2000	Provides additional regulations in regards to Matters of National Environmental Significance.	Part 8 of the Regulations details requirements for operating vessels and aircraft in relation to cetaceans. The requirements are detailed in the Australian National Guidelines for Whale and Dolphin Watching (DEWHA, 2005) *Section 7.2 and 7.8 detail these requirements.*	Department Environment and Energy (DoEE)
Historic Shipwrecks Act 1976	Protects the heritage values of shipwrecks and relics (older than 75 years) below the low water mark.	Anyone who finds the remains of a ship, or an article associated with a ship, needs to notify the relevant authorities, as soon as possible but ideally no later than after one week, and to give them information about what has been found and its location. *Section 5.9 details that there are no historic shipwrecks near or within the permit areas.*	Department Environment and Energy (DoEE)
Navigation Act 2012	Regulates international ship and seafarer safety, shipping aspects of protecting the marine environment and the actions of seafarers in Australian waters. It gives effect to the relevant international conventions (MARPOL 73/78, COLREGS 1972) relating to maritime issues to which Australia is a signatory.	COLREGS - International Regulations for Preventing Collisions at Sea - Rule 27 covers light requirements for vessels not under command or restricted in their ability to manoeuvre. Several Marine Orders (MO) are enacted under this Act relating to offshore petroleum activities, including: • MO Part 21: Safety of navigation and emergency procedures • MO Part 27: Radio equipment • MO Part 30: Prevention of collisions • MO Part 31: Vessel; Surveys and Certification	AMSA

Requirements	Scope	How it Applies to the Activity or Activity's Environmental Management	Administering Authority
	The Act also has subordinate legislation contained in Regulations and Marine Orders.	• MO Part 32: Cargo handling equipment • MO Part 59: Offshore Support Vessel Operations *Section 7 details where the applicable requirements apply to the survey.*	
Offshore Petroleum and Greenhouse Gas Storage Act 2006 Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009	Addresses all licensing, health, safety, environmental and royalty issues for offshore petroleum exploration and development operations extending beyond the three nautical mile limit. Ensures that petroleum activities are undertaken in an ecologically sustainable manner and in accordance with an approved EP.	A titleholder must have an in force EP prior to the commencement of any petroleum activity. *This requirement is met by submission and acceptance of this EP.* A significant modification, change or new stage of an existing activity that is not included in an in force EP requires a revision of the EP to be submitted to NOPSEMA for acceptance. *Section 8.4 details this requirement.* Titleholders are required to maintain financial assurance sufficient to give the titleholder carrying out the petroleum activity, the capacity to meet the costs, expenses and liabilities that may result in connection with carrying out the petroleum activity; doing any other thing for the purpose of the petroleum activity; or complying (or failing to comply) with a requirement under the OPGGS Act in relation to the petroleum activity. *This requirement is required to be met by the titleholder before NOPSEMA can accept the EP.*	National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA)
Offshore Petroleum and Greenhouse Gas Storage (Regulatory Levies) Act 2003 Offshore Petroleum and Greenhouse Gas Storage (Regulatory Levies) Regulations 2004	An Act to impose levies relating to the regulation of offshore petroleum activities and greenhouse gas storage activities.	Requires that EP levies are imposed on EP submissions, including revisions, where the activities to which the EP relates are authorised by one or more Commonwealth titles. *This requirement applies once the EP is accepted.*	NOPSEMA
Protection of the Sea (Prevention of Pollution from Ships) Act 1983	Regulates ship-related operational activities and invokes certain requirements of the MARPOL Convention relating to discharge of noxious liquid substances, sewage, garbage, air pollution etc.	Provides exemptions for the discharge of materials in response to marine pollution incidents. Requires ships greater than 400 gross tonnes to have pollution emergency plans. Provides for discharges and emissions from ships as per MARPOL Annex I, II, III, IV, V and VI. Several Marine Orders are enacted under this Act relevant to the activity, including: • MO Part 91: Marine Pollution Prevention - Oil	AMSA

Requirements	Scope	How it Applies to the Activity or Activity's Environmental Management	Administering Authority
		• MO Part 93: Marine Pollution Prevention – Noxious Liquid Substances • MO Part 94: Marine Pollution Prevention – Harmful Substances in Packaged Forms • MO Part 95: Marine Pollution Prevention - Garbage • MO Part 96: Marine Pollution Prevention – Sewage (MARPOL Annex IV) • MO Part 97: Marine Pollution Prevention – Air Pollution • MO Part 98: Marine Pollution Prevention – Anti-fouling Systems. *Section 7 details where the applicable requirements apply to the survey.*	
Protection of the Sea (Harmful Antifouling Systems) Act 2006	Is an offence to engage in negligent conduct that results in a harmful anti-fouling compound being applied to a ship. Australian ships must hold 'anti-fouling certificates', provided they meet certain criteria.	If required a ship must have a current anti-fouling certificate and must not use harmful antifouling compounds. The Marine Order MO Part 98: Marine Pollution Prevention – Anti-fouling Systems is enacted under this Act. *Section 7.10 details these requirements.*	AMSA
International Association of Geophysical Contractors (IAGC) Environment Manual for Worldwide Geophysical Operations (2013)	Provides the industry with useful information for conducting geophysical field operations in an environmentally sensitive manner.	Provide guidelines for best practice operations of seismic surveys to minimise environment impacts. *Section 7 details applicable guidance.*	International Association of Geophysical Contractors (IAGC)
International Maritime Organisation (IMO) Guidelines for the Control and Management of Ships' Biofouling to Minimize the Transfer of Invasive Aquatic Species (Biofouling Guidelines) 2011	Provide a globally consistent approach to the management of biofouling. They were adopted by the Marine Environment Protection Committee (MEPC) in July 2011 and were the result of three years of consultation between IMO Member States	Specific requirements are that vessels have a biofouling management plan and biofouling record book. *Section 7.10 details these requirements.*	International Maritime Organisation (IMO)

Requirements	Scope	How it Applies to the Activity or Activity's Environmental Management	Administering Authority
WA Department of Fisheries (DoF) Guidance Statement on Undertaking Seismic Surveys in WA Waters	Identifies potential issues of concern associated with seismic surveys on fish and fish habitats, as defined under the Fish Resources Management Act 1994 (FRMA). It is aimed at giving proponents direction on general standards and protocols designed to avoid or mitigate the potential impacts of seismic surveys on fish. It is expected that proponents will incorporate these standards and protocols when planning and implementing seismic surveys.	Provides guidance and mitigation strategies to avoid or minimise potential impacts of seismic surveys on fish. *Section 7.1 details applicable requirements.*	WA Department of Primary Industries and Regional Development (DPIRD)
Draft National Strategy for Mitigating Vessel Strike of Marine Mega-fauna (2016)	The overarching goal of the Strategy is to provide guidance on understanding and reducing the risk of vessel collisions and the impacts they may have on marine mega-fauna.	Though in draft the strategy provides information and guidance on reducing vessel collisions with marine mega-fauna. *Section 7.8 details applicable information and requirements.*	Department Environment and Energy (DoEE)

3 DESCRIPTION OF THE ACTIVITY

3.1 ACTIVITY OVERVIEW

Santos proposes to undertake the Beehive 3D MSS over WA-488-P on behalf of Finniss. The Beehive survey is a typical 3D survey using methods and procedures similar to others conducted in Australian waters. No unique or unusual equipment or operations are proposed.

The Acquisition Area is approximately (~ 975 km^2) with a larger Operational Area (~ 4,675 km^2) around it to allow for vessel turns and testing of equipment. The Operational Area is located in the Joseph Bonaparte Gulf, ~ 225 km west-southwest from Darwin and ~ 65 km from the closest land at Cape Domett in Western Australia (WA), and ~ 60 km from Yelcher Beach in the Northern Territory (NT).

The Acquisition Area was designed to ensure that there is a minimum separation distance (buffer zone) of at least 10 km to two key ecological sensitivities in the southern Joseph Bonaparte Gulf:

1. A shallow bank that forms part of the Carbonate bank and terrace system of the Sahul Shelf Key Ecological Feature (KEF) (see *Section 5.4*); and
2. Designated 'habitat critical to the survival of a species' for flatback turtles adjacent to Cape Domett (see *Section 5.6.7*).

Similarly, the Operational Area has been designed to avoid any overlap with the flatback turtle 'habitat critical to the survival of a species' area.

Water depths in the Acquisition Area range from ~ 30 to ~ 50 m.

The Beehive survey will take a maximum of 30 days to acquire, and will be undertaken within the period of 16 June to 31 October 2018 or 2019.

3.2 LOCATION

The Beehive survey will take place within Commonwealth waters off the WA coast within the Joseph Bonaparte Gulf (JBG) (*Figure 3.1*).

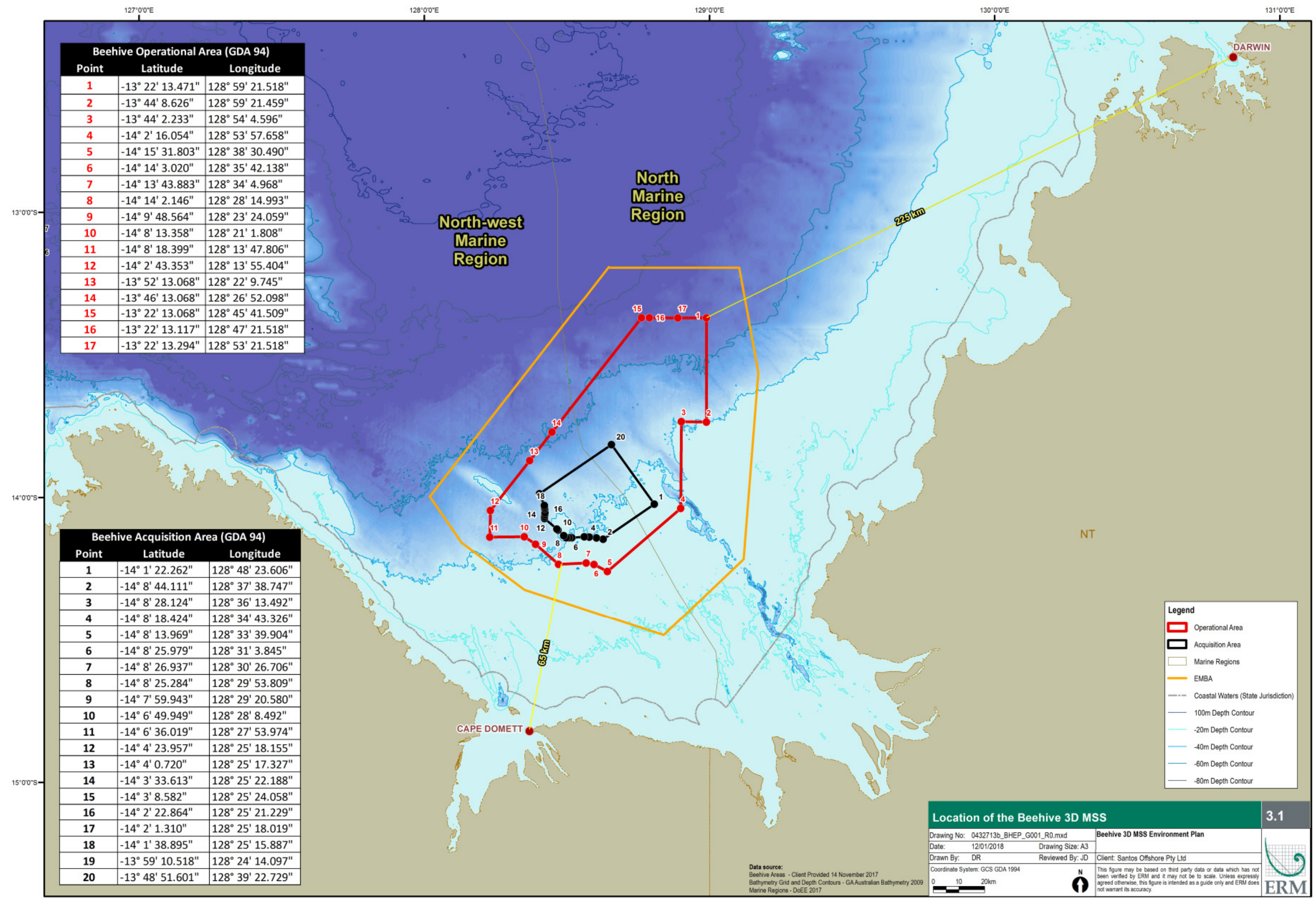
For the survey three areas have been defined:

- WA-488-P permit area - which covers an area of ~ 4,100 km^2.
- Acquisition Area – this is the area in which the survey vessel will travel along pre-determined lines, towing the streamers and releasing sound waves. Within this area the seismic source will be at full power. This covers an area of ~ 975 km^2.

- Operational Area – this is outside the Acquisition Area and is where deployment and retrieval of towed gear, set-up and testing of the seismic source, power-downs during line run-outs, vessel movements during line turns, and soft starts during line run-ins take place. All shotpoints at full power will only occur within the Acquisition Area – this includes any shots that take place during line run-outs. The array will be shut down during line turns.

- The Operational Area covers an area of ~4,675 km^2. For the reminder of time the source will be either shut down as the vessel leaves the Acquisition Area, or it will ramping up (soft start) as the vessel prepares to re-enter the Acquisition Area. This is typically occurs within 0.5 – 1 km of the Acquisition Area boundary.

Coordinates for the Acquisition and Operational Areas are provided in *Table 3.1*.



Beehive Operational Area (GDA 94)		
Point	Latitude	Longitude
1	-13° 22' 13.471"	128° 59' 21.518"
2	-13° 44' 8.626"	128° 59' 21.459"
3	-13° 44' 2.233"	128° 54' 4.596"
4	-14° 2' 16.054"	128° 53' 57.658"
5	-14° 15' 31.803"	128° 38' 30.490"
6	-14° 14' 3.020"	128° 35' 42.138"
7	-14° 13' 43.883"	128° 34' 4.968"
8	-14° 14' 2.146"	128° 28' 14.993"
9	-14° 9' 48.564"	128° 23' 24.059"
10	-14° 8' 13.358"	128° 21' 1.808"
11	-14° 8' 18.399"	128° 13' 47.806"
12	-14° 2' 43.353"	128° 13' 55.404"
13	-13° 52' 13.068"	128° 22' 9.745"
14	-13° 46' 13.068"	128° 26' 52.098"
15	-13° 22' 13.068"	128° 45' 41.509"
16	-13° 22' 13.117"	128° 47' 21.518"
17	-13° 22' 13.294"	128° 53' 21.518"

Beehive Acquisition Area (GDA 94)		
Point	Latitude	Longitude
1	-14° 1' 22.262"	128° 48' 23.606"
2	-14° 8' 44.111"	128° 37' 38.747"
3	-14° 8' 28.124"	128° 36' 13.492"
4	-14° 8' 18.424"	128° 34' 43.326"
5	-14° 8' 13.969"	128° 33' 39.904"
6	-14° 8' 25.979"	128° 31' 3.845"
7	-14° 8' 26.937"	128° 30' 26.706"
8	-14° 8' 25.284"	128° 29' 53.809"
9	-14° 7' 59.943"	128° 29' 20.580"
10	-14° 6' 49.949"	128° 28' 8.492"
11	-14° 6' 36.019"	128° 27' 53.974"
12	-14° 4' 23.957"	128° 25' 18.155"
13	-14° 4' 0.720"	128° 25' 17.327"
14	-14° 3' 33.613"	128° 25' 22.188"
15	-14° 3' 8.582"	128° 25' 24.058"
16	-14° 2' 22.864"	128° 25' 21.229"
17	-14° 2' 1.310"	128° 25' 18.019"
18	-14° 1' 38.895"	128° 25' 15.887"
19	-13° 59' 10.518"	128° 24' 14.097"
20	-13° 48' 51.601"	128° 39' 22.729"

Figure 3.1 Location of the Beehive 3D MSS

Table 3.1 Coordinates for the Beehive 3D MSS Acquisition and Operational areas

Location (GDA 1994 – Degrees Minutes Seconds)			
Acquisition Area		**Operational Area**	
Longitude	**Latitude**	**Longitude**	**Latitude**
-14° 1' 22.262"	128° 48' 23.606"	-13° 22' 13.471"	128° 59' 21.518"
-14° 8' 44.111"	128° 37' 38.747"	-13° 44' 8.626"	128° 59' 21.459"
-14° 8' 28.124"	128° 36' 13.492"	-13° 44' 2.233"	128° 54' 4.596"
-14° 8' 18.424"	128° 34' 43.326"	-14° 2' 16.054"	128° 53' 57.658"
-14° 8' 13.969"	128° 33' 39.904"	-14° 15' 31.803"	128° 38' 30.490"
-14° 8' 25.979"	128° 31' 3.845"	-14° 14' 3.020"	128° 35' 42.138"
-14° 8' 26.937"	128° 30' 26.706"	-14° 13' 43.883"	128° 34' 4.968"
-14° 8' 25.284"	128° 29' 53.809"	-14° 14' 2.146"	128° 28' 14.993"
-14° 7' 59.943"	128° 29' 20.580"	-14° 9' 48.564"	128° 23' 24.059"
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-14° 6' 36.019"	128° 27' 53.974"	-14° 8' 18.399"	128° 13' 47.806"
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-14° 2' 1.310"	128° 25' 18.019"	-13° 22' 13.294"	128° 53' 21.518"
-14° 1' 38.895"	128° 25' 15.887"		
-13° 59' 10.518"	128° 24' 14.097"		
-13° 48' 51.601"	128° 39' 22.729"		

3.3 *TIMING*

The Beehive survey will take a maximum of 30 days to acquire, and will be undertaken within the period of 16 June to 31 October 2018 or 2019.

3.4 *SEISMIC ACTIVITY*

The Beehive survey is a typical 3D survey using methods and procedures similar to others conducted in Australian waters. No unique or unusual equipment or operations are proposed. *Figure 3.2* and *Figure 3.3* detail the Beehive 3D MSS equipment and process as described below and a summary of the survey and equipment parameters is provided in *Table 3.2*.

Table 3.2 Beehive 3D MSS parameters

Parameter	Beehive 3D MSS
WA-488-P Permit Area	~ 4,100 km^2
Acquisition Area	~ 975 km^2
Water depths in Acquisition Area	~ 32 – 51 m
Operational Area	~ 4,675 km^2
Water depths in Operational Area	~ 28 – 63 m
Survey earliest commencement date	1 May 2018 or 2019
Survey latest completion date	31 October 2018 or 2019
Duration of acquisition	20 to 30 days
Length of sail lines	~ 35 km
Time to traverse a sail line (incl. turn)	~ 8 hours
Seismic vessel sail line speed	4.5 - 5 knots (8-9 km/hour)
No. of streamers	8 to 12
Distance between streamers	~ 100 m
Distance between survey lines	8 streamers – 400 m 10 streamers – 500 m 12 streamers – 600 m
Number of lines	8 streamers – 72 10 streamers – 56 12 streamers – 46
Streamer length	~ 6 to 8 km
Streamer tow depth	Between 15 – 20 m
Distance from seismic vessel bow to tail buoy	~ 6.5 to ~ 8.5 km
Sound source size (approximate)	~ 2,380 cui
Sound source tow depth	~ 6 to 8 m
Shot point interval	12.5 m

The survey vessel will travel along a series of pre-determined lines within the Acquisition Area (*Figure 3.1*) at a speed of approximately 4.5 - 5 knots (8-9 km/hour). The vessel will tow two or three sound wave source units, which operate alternatively with one discharging compressed air as the other recompresses, and cables (known as streamers) which contain microphones (known as hydrophones). As the vessel travels along the lines, sound waves (every 8 seconds) will be directed down through the water and into the geology below the seabed. The sound that reflects back is measured by the hydrophones and is later processed to provide information about the structure and composition of geological formations below the seabed.

There will be up to 12 streamers ~ 6 to 8 km long with a tail buoy at the end. The streamers will be towed at a depth of between 15 and 20 m. The distance between each streamer is ~ 100 m. From the bow of the vessel to the tail buoy is ~ 6.5 km to ~ 8.5 km long.

Each sail line is approximately 35 km long and will take approximately 8 hours to acquire and turn around. Time to complete each sail line is dependent on vessel speed and currents. The sails lines are proposed to be orientated in a south-west to north-east direction.

The survey will be conducted 24 hours a day.

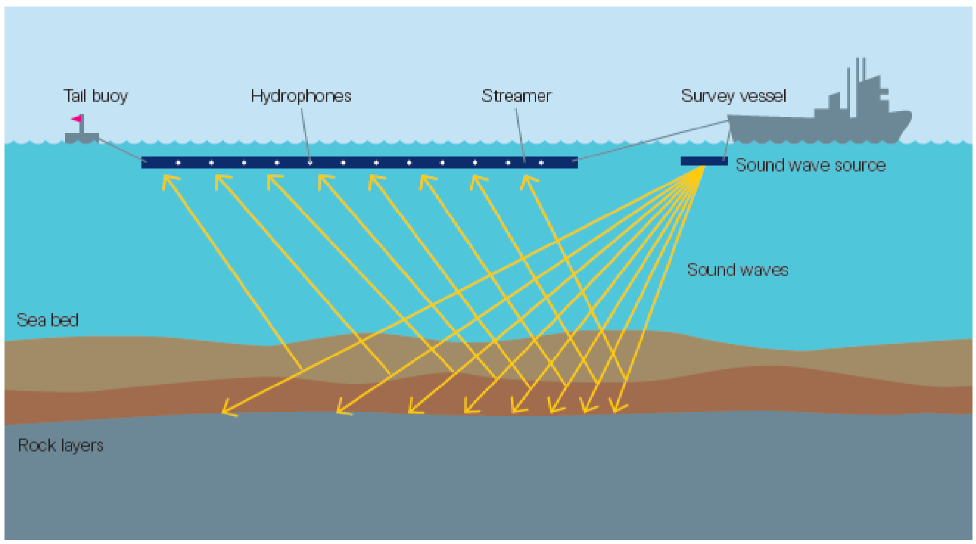

Figure 3.2 Beehive 3D MSS equipment and process vertical view

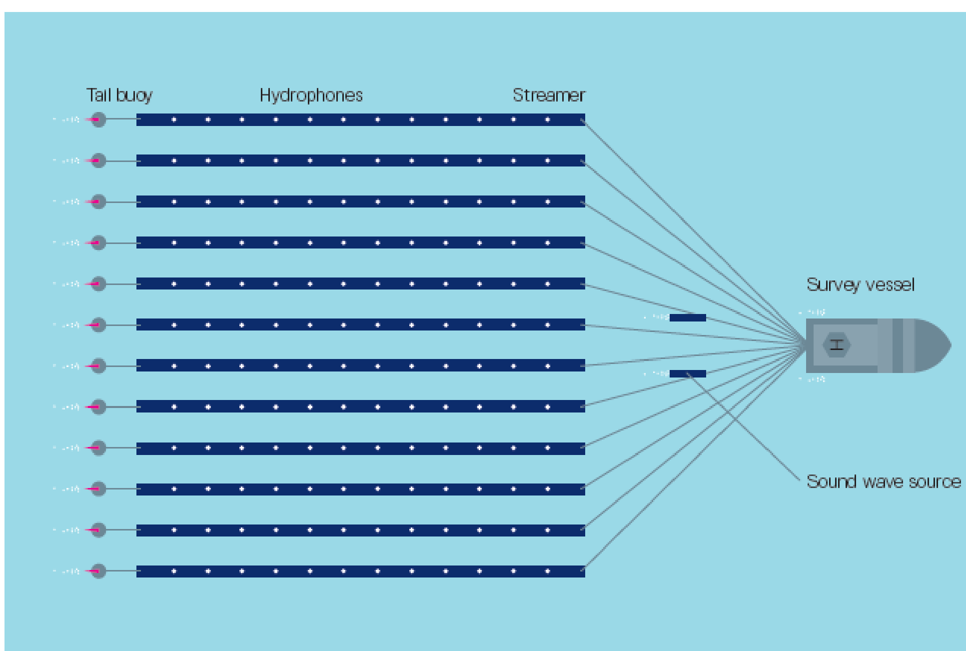

Figure 3.3 *Beehive 3D MSS equipment and process horizontal view*

3.5 SEISMIC SOURCE JUSTIFICATION

The seismic source is comprised of a number of airguns of varying volumes, with the distribution of guns within an array designed such that the primary energy is directed downwards into the subsurface, and not horizontally away from the source. The total volume size of the airgun array has been chosen based on the range of water depths within the Acquisition Area, and depth of the target within the subsurface to ensure adequate seismic imaging.

3.6 SURVEY VESSELS

3.6.1 Seismic Vessel

A purpose-built survey vessel will be used and will carry up to 70 people. While the specific vessel for the survey has yet to be determined, the vessel in *Figure 3.4* is representative of the type of vessel that will be used.

3.6.2 Support Vessels

There will be up to two support vessels that will be used during acquisition of the Beehive 3D MSS. The support vessels will re-supply the survey vessel with logistical supplies, accompany the survey vessel to maintain a safe distance between the towed array and other vessels, and also to manage interactions with shipping and fishing activities, if required. The support vessels may also be used for crew change.

Figure 3.5 and *Figure 3.6* show representative support vessels.

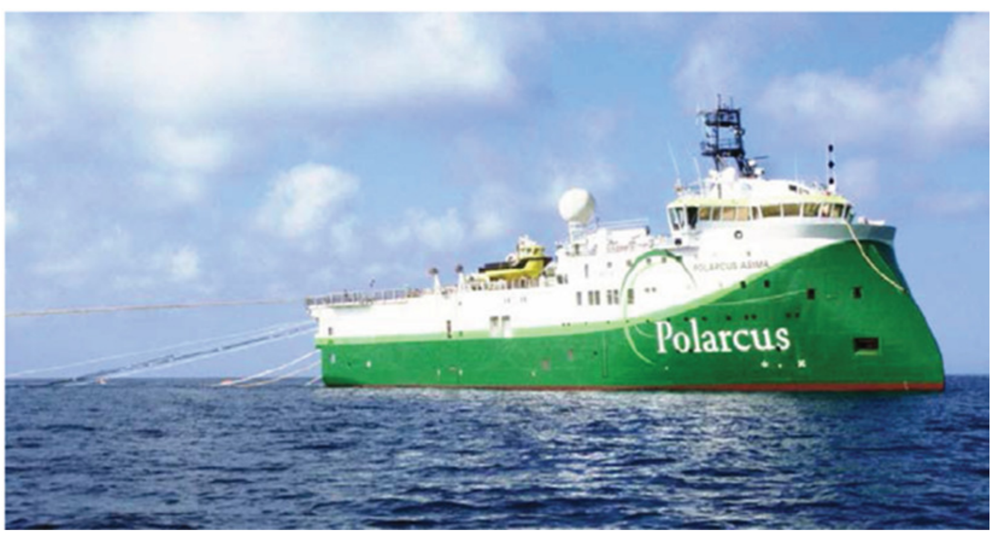

Figure 3.4 *Seismic survey vessel*

Figure 3.5 Support vessel

Figure 3.6 Support vessel

4 CONSULTATION

The principal objectives of consultation undertaken for the Beehive 3D MSS are:

- Identify the relevant stakeholders.
- Initiate and maintain open communications between relevant stakeholders and Santos.
- Identify, establish and implement stakeholder engagement tools for initial and on-going communications.
- Establish an open and transparent process for input.
- Proactively seek agreement with relevant stakeholders on recommended strategies to minimise negative impacts and maximise positive impacts of the activity.
- Provide a means for recording initiatives in which communication and/or consultation is undertaken, issues raised and responses recorded.

Stakeholder consultation has been guided by the following:

- NOPSEMA Decision-Making Guideline – Criterion-10A(g) Consultation Requirements
- APPEA Stakeholder Consultation and Engagement Principles and Methodology – Draft
- AFMA's Guidelines for Petroleum Industry Consultation with AFMA (AFMA 2015)
- The Western Australian Department of Fisheries' Guidance Statement for oil and gas industry consultation with the Department of Fisheries (Department of Fisheries, 2013).

4.1 RELEVANT STAKEHOLDERS

For the consultation process Santos has used the requirements in the OPGGS (E) Regulations in regards to a relevant person:

- Each Department or agency of the Commonwealth to which the activities to be carried out under the environment plan, or the revision of the environment plan, may be relevant;
- Each Department or agency of a State or the Northern Territory to which the activities to be carried out under the environment plan, or the revision of the environment plan, may be relevant;

- The Department of the responsible State Minister, or the responsible Northern Territory Minister;
- Person or organisation whose functions, interests or activities may be affected by the activities to be carried out under the environment plan, or the revision of the environment plan;
- Any other person or organisation that the titleholder considers relevant.

Table 4.1 Beehive 3D MSS assessment of stakeholders

Stakeholder	Relevant to Beehive 3D MSS	Reasoning
Department or agency of the Commonwealth to which the activities to be carried out under the environment plan, or the revision of the environment plan, may be relevant		
Australian Border Force (ABF)	×	Responsible for coordinating offshore maritime security. ABF confirmed during engagement for the Santos Fishburn EP - they do not need to be notified of the survey as they receive the notifications via AHS Notice to Mariners. Based on this information no consultation is required, as not considered to be a relevant stakeholder.
Australian Fishing Management Authority (AFMA)	✓	Responsible for managing Commonwealth fisheries. Confirmed Northern Prawn Fishery is the only Commonwealth Fishery that operates in the area. AFMA provided contact details for Commonwealth Fisheries Association.
Australian Maritime Safety Authority (AMSA)	✓	AMSA is the statutory and control agency for vessels emergencies in Commonwealth waters. Santos has a signed MoU with AMSA regarding response arrangements. Arrangements are detailed in OPEP Section 8.3.
Australian Hydrographic Service (AHS)	✓	Responsible for Notice to Mariners. Required to notify AHS a minimum of 3 weeks prior to commencement of activities. Detailed in *Section 4.4* Ongoing Consultation.
Department of Defence (DoD)	✓	The Beehive 3D MSS, overlaps with the North Australian Exercise Area (NAXA), where The Department of Defence conduct a bi-annual military exercise. The DoD has been considered relevant as Exercise KAKADU is planned for September 2018.
Department of the Environment and Energy (DoEE)	×	As per the Australian Government Agencies' Roles and Relevance under the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* Guidance the DoEE's functions, interests and activities have been incorporated in the requirements of the Program, the DoEE is not considered a relevant agency for consultation purposes under the Program. This does not negate the fact that it may be beneficial for titleholders to contact the with regard to its other functions, interests and activities that fall outside the Program (as described above). The Beehive 3D MSS does not trigger any of the DoEE's other functions, interests and activities, hence they were assessed as not being a relevant stakeholder.
Department of Agriculture and Water Resources (DAWR)	×	There are no issues of biosecurity, therefore this stakeholder is not considered to be a relevant stakeholder.
Director of National Parks (DoNP)	✓	The DoNP is a relevant person for consultation where an environmental incident occurs in Commonwealth waters surrounding an Australian marine park and may impact on the values within the reserve.

Stakeholder	Relevant to Beehive 3D MSS	Reasoning
		The Beehive 3D MSS Acquisition Area is located 10 km from the Joseph Bonaparte Gulf Marine Park. The Operational Area borders the marine park and the EMBA overlaps the marine park. Therefore, the DoNP is considered relevant.
National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA)	✓	Statutory authority for offshore petroleum activities. Consultation prior to EP submission is not required.
Department or agency of the State or the Territory to which the activities to be carried out under the environment plan, or the revision of the environment plan, may be relevant and the Department of the responsible State Minister		
WA Department of Aboriginal Affairs (DAA)	×	No customary fishing activities in the area. This was confirmed during consultation for the Santos Fishburn EP (survey located too far offshore). Based on this information no further consultation required, as not considered to be a relevant stakeholder.
WA Department on Primary Industries and Regional Development (Fisheries) (DPIRD)	✓	Responsible for managing State fisheries. Considered to be a relevant stakeholder and engaged as part of the consultation process.
WA Department of Transport (WA DoT)	×	Control agency for marine pollution emergencies if impact to State waters. DoT Offshore Petroleum Industry Guidance Note “Marine Oil Pollution: Response and Consultation Arrangements” (December 2017) - Section 10.1 requires petroleum titleholders to consult with DoT for activities that have the potential to cause a marine pollution emergency in State Waters. As per *Section 7.11* (Diesel Refuelling Spill) and *Section 7.12* (Diesel Spill from a Vessel Collision), no impacts to State waters were identified. Based on this information no further consultation required as not a relevant stakeholder.
NT Department of Primary Industries and Resources (Primary Industry and Fisheries) (DPIR)	✓	Responsible for managing NT fisheries. Considered to be a relevant stakeholder and engaged as part of the consultation process.
NT Department of Transport (NT DoT) – Marine Safety Branch	×	Control agency for marine pollution emergencies if impact to NT waters. No impacts to NT waters were identified (see *Sections 7.11* and *7.12*). Based on this information no further consultation required, as not considered to be a relevant stakeholder.
Department of the responsible State Minister, or the responsible Northern Territory Minister		
WA Department of Mines, Industry Regulation and Safety (DMIRS)	✓	Consultation required as per DMP “Consultation Guidance Note (For the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009)” - Sections 2.2 and 2.3 includes requirements for activity pre-start and cessation notifications.

Stakeholder	Relevant to Beehive 3D MSS	Reasoning
NT Department of Primary Industries and Resources (DPIR)	✓	Responsible for managing petroleum exploration and development, and fisheries in NT waters.
Person or organisation whose functions, interests or activities may be affected by the activities to be carried out under the environment plan, or the revision of the environment plan		
Commonwealth Fisheries Association (CFA)	✓	AFMA informed Santos to contact CFA as they are responsible for the management of the Northern Prawn Fishery (NPF). Therefore, CFA have been considered to be a relevant stakeholder.
Northern Prawn Fishery (NPF - Commonwealth)	✓	The NPF is active within and near the WA-488-P permit area. Consultation to be undertaken through Northern Prawn Fishery Industry Pty Ltd (NPFI).
Western Tuna and Billfish Fishery (WTBF - Commonwealth)	×	The fishery covers the Operational Area and EMBA, however efforts are concentrated off south-west WA. Therefore, not considered to be a relevant stakeholder.
Western Skipjack Fishery (WSF - Commonwealth)	×	The Skipjack Tuna Fishery is not currently active and the management arrangements for this fishery are under review. Therefore not considered to be a relevant stakeholder.
Southern Bluefin Tuna Fishery (SBTF - Commonwealth)	×	The Southern Bluefin Tuna Fishery generally targets waters in the Great Australian Bight and off South Australia. Spawning area is off the north-west of WA outside of Joseph Bonaparte Gulf (JBG).Therefore, not considered to be a relevant stakeholder.
North West Slope Trawl Fishery (NWSTF - Commonwealth)	×	Fishery is located in deep water from the coast of the Prince Regent National Park to Exmouth between the 200 m depth contour to the outer limit of the Australian Fishing Zone (AFZ). This area is not near the Operational Area or EMBA. Therefore, not considered to be a relevant stakeholder.
Northern Demersal Scalefish Managed Fishery (NDSMF - WA)	✓	The fishing operates off the north-west coast of WA. The Operational Area and EMBA are located within Fishing Area 2 – Zone A. The fishery operates year-round. Area 2 is further divided into zones. Zone A is an inshore area, Zone B comprises the area with most historical fishing activity and Zone C is an offshore deep slope area representing waters deeper than 200 m. The Operational Area overlaps statistical blocks 13280 and 14280 (*Figure 7.2*). Catch was reported in these two blocks in 2012 and 2015 but no data are available as less than 3 vessels were operating in these areas.
Mackerel Managed Fishery (MMA - WA)	✓	The fishery is located between Geraldton and the NT border and has the potential to operate in the JBG. The Operational Area and EMBA are located in Area 1 (Kimberley – WA/NT Border). In 2014, there were 3 licences operating in Area 1 of the fishery. In 2014, the majority of the catch was taken in Area 1. The fishing season is between May and October (peak in July/August). The Operational Area overlaps statistical blocks 13280 and

Stakeholder	Relevant to Beehive 3D MSS	Reasoning
		14280. Catch was reported in these two blocks in 2012 and 2013 but no data are available as less than 3 vessels were operating in these areas.
Joint Authority Northern Shark Fishery (JANSF - WA)	×	The Joint Authority Northern Shark Fishery extent does overlap with the proposed Beehive 3D MSS, however the fishery has not been active since 2013.
Beche-de-mer Fishery	×	The WA sea cucumber fishery is only permitted to operate in WA State waters, and hence does not overlap the Operational Area or EMBA. Therefore, not considered to be a relevant stakeholder.
Marine Aquarium Fish Managed Fishery	×	The fishery extends into Commonwealth waters; however the fishery currently operates only in WA State waters. There is no overlap with the Operational Area and EMBA. Therefore, not considered to be a relevant stakeholder.
Specimen Shell Managed Fishery	×	Fishery covers entire WA coastline, however, concentrates its efforts in areas adjacent to population centres, located in shallow waters. Therefore, not considered to be a relevant stakeholder.
Kimberley Barramundi and Gillnet Fishery	×	Located nearshore and estuarine zones from the NT border to the top end of Eighty Mile Beach, south of Broome. No overlap with either the Operational Area or EMBA. Therefore, not considered to be a relevant stakeholder.
Pearl Oyster Managed Fishery (POMF)	×	The survey is located within Zone 4 of the POMF, which is not fished as it is not commercially viable (however pearl farming does occur). There is a Pearl Oyster Fishery area to the northeast of the EMBA. According to information from the NT DPIR it appears that there has been no effort in this area since 2008. The fishery has been considered not relevant, however the PPA has been engaged to confirm the information Santos has is correct.
Demersal Fishery (NT)	✓	The Demersal Fishery extent is located within the Beehive 3D MSS Acquisition Area and actively fishes within the Operational Area. Consultation has been undertaken with licence holders.
Northern Prawn Fishing Industry Pty Ltd (NPFI)	✓	The NPF is active within and near the WA-488-P permit area. Consultation was undertaken with the NPFI.
Austral Fisheries	×	NPF licence holder which is active within and near the WA-488-P permit area. During consultation on the Santos Fishburn EP, Austral Fisheries requested that engagement be undertaken via NPFI. Based on this information no direct consultation has been undertaken with Austral Fisheries.
Charter Fishing	×	From consultation for the Santos Fishburn EP, the WA DPIRD confirmed that there is no reported charter fishing in area. Based on this information no further consultation required, as not considered to be a relevant stakeholder.

Stakeholder	Relevant to Beehive 3D MSS	Reasoning
Customary Fishing	×	From consultation for the Santos Fishburn EP, WA DAA and Kimberley Land Council (KLC) confirmed that the area does not intersect with any Aboriginal heritage places, including customary fishing areas. Based on this information no further consultation required, as not considered to be a relevant stakeholder.
NT Seafood Council (NTSC)	✓	NTSC represents the seafood industry. Licence holders within the NT-managed fisheries are members of the NTSC.
Recfishwest	×	Recfishwest confirmed during consultation for the Santos Fishburn EP that the area of the proposed Fishburn seismic program is highly unlikely to intersect with any recreational fishing activities given its remote location. Based on this information no further consultation required, as not considered to be a relevant stakeholder.
Western Australian Fishing Industry Council (WAFIC)	✓	Members potentially fish in or near the WA-488-P permit area. Consultation undertaken to identify WA commercial fishers in and around the survey area.
Pearl Producers Association (PPA)	✓	Contact was made with PPA to confirm that the proposed activity occurs outside the active pearling area. During consultation for the Santos Fishburn EP the PPA confirmed that the survey area did not overlap an active pearling area. On this basis, the PPA are not considered to be a relevant stakeholder.
Northern Wildcatch Seafood Australia (NSWA)	✓	NDSMF licence holder. Considered to be a relevant stakeholder.
Any other person or organisation that the titleholder considers relevant		
Australian Marine Oil Spill Centre (AMOSC)	✓	Santos is a participating member of AMOSC. In an oil spill AMOSC would provide equipment and support. AMOSC have reviewed the OPEP for the Beehive 3D MSS.
Kimberley Land Council (KLC)	✓	KLC was engaged during consultation for the Santos Fishburn EP, however no concerns were raised. KLC have continued to be engaged.
Origin Energy Resources	✓	Exploration Permit - NT/P84 (survey extends into title block). Exploration Permit -WA-454-P (survey extends into title block).
Woodside Energy Ltd.	✓	Exploration Permit - WA-522-P (~ 65 km from Operational Area).
Engie Bonaparte Pty Ltd	✓	Retention Lease - WA-27-R (~ 55 km from Operational Area), Retention Lease - WA-40-R (~ 75 km from Operational Area) and Retention lease WA-6-R (~ 55 km from Operational Area).
PGS	✓	Titleholder for the proposed Rollo Multi-client Marine Seismic and CSEM Surveys. The Rollo operational area has been reduced in size and now excludes NT waters and consequently the Beehive 3D MSS area.

Stakeholder	Relevant to Beehive 3D MSS	Reasoning
TGS	✓	Titleholder for the North West Shelf Renaissance North Multi Client Marine Seismic Surveys. TGS have confirmed that the operational area has been reduced in size and now excludes NT waters and consequently the Beehive 3D MSS area.
Eni Australia B.V.	✓	Blacktip Wellhead Platform (located within the Operational Area, ~ 3 km from the Acquisition Area boundary).

Santos understands that the list of relevant stakeholders is not exhaustive and additional stakeholders may be identified as part of ongoing consultation. Should additional stakeholders be identified prior to, or during the survey, these stakeholders will be contacted, provided appropriate information about the survey and invited to make comment. Evidence of additional stakeholder consultation will be documented in the Stakeholder Consultation Log (Appendix 2 to this EP). The Stakeholder Consultation Log is a "living document" which will be updated throughout the survey and will be used during the post-survey review of environmental performance.

4.2 CONSULTATION METHOD

The consultation process was undertaken by Environmental Resources Management Pty Ltd (ERM), on behalf of Finniss and Santos for the Beehive 3D MSS. The process is detailed in *Table 4.2*, and a summary of the consultation is provided in Appendix 2.

Table 4.2 Beehive 3D MSS consultation process

Stage	Timing	Information Provided
Early Notification	November 2017	An initial email was distributed to stakeholders providing information on the proposed Beehive 3D MSS and informing stakeholders that Finniss Offshore Exploration (titleholder of WA-488-P) is in the early stages of preparing an Environment Plan to NOPSEMA. A figure of the Beehive 3D MSS was attached.
Stakeholder Update	December 2017	Updates were sent to stakeholders informing them that Santos Limited entered into an agreement with Melbana Energy to partially fund and operate the Beehive 3D MSS. The press release from Santos was attached. Stakeholders were also informed that Santos is in the early stages of EP development.
Stakeholder Letter Issued to Fishing Licence Holders	January 2018	A stakeholder letter, with an attached figure of the proposed Beehive 3D MSS was sent to license holders, in the Mackerel Managed Fishery, Northern Demersal Scalefish Managed Fishery and Demersal Fishery.
EP Submission	February 2018	Email notification to all stakeholders, informing stakeholder the EP has been submitted to NOPSEMA for review. A link will be provided to the EP Status page, so stakeholder can follow the progress of the EP.
EP Acceptance	May 2018	An update will be sent to stakeholders, informing them that the EP has been accepted by NOPSEMA, and a link to the EP summary will be provided.

4.3 *Consultation Results*

A summary of the key issues and concerns raised by stakeholders during consultation, including an assessment of the merits of objections and claims, are included in Appendix 2.

4.4 *Ongoing Consultation*

From the stakeholder consultation undertaken (documented in Appendix 2) and the following notifications and ongoing consultation are required:

- Notify Australian Hydrographic Service a minimum of 3 weeks prior to the commencement of activities.
- Notify Department of Defence (offshore.petroleum@defence.gov.au and ADF.Airspace@defence.gov.au) 14 days prior to the commencement of activities.
- Notify Department of Defence of any updates, and of survey commencement.
- Notify Defence upon cessation of acquisition and completion of the survey.
- Notify WA Department of Mines, Industry Regulation and Safety (DMIRS) of start and cessation of activity. Prestart notification to be undertaken at least 10 days prior to the activity commencing as per Regulation 30 of the OPGGS(E)R.
- Notify NPFI (ceo@npfindustry.com.au) and AFMA (petroleum@afma.gov.au) of any updates, survey commencement (4 weeks prior to commencement) and cessation. In addition, keep NPFI informed of NOPSEMA's assessment of the EP.
- Provide the NPFI with a handout on the Beehive 3D MSS (including the contact details for the seismic vessel and support fleet), who will distribute the handout during the pre-season briefing for the second fishing season, or via email to fleet managers / vessel skippers.
- If survey timing overlaps the second fishing season for the NPF Santos will provide skippers of prawn trawlers operating in the JBG (as advised by the NPFI) with a daily report, unless advised they have no need for this information. As a minimum the daily report will include:
    - Current survey vessel position
    - 48 hour look ahead for survey activities and location
    - Support and chase vessel activities and locations
    - Contact details for survey, support and chase vessels

- Send AMOSC a copy of the Beehive 3D MSS OPEP once EP has been accepted. Also send AMOSC notification of survey commencement and cessation.

5 DESCRIPTION OF EXISTING ENVIRONMENT

This section describes the physical, biological, cultural and socio-economic environment and identifies any relevant values and sensitivities of the environment that may be affected by the activity (EMBA). The EMBA is based on the risk assessment undertaken in *Section 7*, where the area covered by a diesel spill resulting from a vessel collision was identified as the largest 'footprint' for the survey. *Section 7.12.2* details how the EMBA was developed.

Using Santos' and publicly available information, and the results from the Protected Matters Search, a review of biological, cultural and socio-economic environment was undertaken to identify the environmental values and / or sensitivities that may be present occur within the EMBA. *Table 5.1* provides a summary of these values and sensitivities.

Table 5.1 Environmental values and/or sensitivities with the potential to occur within the EMBA

Environmental Value / Sensitivity	Summary
Key Ecological Features	The EMBA overlaps one shoal/bank feature that is part of the Carbonate bank and terrace system of the Sahul Shelf KEF.
Benthic habitats	Sandy substrates that support patches of low to high abundance of epifauna such as feather stars, sea pens, sea fans, sea whips, soft corals, bryozoans, hydroids and sponges. Unlikely to contain hard or reef forming corals given water depths within the EMBA.
Planktonic communities	Phytoplankton (algae) and zooplankton (fauna including larvae) likely to be present. Brown tiger prawns spawning period is between July and October. Eggs and larvae may be present in the EMBA.
Fish assemblages	No protected or commercial species habitats were identified as occurring in the area. Likely that a range of fish species including reef fish may be present in the EMBA with more abundance of species expected associated with the shoal/bank feature in the south-western corner of the Operational Area.
Sharks and rays	Largetooth sawfish, green sawfish, dwarf sawfish, narrow sawfish and northern river shark – may be present as EMBA overlaps normal distribution area for these species. No overlap with BIAs. Whale shark - may transit through the area. No feeding, breeding or aggregation areas. No overlap with BIAs. Shortfin and longfin mako - may transit through the area. No feeding, breeding or aggregation areas. Reef manta ray and giant manta ray - may transit through the area. No feeding, breeding or aggregation areas.

Environmental Value / Sensitivity	Summary
Marine reptiles	Green, olive ridley and flatback turtles – likely to be present as EMBA overlaps foraging BIA for green and olive ridley turtles, and internesting 'habitats critical to survival' for flatback turtles. Loggerhead, leatherback and hawksbill turtles - oceanic species, possibly may transit the EMBA. Several species of seasnake may occur within the EMBA, and saltwater crocodiles may transit the area.
Seabirds	The EMBA is adjacent to a foraging BIA for the lesser crested tern. This species breeds on islands off the north Kimberley coastline and may forage within the EMBA.
Marine mammals	No migratory, resting, feeding or calving areas for cetaceans within or near the EMBA. Sei, blue, and Bryde's whales may transit through deeper waters in the northern part of the EMBA. Spotted bottlenose dolphin and killer whale – may occur in the EMBA as have been recorded in Oceanic Shoals Marine Park. Though not abundant in the area, dugongs have been reported to occur in shallow coastal waters in the eastern JBG. This species may transit the EMBA.
Commercial fisheries	The EMBA overlaps areas fished in the Northern Prawn Fishery (Commonwealth), Mackerel Managed Fishery (WA), Northern Demersal Scalefish Managed Fishery (WA), and Demersal Fishery (NT). Most of the Acquisition Area is located within the banana prawn seasonal closure area within the southern JBG.
Petroleum activities	No activities have the potential to overlap with the Beehive survey.
Shipping	Low levels of vessel activity.
Defence activities	The EMBA overlaps part of the NAXA in the southern Joseph Bonaparte Gulf. The NAXA is the primary location of the KAKADU training exercise that operates biannually, with the 2018 exercise scheduled for 31 August – 15 September 2018.
Australian Marine Parks	The EMBA overlaps portions of the Multiple Use Zone and Special Purpose Zone of the Joseph Bonaparte Gulf Marine Park. The EMBA is located ~80 km from Oceanic Shoals Marine Park.
State / Territory Marine Parks	The EMBA is located ~ 25 km from the boundary of the proposed WA North Kimberley Marine Park, and ~ 34 km from the King Shoals Sanctuary Zone component of this park.

5.1 *Data Sources*

The information provided in this section has been derived from desktop reviews. This includes peer reviewed journals, and government and industry reports. The key sources of information referred to in this section are from the Department of the Environment and Energy (DOEE) resources and published literature, including but not limited to:

- An EPBC Act Protected Matters Database search was conducted to identify listed threatened and migratory species, and Threatened Ecological Communities occurring in the EMBA.
- Species Profile and Threats (SPRAT) Database, which includes information about species and ecological communities protected under the EPBC Act, available at: http://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl.
- National Conservation Values Atlas, which includes information on Biologically Important Areas (BIAs) for protected species under the EPBC Act. These are areas that are particularly important for the conservation of protected species and where aggregations of individuals display biologically important behaviour such as breeding, foraging, resting or migration (Commonwealth of Australia 2012).

5.2 REGIONAL ENVIRONMENT

The Beehive Operational Area and EMBA are located on the boundary between the North-west Marine Region (NWMR) and the North Marine Region (NMR). Whilst the majority of the Operational Area is located within the NMR and most of the Acquisition Area is located within the NWMR (*Figure 5.1*). The Acquisition and Operational Areas are located within the Bonaparte Gulf IMCRA v4 mesoscale bioregion, whilst the EMBA also partially overlaps the Cambridge-Bonaparte and Anson Beagle mesoscale bioregions (*Figure 5.1*).

The Bioregional Profiles for the NWMR (DEWHA 2008a) and the NMR (DEWHA 2008b), which form part of the respective Bioregional Plans, have been used in conjunction with other relevant management plans, reports and published papers to inform this description of the environment.

5.2.1 North-west Marine Region and North Marine Region

The NWMR comprises Commonwealth waters from the Western Australia–Northern Territory border to Kalbarri, south of Shark Bay. The North-west Marine Bioregion is characterised by the large area of continental shelf and continental slope, highly variable tidal regions and very high cyclone incidence (DEWHA 2008a).

The NMR comprises Commonwealth waters from west Cape York Peninsula to the Western Australian-Northern Territory (WA-NT) border. The marine environment of the NMR is known for its high diversity of tropical species but relatively low endemism, in contrast to other bioregions. This region is highly influenced by tidal flows and less by ocean currents (DEWHA 2008b).

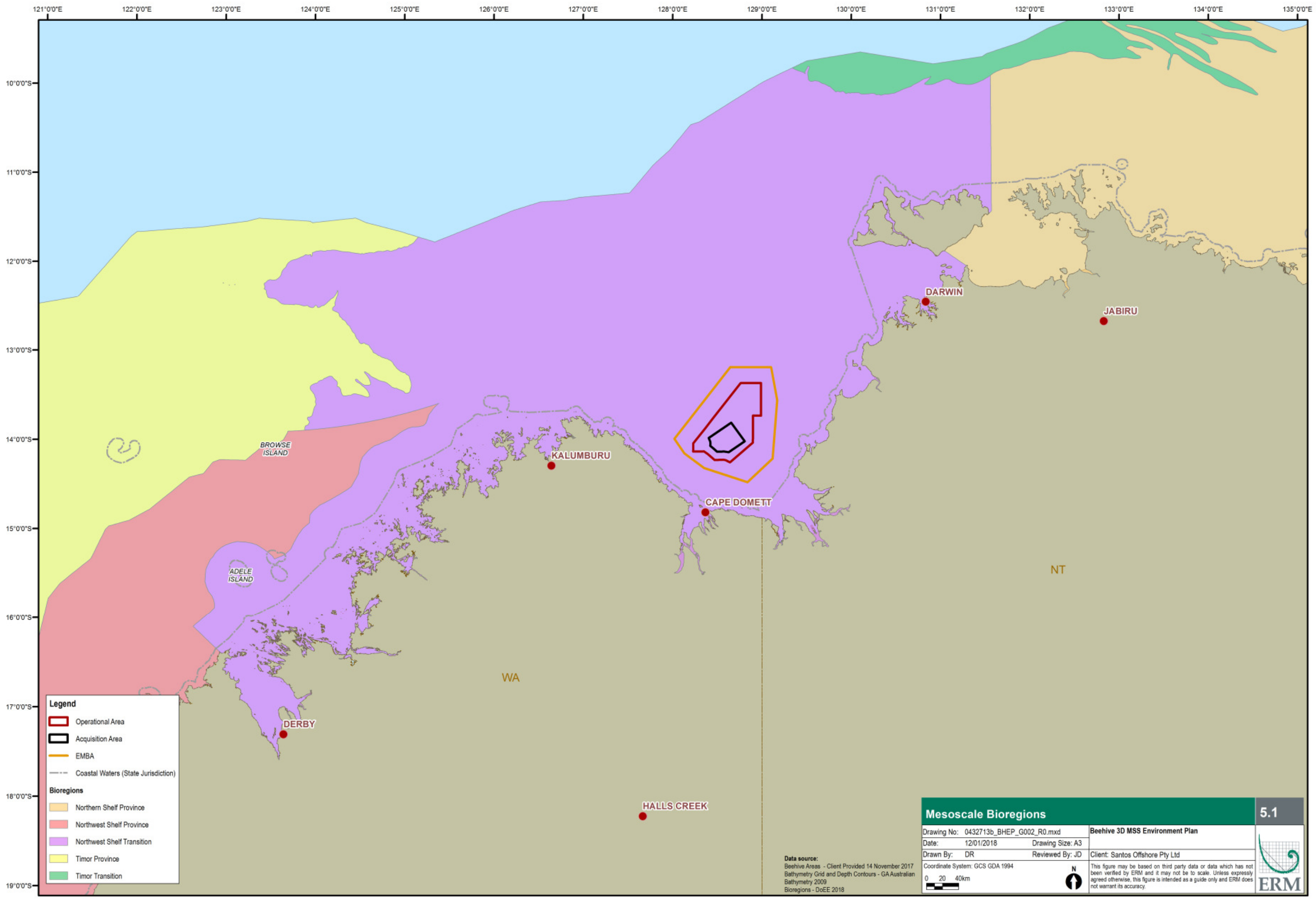

Figure 5.1 IMCRA mesoscale bioregions

5.3 *MATTERS OF NATIONAL ENVIRONMENTAL SIGNIFICANCE*

A search of the DoEE Protected Matters Database was undertaken covering a 1 km buffer around the Beehive 3D MSS EMBA. The Matters of National Environmental Significance (MNES) identified by the search are summarised in *Table 5.2*.

Table 5.2 Protected Matters Database search summary

MNES	Results	Comments
World Heritage Properties	None	
National Heritage Places	None	
Wetlands of International Importance	None	
Great Barrier Reef Marine Park	Not applicable	
Commonwealth Marine Area	1	The Commonwealth Marine Area is from 3 nm to 200 nm from the coast.
Listed Threatened Ecological Communities	None	
Listed Threatened Species	19	See Sections 5.6.2 – 5.6.9
Listed Migratory Species	37	See Sections 5.6.2 – 5.6.9
Other Protected Matters	**Results**	**Comment**
Commonwealth Land	None	
Commonwealth Heritage Places	None	
Listed Marine Species	66	See Sections 5.6.2 – 5.6.9
Whales and Other Cetaceans	14	See Section 5.6.9
Critical Habitats	None	
Commonwealth Reserves Terrestrial	None	
Commonwealth Reserves Marine	2	The EMBA overlaps portions of the Multiple Use Zone and Special Purpose Zone of the Joseph Bonaparte Gulf Marine Park. See Section 5.12.
Extra Information	**Results**	**Comment**
State and Territory Reserves	None	
Regional Forest Agreements	Not applicable	
Invasive Species	None	
Nationally Important Wetlands	None	
Key Ecological Features (Marine)	1	Carbonate bank and terrace system of the Sahul Shelf. See Section 5.4

5.4 *KEY ECOLOGICAL FEATURES*

Key ecological features (KEFs) are elements of the Commonwealth marine environment which, based on current scientific understanding, are considered to be of regional importance for either the region's biodiversity or ecosystem function and integrity.

The Beehive EMBA overlaps one bank/shoal feature that is part of the carbonate bank and terrace system of the Sahul Shelf KEF. The Operational Area overlaps the south-east part of this bank/shoal (*Figure 5.2*).

The carbonate bank and terrace system of the Sahul Shelf consist of a series of drowned carbonate banks that are generally 10 km^2 in area with flat tops, developed as terraces and benches, and have steep slopes (on average ~ 20°) (Baker et al. 2008). It is thought that the formation of these banks is associated with hydrocarbon seeps (DEWHA 2008a).

The carbonate bank and terrace system of the Sahul Shelf KEF is regionally important because of its role in enhancing biodiversity and local productivity relative to the surrounding areas. The KEF provides areas of hard substrate in an otherwise soft sediment environment that are important for sessile species. Rising steeply from depths of about 80 m some banks rise to within 30 m of the water surface, allowing light dependent organisms to thrive. Banks that rise to at least 45 m water depth support more biodiversity, such as communities of sessile benthic invertebrates including hard and soft corals, sponges, whips, fans and bryozoans (DoEE 2016a). Brewer et al. (2007) also noted that banks within this feature support a high diversity of organisms including reef fish.

The banks, and channels between them, are also known foraging areas for flatback, olive ridley and loggerhead turtles (DEWHA 2008a).

At the closest point, the boundary of the EMBA is located ~67 km from the nearest pinnacle that forms part of the pinnacles of the Bonaparte Basin KEF (*Figure 5.2*).

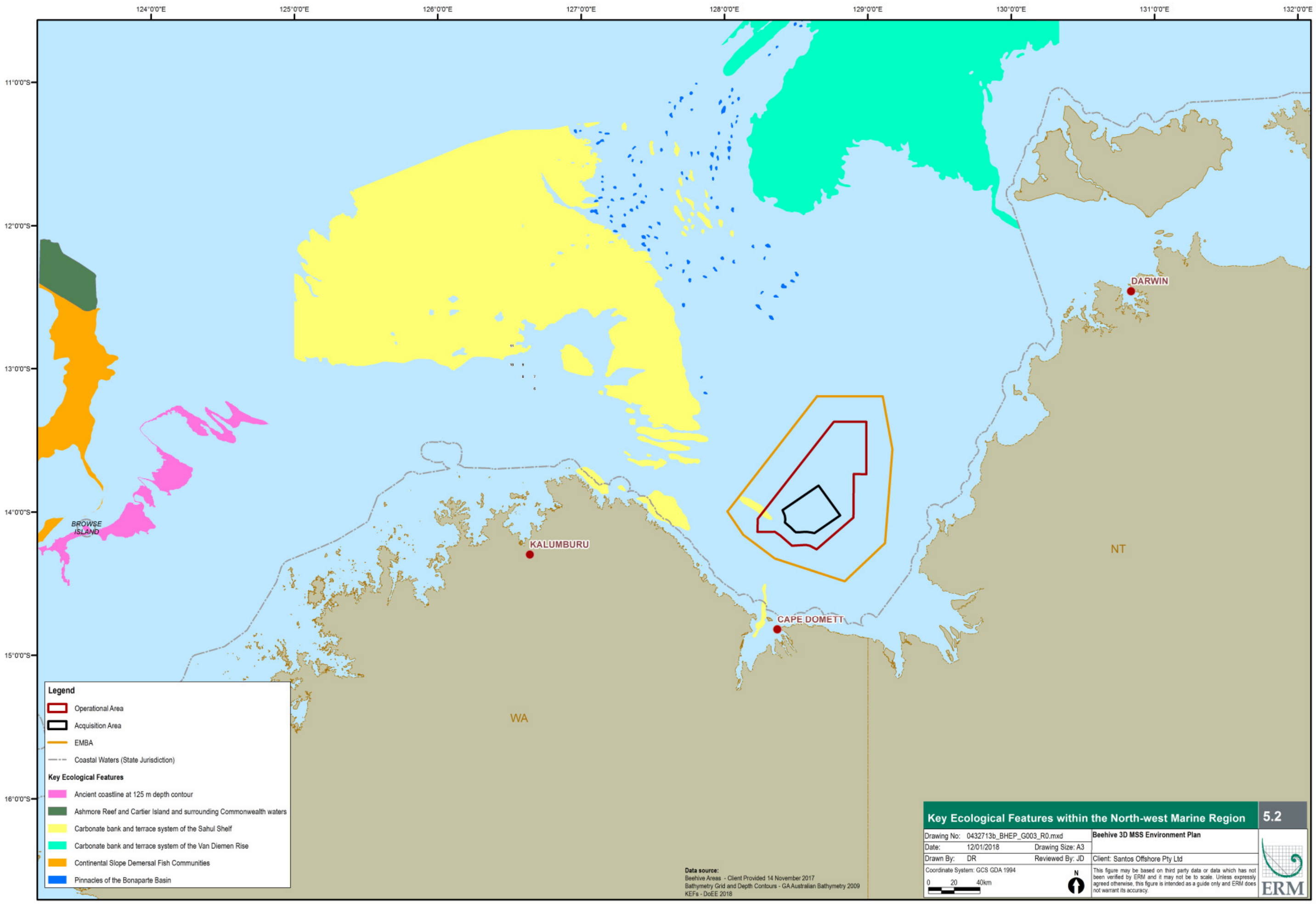

Figure 5.2 Key Ecological Features within and adjacent to the EMBA

5.5 PHYSICAL ENVIRONMENT

5.5.1 *Climate*

The region has a tropical monsoonal climate with two distinct seasons known as the North-west Monsoon or "wet season" (late October to mid-March) and the South-east Monsoon or "dry season" (May to mid-October). Regular and high rainfall is characteristics of the North-west Monsoon, particularly over coastal areas and during cyclones. This is due to large amounts of moisture being gathered as the monsoon crosses the sea from the Asian high-pressure belt on its way to the intertropical convergence zone, which migrates southward close to or over northern Australia. Conversely, the South-east Monsoon originates from the Southern Hemisphere high-pressure belt and is relatively dry and cool.

Cyclones are common in the region, occurring between December and April (BoM 2016). These phenomena result in severe storms with gale force winds and a rapid rise in water levels.

5.5.2 *Air Temperatures*

Wyndham, located on the WA mainland, is the nearest meteorological station to the Beehive Operational Area. Data collected from 1968 to 2016 show that the highest maximum temperature (mean of 39.4°C) occurs in November whilst the lowest maximum temperature (mean of 16.9°C) occurs in July (BoM 2016).

5.5.3 *Rainfall*

Data collected from 1968 to 2017 at the Wyndham weather station show that the mean annual rainfall is 826 mm, with the highest rainfall in February (204 mm) and the least in August (0 mm) (BoM 2015). Typically, the majority of the rain occurs from December to April (mean of 704.5 mm).

5.5.4 *Winds*

Wind patterns in the region are controlled by the seasonal migration of high-pressure cells from latitudes 25-30°S in winter to 35-40°S in summer (Pearce et al. 2003). Wind data from the National Centre for Environmental Prediction Climate Forecast System Reanalysis demonstrated two predominant (general) directions; 1) west or northwest winds during the months September to March; and 2) southeast winds during April to August (see *Figure 5.3* and *Table 5.3*). Monthly average wind speeds range from 8–14 knots and the monthly maximum wind speeds range from 22–50 knots (*Table 5.3*). The maximum wind speed occurred during March. Note these maximums do not include any short-term wind gusts during severe storms (RPS-APASA 2017). For the period during which the survey is planned to be acquired (May to October inclusive) average wind speeds range from 8 to 13 knots, primarily from the southeast (*Table 5.3*).

Table 5.3 ***Predicted average and maximum wind speed for the wind node within the Beehive survey area***

Month	Average Wind Speed (knots)	Maximum Wind Speed (knots)	General Direction (From)
January	14	43	West
February	12	36	West
March	10	51	West
April	9	32	Southeast
May	12	26	Southeast
June	13	28	Southeast
July	13	30	Southeast
August	10	28	Southeast
September	9	29	Northwest
October	8	22	Northwest
November	9	23	Northwest
December	9	31	West
Minimum	**8**	**22**	
Maximum	**14**	**51**	

5.5.5 Waves

Short period waves, within the northwest shelf region are generated by local synoptic winds and are typically the largest during winter months when the south-easterly trade winds dominate (Maxwell et al. 2004).

Long period waves are influenced by swells generated in the Southern Ocean. In the Bonaparte Basin, the Southern Ocean swell is slightly higher during winter than in summer due to the northerly migration of swell-generating storms. The wave period and significant wave height generated by this swell is highly dependent on the exact location within the basin. For example, the JBG is protected from the Southern Ocean swell and therefore swells affecting the area are limited to those generated by cyclones or prolonged storm winds (Maxwell et al 2004).

The region is a moderate-energy environment except when influenced by tropical cyclones which generate short-term major fluctuations in sea levels. Depending on the size, intensity, speed and relative location of the cyclone, swells generated may have periods of 6-18 s and wave heights of 0.5-9 m.

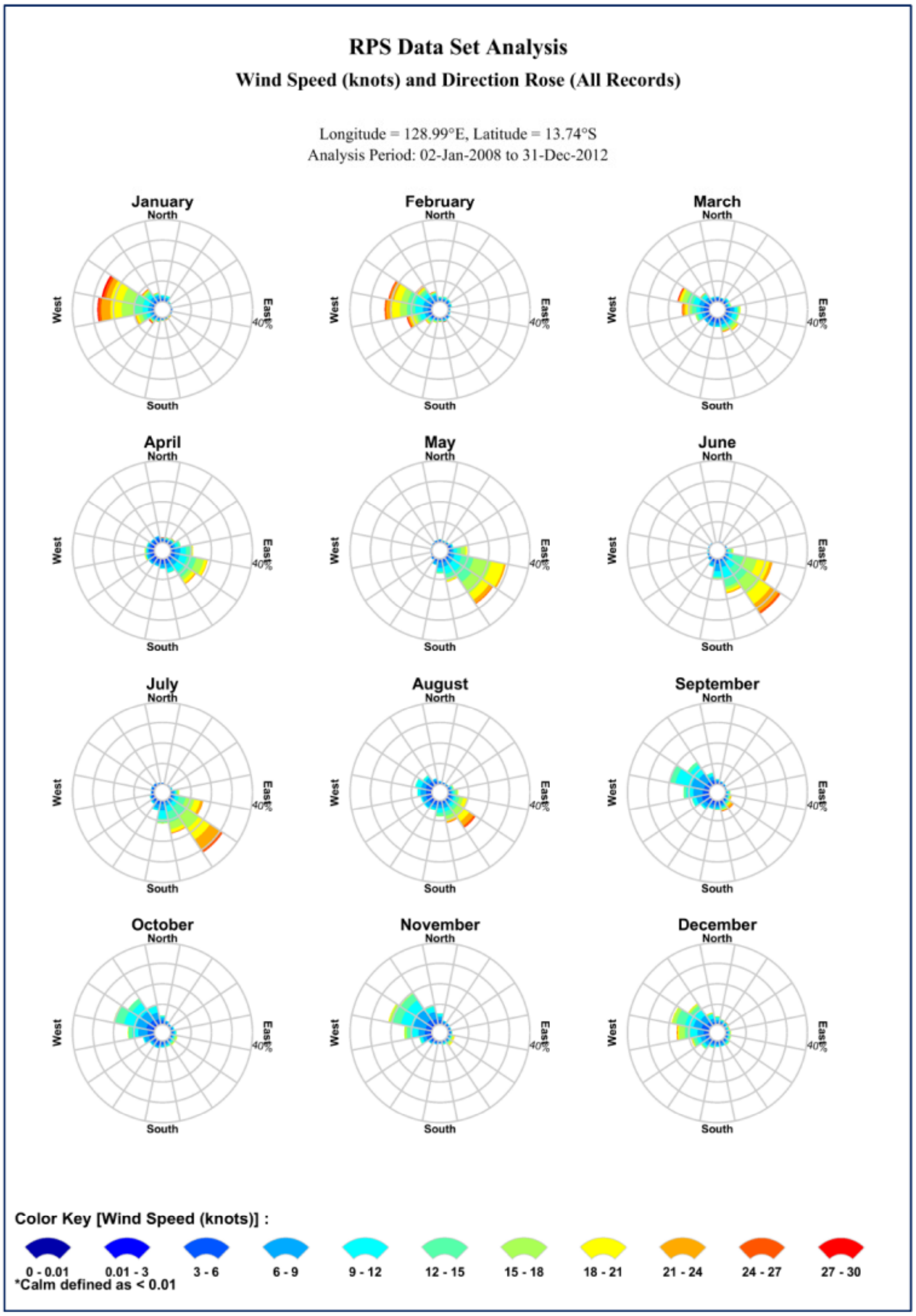

Figure 5.3 Modelled monthly wind roses (2008-2012) for the wind node within the Beehive survey area

5.5.6 Sea Temperature and Salinity

Surface water temperatures and salinities vary seasonally and are influenced by the Indonesian Throughflow. During the North-west Monsoon, a thermocline flow of relatively cool water dominates resulting in the tropical Indian Ocean being cooled rather than warmed (Ding et al. 2013). The region typically has average sea surface temperatures of 25-30°C and salinities of 35-36 psu (*Table 5.4*) (RPS-APASA 2017).

Table 5.4 ***Monthly average sea surface temperature and salinity in the Joseph Bonaparte Gulf***

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature (°C)	30.3	28.9	30.3	29.6	27.5	26.1	25.8	25.4	27.4	29.3	29.7	30.2
Salinity (psu)	36.1	35.5	36.4	35.3	34.6	35.0	35.5	35.4	36.1	35.2	35.0	35.2

5.5.7 Tides

The Bonaparte Basin is subject to a semi-diurnal tides with two high and low tides per day, and has the highest tidal range in northern Australia (> 4 m) (DEWHA 2007a). Within the Bonaparte Gulf mesoscale bioregion, tides range from 2-3 m offshore (microtidal) rising to 3-4 m inshore (mesotidal).

5.5.8 Currents

Broad-scale ocean circulation of the North Australian Shelf is dominated by the Indonesian Throughflow current system. The modelled combined current data (ocean plus tides) (RPS-APASA 2017) shows that waters in the Beehive survey area drift in two predominant (general) directions; north-northwest or south-southeast. This is aligned with the general tidal axis in this area. Typical (or average) current speeds were about 0.5 m/s with peak speeds reaching about 1.4 m/s. (*Table 5.5* and *Figure 5.4*).

For the period during which the survey is planned to be acquired (May to October inclusive) average current speeds range from 0.11 to 0.16 m/s to the west-northwest in June and July and east-northeast in August (RPS-APASA 2016).

Table 5.5 ***Predicted monthly average and maximum surface current speeds near the Beehive survey area***

Month	Average Current Speed (knots)	Maximum Current Speed (knots)	General Direction (Towards)
January	0.52	1.33	North-northwest and South-southeast
February	0.54	1.34	North-northwest and South-southeast
March	0.52	1.30	North-northwest and South-southeast
April	0.51	1.33	North-northwest and South-southeast
May	0.50	1.30	North-northwest and South-southeast
June	0.48	1.27	North-northwest and South-southeast
July	0.48	1.27	North-northwest and South-southeast
August	0.51	1.40	North-northwest and South-southeast
September	0.52	1.31	North-northwest and South-southeast
October	0.51	1.41	North-northwest and South-southeast

Month	Average Current Speed (knots)	Maximum Current Speed (knots)	General Direction (Towards)
November	0.48	1.42	North-northwest and South-southeast
December	0.47	1.39	North-northwest and South-southeast
Minimum	**0.47**	**1.27**	
Maximum	**0.54**	**1.42**	

5.5.9 *Bathymetry*

Water depths in the EMBA range from ~85 m (offshore) to ~18 m (inshore) (*Figure 5.5*). The bathymetry in parts of the southern of the Gulf is strongly influenced by the strong tidal movement and channels of the Ord, Keep, Victoria and Fitzmaurice Rivers. A series of extensive sandbars, known as the King Shoals and Medusa Banks, have been generated in the south-west by the strong outflows of sediment-laden water from Cambridge Gulf. Similar sandbars can be found in the south-east of the JBG.

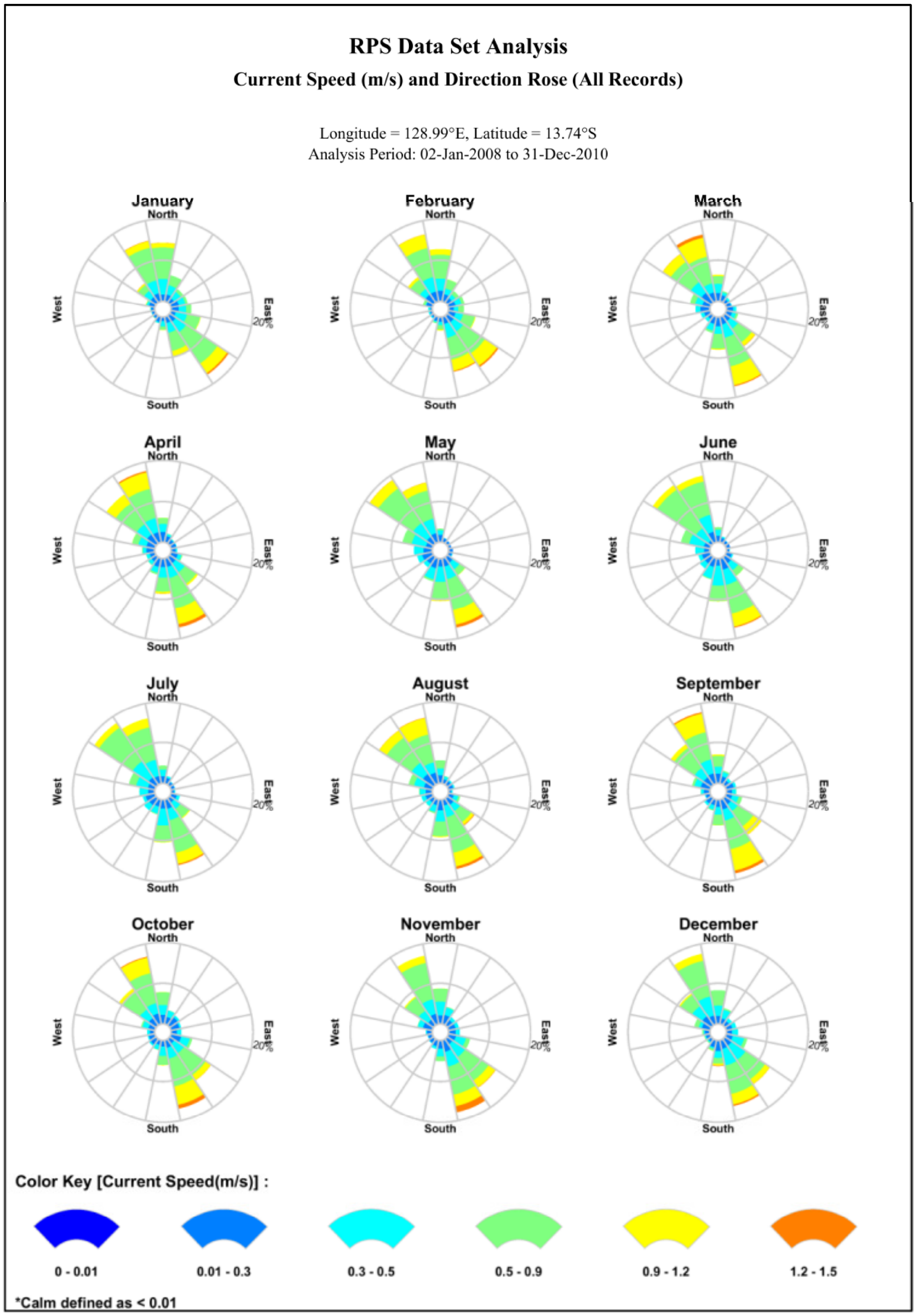

Figure 5.4 *Monthly surface current rose plots within the Beehive survey area (combined HYDROMAP & HYCOM data 2008 – 2012)*

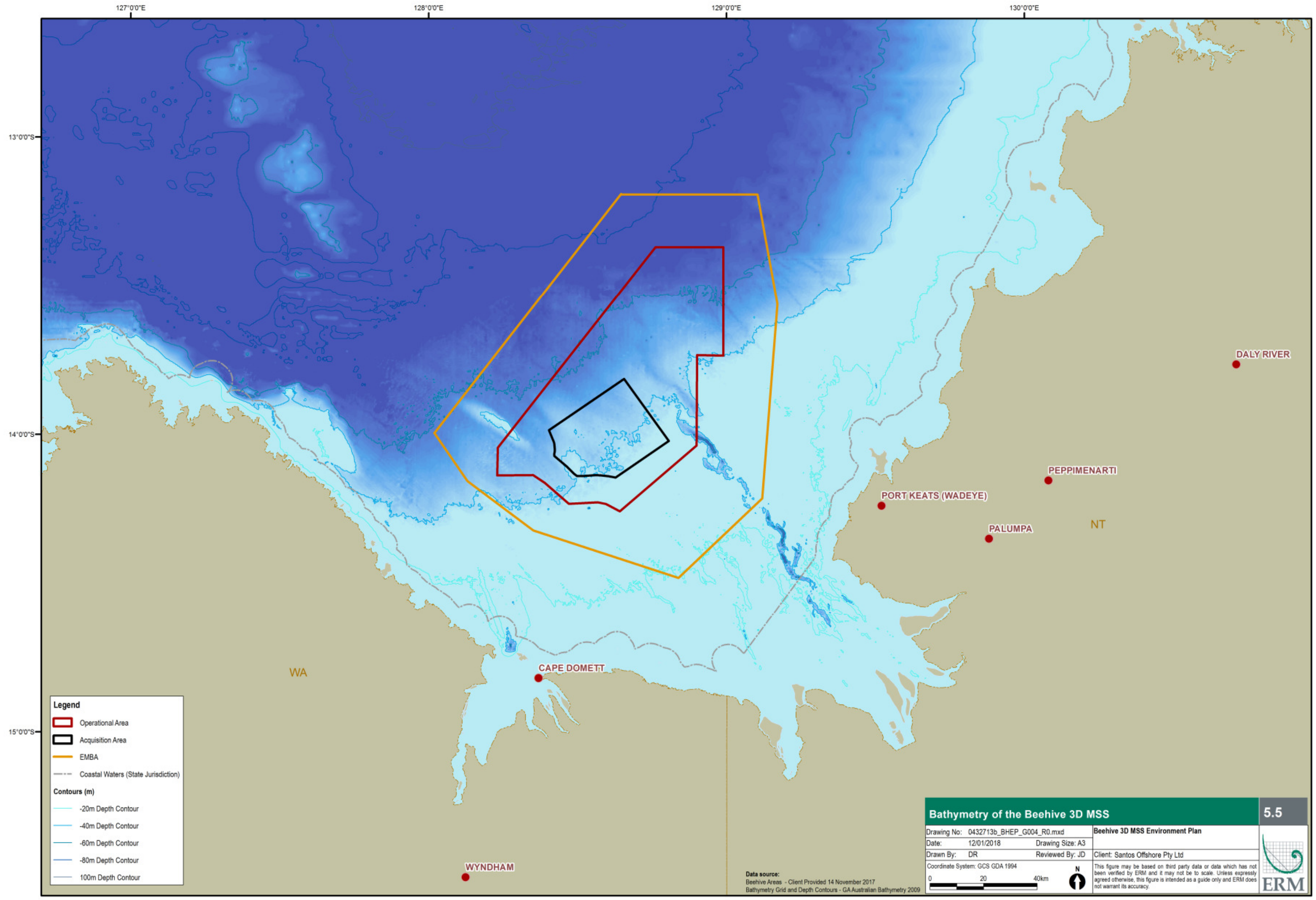

Figure 5.5 Bathymetry of the Operational and Acquisition areas and EMBA

5.5.10 *Geomorphic Features*

The JBG includes ten geomorphic features, with the inner area comprising mostly shelf, the outer area comprising basin, and the outer Gulf – Timor Sea comprising banks and terraces separated by deep/hole/valley features (Przeslawski et al. 2011). The Beehive EMBA is within the inner area of the JBG, and as shown in geomorphic features within the EMBA consist of:

- Shelf – low-relief expanses of unconsolidated sediment.
- Banks/shoals – local or regional areas of elevated seafloor with one or more steep sides.
- Basin – low-relief expanses of unconsolidated sediment.
- Deep/hole/valley - dominated by flat soft sediment expanses.
- Tidal-sandwave/sand bank.

Przeslawski et al. (2011) describe a habitat classification system based on regional-scale derivations of seascapes from combined interpolation of seven environmental factors in the JBG. The Operational and Acquisition areas are located predominantly in Seascape 5 (shelf, shallow, very high exposure, gravely, very high primary production, warm) and Seascape 4 (shelf, high exposure, high primary production).

5.5.11 *Sedimentology*

The top layer of sediment in the JBG from ~ 3 to 35 km offshore is expected to be greater than 1 m in depth and consists of sands and gravels with variable proportions of clay. This material is primarily alluvium, derived from sedimentary sandstones and basal conglomerate. Sonar images indicate some minor paloeochannels in this area containing megaripple or sand waves. These sediments are generally unconsolidated coarse sand, fine gravel interspersed with areas of flat and featureless seabed containing very soft to firm gravelly clays (Woodside 2004).

The main drainage channels for the Victoria River System occur from approximately 35 to 58 km offshore. This area is dynamic as currents and tidal influence are constantly changing the seabed features in the area. Due to the dynamic nature of the channels, the thickness of the top layer of sediment is expected to be variable. A top layer greater than one metre in depth and consisting of sands and gravels with variable proportions of clay is expected from 59 km to 65 km offshore, with some minor paloeochannels occurring. The influence of alluvial inputs diminishes from around 60 km offshore to the Blacktip Wellhead Platform (WHP) (which is located within the Beehive Operational Area). This top layer increases to greater than two metres in depth from 66 km offshore and the sediments range from loose silty/clayey sands from 66 km to 75 km and very soft clayey silt and silty clay from 75 km offshore to the WHP location. Again, the seabed alternates between flat and featureless seabed containing very soft to firm silty clay and an area of hummocky seabed containing megaripple or sand waves, though the seabed is generally flat from about 66 km offshore to the WHP location (Woodside 2004).

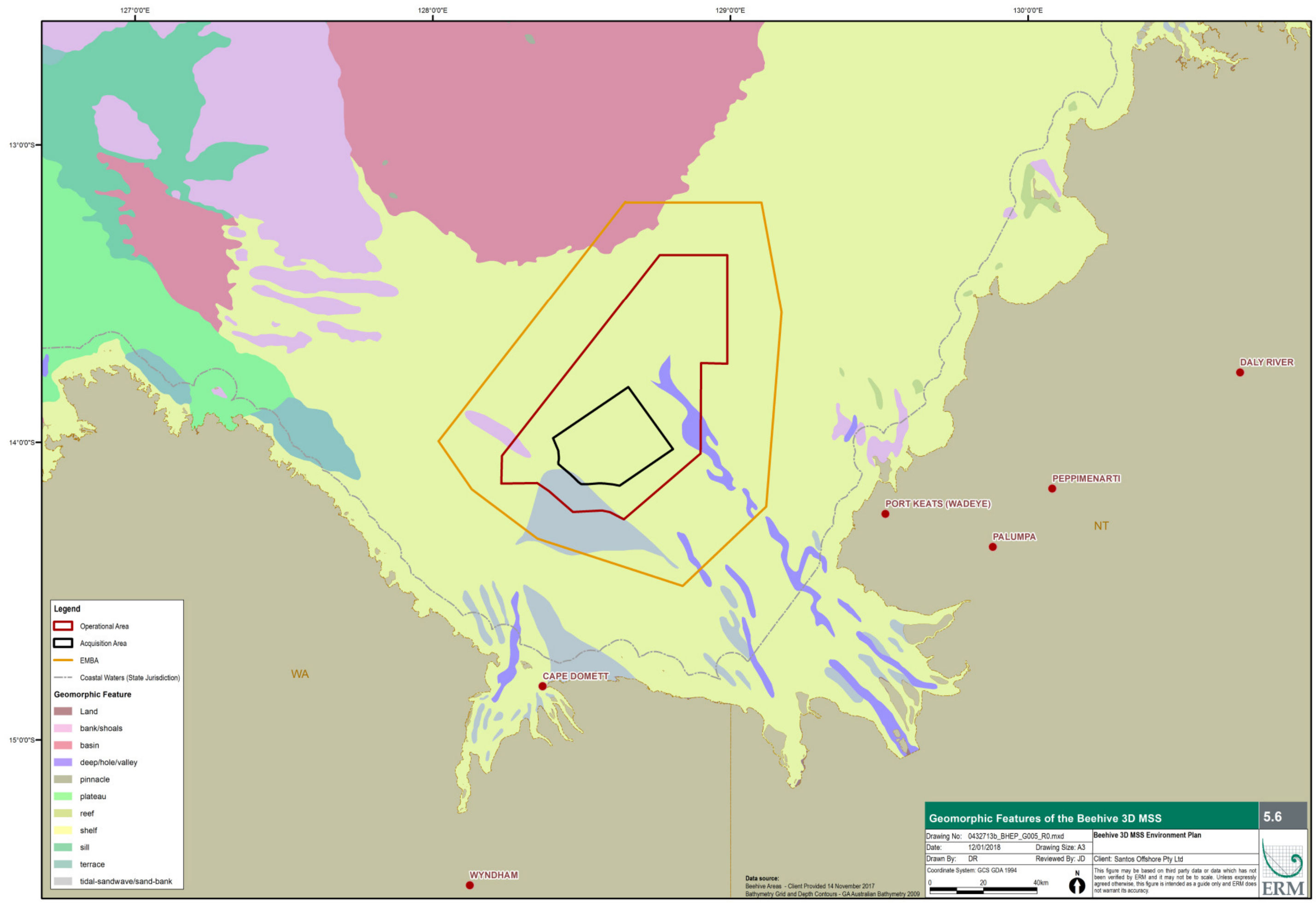

Figure 5.6 Geomorphic features of the Operational Area and EMBA

5.6 *Biological Environment*

5.6.1 *Benthic Environment*

The benthic environment of the JBG is linked to its geomorphic features, with the majority of the area characterized by infaunal plains, with some localised reefs and outcrops supporting sponge gardens. Przeslawski et al. (2011) provides an overview of the benthic environment associated with the different geomorphic features within the EMBA (*Figure 5.7*):

- Shelf – sediment plains that are swept by strong tidal currents and are subject to large influxes of suspended sediment and freshwater, particularly during the wet season. Support diverse infaunal communities that play a key ecological role by contributing to nutrient cycling and sediment turnover (bioturbation) at the local scale. Low abundance of crustaceans, echinoderms and sessile epifauna.
- Banks/shoals - elevated features with a relatively high proportion of hard substrate that support patches of moderately dense octocoral and sponge gardens which in turn provide habitat for other epifauna and cryptofauna. Banks support high numbers of epifaunal species. Infaunal species richness is moderately high in bank sediments. Very few macroalgae (including *Halimeda*) or reef-forming hard corals were recorded.
- Basin - low-relief expanses of unconsolidated sediment, and the available biological data suggests that these habitats are dominated by infauna with limited epifauna
- Deep/hole/valley - dominated by flat soft sediment expanses. Support low-moderate numbers of epifaunal species and include many debris-swept channels, which in places expose small patches of underlying rock that support moderate densities of sessile animals.
- Tidal-sandwave/sand bank – high disturbance, soft substrate, limited biota.

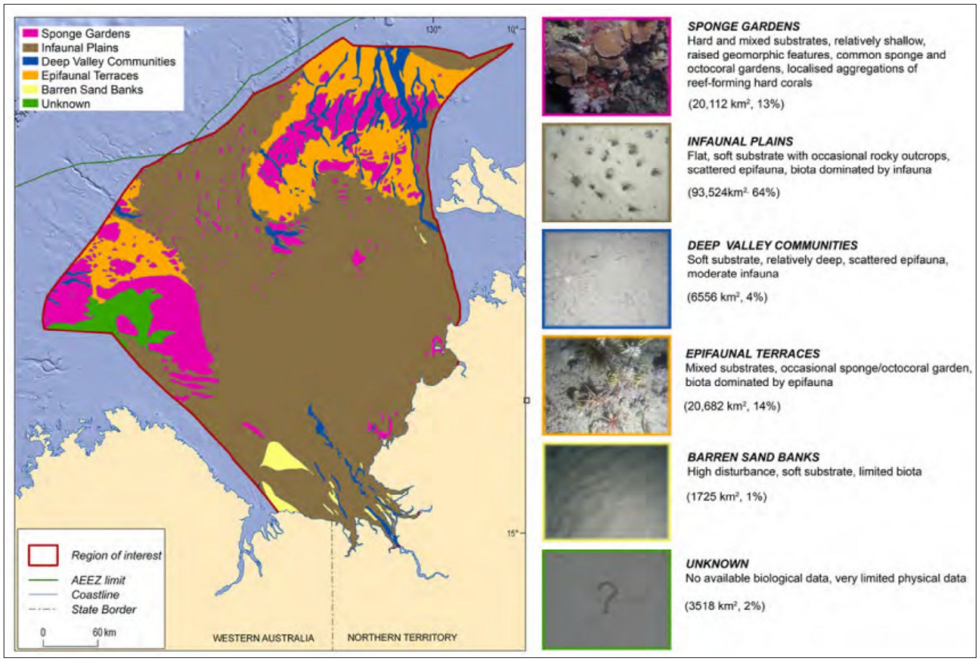

Figure 5.7 ***Generalise habitat map showing the potential distribution of habitats and biological communities in the Joseph Bonaparte Gulf (Przeslawski et al. 2011)***

As is evident in *Figure 5.7* above, the dominant habitat type across most of the EMBA and Operational Area is infaunal plains, which are characterised by flat, soft substrates with occasional rocky outcrops, scattered epifauna, and biota dominated by infauna.

Infaunal Communities

Studies conducted on the infauna within the Blacktip Project area found infauna to be diverse and abundant, with two major phyla, Arthropoda (crustaceans) and Annelida (polychaete worms) contributing over 80% of the total number of individuals (Woodside 2004). Arthropoda species recorded include tanaids (shrimps), brachyurans (crabs) and grammarid amphipods. The Annelida were diverse comprising of 36 families, with the most abundant families being Terebellidae, Spionidae, Onphidae, Maldanidae and Ampharetidae. Members of these families are mainly tube-dwelling worms that feed on detrital material on the surface or in the surface sediments. Other abundant infauna were the Cnidaria (hydroids, soft corals), Mollusca (mainly bivalves) and Echinodermata (brittle stars, sea urchins).

The Blacktip baseline studies found that infauna species richness and abundance in the JBG was related to sediment particle size. Richness and species abundance increased with distance from the mouth of the Victoria River, which coincided with an increasing proportion of fine particles in the sediment (Woodside 2004). Sites near the Victoria River mouth generally had coarser sediments and lower species richness and abundance. The Blacktip sampling sites supported a richer assemblage than sites closer to the Victoria River mouth (Woodside 2004).

A baseline marine survey, conducted in May 2004 at the Blacktip WHP location, and along the pipeline route also documented a species rich fauna, with 135 nominal species identified. However, faunal abundance was low with only 528 individuals recorded and only 14 species recording more than 10 individuals across all the offshore samples. The composition of the infaunal community was somewhat unusual. Continental shelf infauna are generally dominated by polychaete worms. However, nearly three times as many crustaceans were collected as polychaetes. Bryozoans and hydroids were the next most abundant group after the crustaceans; and, nearly as many molluscs and echinoderms were collected as polychaetes. The most abundant species were a porcelain crab followed by a brittle star (Woodside 2004).

The study also observed that sites near the Victoria River mouth, which generally had coarser sediments, had a greater proportional abundance of crustaceans and cnidarians (hydroids and soft corals) compared to sites further offshore, which supported a predominantly deposit feeding infauna (Woodside 2004).

5.6.1.1 Crustaceans

In a study of prawn trawl bycatch in the JBG, which included sampling locations within the Beehive Operational Area and EMBA, Tonks et al. (2008) found that four crustacean species dominated the invertebrate component of the bycatch: *Charybdis callianassa* (Portunidae); *Trachypenaeus gonospinifer* (Penaeidae); *Metapenaeopsis novaeguineae* (Penaeidae); and *Solenocera australiana* (Solenoceridae).

The dominant prawn species of the JBG are the penaeid species, namely tiger prawn (*Penaeus esculentus*), banana prawn (*P. merguiensis*) and red-legged banana prawn (*P. indicus*). These species occur in coastal waters to depths of approximately 200 m, and are widely distributed through subtropical and tropical waters from Western Australia to New South Wales (Jones and Morgan 1994). Shallower inshore waters act as nursery grounds for juveniles, such as the river and tidal creek systems of the JBG. Small numbers of prawns can also be found in mangrove habitats. More is known about the distribution and abundance of prawns in the JBG compared to other crustaceans because a number of species are commercially harvested.

As discussed in detail in *Section 5.7.2*, prawns are commercially caught in areas of the JBG, mainly in the west of the gulf and in Fog Bay (Northern Territory) to the north of the Beehive Acquisition and Operational areas. The juvenile prawns that migrate offshore to the fishery come from mangrove nursery habitats from the Victoria River in the east of the Gulf, to the Ord River and Cambridge Gulf in the west, forming a very extensive migration throughout the lower region of the JBG. Although there is no data on the exact timing of the migration, it is likely to be from February to April and October to December. Migration of the juveniles is thought to be triggered by rainfall and river discharge.

5.6.1.2 *Molluscs*

The JBG has relatively low mollusc species diversity, with less than 100 species recorded in the region (Walker et al. 1996). Squid are a large bycatch of the Northern Prawn Fishery, and may occur periodically in large numbers in the area, although very little is known regarding the distribution of squid in the area.

5.6.2 *Pelagic environment*

A search of the DoEE Protected Matters Database was undertaken covering a 1 km buffer around the Beehive 3D MSS EMBA. *Table 5.6* details fauna identified by the Protected Matters Search and any applicable management plans, recovery plans and approved conservation advice.

Table 5.6 Threatened and Migratory Species that may occur in the EMBA

Common Name	Scientific Name	EPBC Act Status	Management Plan / Recovery Plan and Approved Conservation Advice	Relevant Management Actions
Sharks				
Narrow sawfish	*Anoxypristis cuspidata*	Migratory	-	-
White shark	*Carcharodon carcharias*	Vulnerable, Migratory	Recovery Plan for the White Shark (*Carcharodon carcharias)*	None identified
Northern river shark	*Glyphis garricki*	Endangered	Sawfish and River Sharks Multispecies Recovery Plan	None identified
Shortfin mako	*Isurus oxyrinchus*	Migratory	-	-
Longfin mako	*Isurus paucus*	Migratory	-	-
Dwarf sawfish	*Pristis clavata*	Vulnerable, Migratory	Sawfish and River Sharks Multispecies Recovery Plan Approved Conservation Advice for *Pristis clavata* (dwarf sawfish)	None identified
Freshwater sawfish	*Pristis*	Vulnerable, Migratory	Sawfish and River Sharks Multispecies Recovery Plan	None identified
Green sawfish	*Pristis zijsron*	Vulnerable, Migratory	Sawfish and River Sharks Multispecies Recovery Plan Approved Conservation Advice for *Pristis zijsron* (green sawfish)	None identified
Whale shark	*Rhincodon typus*	Vulnerable, Migratory	Whale Shark (*Rhincodon typus)* Recovery Plan 2005-2010 *expired recovery plan	Evaluate risk of vessel strike (*Section 7.8*) Evaluate risk from noise emissions (*Sections 7.1* and *7.2*)
Rays				
Reef manta ray	*Manta alfredi*	Migratory	-	-
Giant manta ray	*Manta birostris*	Migratory	-	-
Reptiles				
Loggerhead turtle	*Caretta*	Endangered, Migratory	Recovery Plan for Marine Turtles in Australia 2017 - 2027	Evaluate risk of vessel strike (*Section 7.8*)
Green turtle	*Chelonia mydas*	Vulnerable, Migratory		
Leatherback turtle	*Dermochelys coriacea*	Endangered, Migratory		

Common Name	Scientific Name	EPBC Act Status	Management Plan / Recovery Plan and Approved Conservation Advice	Relevant Management Actions
Hawksbill turtle	*Eretmochelys imbricata*	Vulnerable, Migratory		Management of marine debris (Section 7.6) Soft start procedures to be implemented for seismic surveys that occur within the distribution of marine turtles (*Section 7.1*). Spill risk strategies and response programs include management for marine turtles and their habitats (*Sections 7.11* and *7.12*), Management of light pollution (*Section 7.3*) Management of vessel/fauna interactions (*Section 7.8*).
Olive ridley turtle	*Lepidochelys olivacea*	Endangered, Migratory		
Flatback turtle	*Natator depressus*	Vulnerable, Migratory		
Salt-water crocodile	*Crocodylus prosus*	Migratory	-	-
Marine Birds				
Common noddy	*Anous stolidus*	Migratory	-	-
Red knot	*Calidris canutus*	Endangered	Approved Conservation Advice for *Calidris canutus* (red knot).	None identified
Curlew sandpiper	*Calidris ferruginea*	Critically Endangered, Migratory	Approved Conservation Advice for *Calidris ferruginea* (curlew sandpiper).	None identified
Streaked shearwater	*Calonectris leucomelas*	Migratory	-	-
Lesser frigatebird	*Fregata ariel*	Migratory	-	-
Great frigatebird	*Fregata minor*	Migratory	-	-
Eastern curlew	*Numenius madagascariensis*	Critically Endangered, Migratory	Approved Conservation Advice for *Numenius madagascariensis* (eastern curlew).	None identified
Mammals				
Sei whale	*Balaenoptera borealis*	Vulnerable, Migratory	Conservation Advice *Balaenoptera borealis* (sei whale) *not a recovery plan	Minimise vessel collisions (*Section 7.8*)
Bryde's whale	*Balaenoptera edeni*	Migratory	-	-

Common Name	Scientific Name	EPBC Act Status	Management Plan / Recovery Plan and Approved Conservation Advice	Relevant Management Actions
Blue whale	*Balaenoptera musculus*	Endangered, Migratory	Conservation Management Plan for the Blue Whale 2015-2025	Minimise vessel collisions (*Section 7.8*)
Fin whale	*Balaenoptera physalus*	Vulnerable, Migratory	Conservation Advice *Balaenoptera physalus* (fin whale) *not a recovery plan	Minimise vessel collisions (*Section 7.8*)
Dugong	*Dugong dugon*	Migratory	-	-
Humpback whale	*Megaptera novaeangliae*	Vulnerable, Migratory	Conservation Advice for *Megaptera novaeangliae* (humpback whale) *not a recovery plan	Assess and address anthropogenic noise (*Sections 7.1* and *7.2*) Minimise vessel collisions (*Section 7.8*) Report all fauna strike events (*Section 7.8*)
Killer whale	*Orcinus orca*	Migratory	-	-
Indo-Pacific humpback dolphin	*Sousa chinensis*	Migratory	-	-
Spotted bottlenose dolphin	*Tursiops aduncus*	Migratory	-	-

5.6.3 *Plankton*

Plankton consists of microscopic organisms typically divided into phytoplankton (algae) and zooplankton (fauna including larvae). Plankton play a major role in the trophic system with phytoplankton being a primary producer and zooplankton a primary consumer. Phytoplankton rapidly multiply in response to bursts of nutrient availability and are subsequently consumed by zooplankton that in turn are consumed by other fauna species.

Nutrients and planktonic organisms (including many species of larval recruits) are transported to and from the JBG by the southerly movement of the Indonesian Throughflow and the south-east and north-west monsoonal wind-driven currents (Brewer et al. 2007).

The WA Department of Primary Industries and Regional Development (DPIRD) have indicated that the species in *Table 5.7* may spawn within the North Coast bioregion, including the JBG (DoF 2013). A review of available data identified it is unlikely that spawning of these species would occur in the area during the period proposed for acquisition (*Table 5.7*).

Based on information from the Northern Prawn Fishery Industry (NPFI) during the Santos Fishburn 3D MSS, commercial prawn species such as banana, tiger and endeavour prawns may spawn within the Acquisition Area. Advice from the NPFI is that banana prawns spawn offshore near to the fishing area throughout the year with two spawning peaks: the late dry season (September-November) and the late wet season (March-May). These peak spawning periods are outside the period proposed for acquisition.

Endeavour prawns spawn throughout the year, with blue endeavour prawns having spawning peaks in March and September and red endeavour prawns have a spawning peak in September to December. Based on the endeavour prawn spawning habitat preferences it is unlikely that they would spawn in the offshore area of the survey.

Brown tiger prawns peak spawning period is between July and October. A twelve-month-old female prawn can produce hundreds of thousands of eggs at a single spawning and may spawn more than once in a season. The eggs sink to the bottom after release, where they hatch into larvae within about 24 hours. Less than 1% of these offspring survive the two to four week planktonic larval phase to reach suitable coastal nursery habitats where they may settle. After one to three months on the nursery grounds, the young prawns move offshore onto the fishing grounds. See *Section 5.7.2* for more information.

During stakeholder engagement for the Santos Fishburn 3D MSS the Pearl Producers Association (PPA) noted that at the proposed depths where that survey took place within the JBG place, there will most likely be a variable distribution of *Pinctada maxima* (silver lipped pearl oyster). *P. maxima* are known to be sparsely distributed in the JBG out to the 100 m isobath. The species spawns in the spring months of September or October, with primary spawning from the middle of October to December. A smaller secondary spawning occurs in February and March (Hart et al. 2016). Hence, spawning of this species is outside the period proposed for survey acquisition.

Table 5.7 Assessment of the potential of spawning of fish species during the Beehive 3D MSS

Key Fish Species	Spawning/ Aggregation Times	Likely to be Spawning near Survey Location	Information
Pink snapper (*Chrysophrys auratus)*	May – July	No	In the North Bioregion pink snapper spawn during the period May to July, however, this is classed as rare (DoF 2013; see *Table 5.8*. DoF (2017a) states "pink snapper are found from the warmer waters to the north of Karratha to the cooler waters of the Great Australian Bight. In some locations, pink snapper gather seasonally to spawn in large schools called 'aggregations'. The best known of these occur in Shark Bay and in Cockburn and Warnbro sounds off the Perth metropolitan area. Pink snapper form spawning 'aggregations' (groups) of thousands, which are often found in the same few locations each year."
Rankin cod (*Epinephelus multinotatus*)	Aug - Oct	No	In the North Coast bioregion Rankin cod spawn during the period August to October (see *Table 5.8*).
Spanish mackerel (*Scomberomorus commerson)*	Aug - Nov	No	In the North Coast bioregion Spanish mackerel spawn during the period August to November (see *Table 5.8*). DoF (2017b) says "Adults 'aggregate' (form groups) to feed and 'spawn' (release sperm and eggs) in coastal areas." The Acquisition Area is ~ 70 km from coastal areas.

Table 5.8 DoF (2013) information on key fish species spawning period

Appendix 2: Spawning period (indicated in red) for some key fisheries species and their bioregional distribution[1]

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Bioregion
Blacktip shark (*Carcharhinus tilstoni and C. limbatus*)											■	■	North Coast
Goldband snapper (*Pristipomoides multidens*)	■	■	■	■									North Coast
Rankin cod (*Epinephelus multiinotatus*)								■	■	■			North Coast
Red Emperor (*Lutjanus sebae*)	■		■							■			North Coast
Sandbar shark (*Carcharhinus plumbeus*)	■									■	■	■	North Coast
Spanish mackerel (*Scomberomorus commerson*)								■	■	■	■		North Coast
Pink snapper (*Pagrus auratus*)					■	■	■						North Coast (rare)
Baldchin groper (*Choerodon rubescens*)	■	■							■	■	■	■	Gascoyne
Blacktip shark (*Carcharhinus tilstoni and C. limbatus*)											■	■	Gascoyne
Crystal (snow) crab (*Chaceon* spp.)	■	■	■	■	■	■	■	■	■	■	■	■	Gascoyne
Goldband snapper (*Pristipomoides multidens*)	■	■	■	■									Gascoyne
King George whiting (*Sillaginodes punctata*)						■	■	■	■				Gascoyne
Pink snapper (*Pagrus auratus*)					■	■	■						Gascoyne
Rankin cod (*Epinephelus multinotatus*)								■	■	■			Gascoyne
Red Emperor (*Lutjanus sebae*)	■		■							■			Gascoyne
Sandbar shark (*Carcharhinus plumbeus*)	■									■	■	■	Gascoyne
Spanish mackerel (*Scomberomorus commerson*)								■	■	■	■		Gascoyne

■ = spawning period

5.6.4 *Fish*

The Protected Matters Database search identified 21 pipefish species, four seahorse species and four pipehorse species that may potentially occur in the EMBA. Seahorses (*Hippocampus* spp.) and pipefish (*Solegnathus* spp.) are among the site-associated fish genera (DSEWPAC 2012a).The species group report card – bony fishes (DSEWPAC 2012d), which supplements and supports the NWMR bioregional plan, states that almost all syngnathids (pipefish, seahorses and pipehorses) live in nearshore and inner shelf habitats, usually in shallow, coastal waters, among seagrasses, mangroves, coral reefs, macroalgae-dominated reefs, and sand or rubble habitats with temperate water species predominately inhabit seagrasses and macroalgae, while tropical species are primarily found among coral reefs. A review of information on habitat preference and water depth range has been conducted for the 29 syngnathid species identified in the Protected Matters Database search (*Table 5.9*). The water depths of the EMBA range from 20 – 90 m. Of the 29 syngnathid species listed in *Table 5.9* 17 species have been recorded in water depths >20 m. However, the majority of these species are not expected to occur across the flat, soft substrates that predominate throughout the Operational Area and EMBA. These species are more likely to be associated with habitats found in coastal waters of the southern JBG.

Seahorses and pipefishes have been recorded as bycatch in the NWMR from the trawl operations of the Northern Prawn Fishery (NPF) (DSEWPAC 2012d), however, no pipefish, seahorse or pipehorse species were identified in a study of species composition of prawn trawl bycatch undertaken within and to the west of the EMBA (Tonks et al. 2008). *Figure 5.8* shows the locations of the NPF bycatch study locations in comparison to the EMBA and Operational Area.

Table 5.9 Summary of habitat preference and depth range for syngnathid species that may occur within EMBA

Species	Habitat[1,2,3,4]	Depth Range (m)
Campichthys tricarinatus	Sand, coral rubble, algae (including *Sargassum*), isolated coral knolls, soft corals, small sponges, low coral outcrops, sheltered reef and rocky islets in depths of 3-11 m.	2-11
Choeroichthys brachysoma	Has been recorded in depths of up to 27.4 m it most commonly occurs in seagrass, reef and coral habitats in depths of less than 5 m. Reefs (fringing, exposed, sheltered and limestone), live corals (including *Porites*, *Acropora*, *Millepora* and *Synarea*), soft corals, dead corals, algae (including *Sargassum* and filamentous algae), seagrass, sponges, hydroids, coral and shell rubble, coral rock, beach rock, sandstone terraces, isolated rock pools, caves, lagoons, mud, sand, and silt.	1-27
Choeroichthys suillus	Occurs in inshore reef habitats. Coral knolls, live corals, coral rubble, shell rubble, coral rock, ledges, sand, seagrass and algae in depths of 1-14 m.	1-15
Corythoichthys amplexus	Most commonly found in depths greater than 9 m. Outer reefs, reef edges, coral gutters, bomboras, caves, isolated coral knolls, reef walls and slopes, against drop-offs, ledges, live corals (including *Acropora*, alcyonarians and gorgonians), soft corals, sand rubble, lagoons, sand and fine silt, in depths of 0-35 m.	0-35
Corythoichthys flavofasciatus	Fringing coral reefs, coral reef crests, reef flats, live corals (including *Acropora*), gorgonians, limestone rock platforms, soft corals, dead corals, algae, encrusting organisms, rubble, rocky shores, gutters, drop-offs, bomboras, pools, caves and sand, in depths of 0.1-30 m	<1-30
Corythoichthys haematopterus	Occurs on reef crests and slopes and on rubble patches and large coral heads. It is also known from intertidal and generally shallow sheltered inner reef flats and rubble lagoons, usually in association with partially silty habitats.	1-20
Corythoichthys schultzi	Coral reefs and outer reef edges, wrecks, bomboras, coral knolls, channels, live corals (including *Acropora* and alcyonarians), mangroves, weed beds, coral rubble, sand rubble, vertical walls, caves, lagoons, sand and silt, in depths of 1-30 m.	1-30
Doryrhamphus excisus	Inhabits coastal to outer reefs, in a variety of habitats including lagoons, reef flats, reef slopes and walls, channels, coral gutters, usually in or near crevices and caves, in depths between 5 and about 45 m.	5-45
Doryrhamphus janssi	Inhabits sheltered inshore coral reefs where pairs usually maintain cleaning stations in caves and crevices with sponges, and below large plate corals.	14-44
Festucalex cinctus	Usually dredged or trawled in depths of 8-31 m but divers also found over rubble bottoms in depths of 12 m. Occurs in sponge and seagrass habitats in sheltered coastal bays with sparse low algal growth.	1-31
Halicampus brocki	Occurs on coral and rocky reefs with algae. Inhabits patches of coral and macro-algae on coastal reefs at 3-45 m.	3-45
Halicampus grayi	inhabits silty and muddy soft bottoms on the continental shelf from inshore bays to deep offshore areas to 100 m.	0-100
Halicampus spinirostris	Inhabits shallow coral rubble areas in lagoons and intertidal zones of inshore coral reefs in 5-10 m.	5-10
Haliichthys taeniophorus	Inhabits a variety of inshore shallow water areas including weedy regions bordering open substrates, coral reefs, rocky, gravel, sandy and muddy substrates; also associated with sponges, algae, hydroids, shells and seagrass usually from 1-18 m.	0-18

Species	Habitat[1,2,3,4]	Depth Range (m)
Hippichthys cyanospilos	Inhabits brackish shallow-water environments in estuaries and lower reaches of coastal rivers and streams, often amongst mangroves to 4 m.	0-4
Hippichthys parvicarinatus	An endemic species restricted to estuarine and freshwater habitats in the Northern Territory.	0-5
Hippichthys penicillus	Found in lower reaches of streams and rivers, seagrass beds in estuaries and other shallow inshore habitats.	0-5
Hippocampus histrix	Inhabits areas with both hard and soft bottoms, often attached to soft corals or sponges at 10-95 m, usually 15-40 m. Also found on shallower algae-rubble or rocky reef areas in about 10 m depth.	5-95
Hippocampus kuda	Found in shallow inshore waters normally between 0-8 m depth with a maximum recorded depth of up to 55 m. Inhabits coastal bays, harbours and lagoons, sandy sediments in rocky littoral zones, macroalgae and seagrass beds, mangroves, muddy bottoms, and shallow reef flats.	0-55
Hippocampus planifrons	Inhabits algal and rubble reefs in shallow bays from the intertidal to depths of 20 m.	0-20
Hippocampus spinosissimus	Benthic in inner reef waters on rubble substrates and in sponge and seagrass habitats near coral reefs at 20-63 m; often attached to corals in deep current-prone channels between reefs or islands.	20-70
Micrognathus micronotopterus	Usually inhabits shallow inshore reefs and tidepools, amongst sparse seagrasses and algae-rubble, in depths from 1-5 m, although individuals have been collected from depths to 10 m.	1-10
Solegnathus hardwickii	Mostly known from trawled specimens captured from 12 m to 100 m depth, though it has been collected in depths of up to 180 m.	12-180
Solegnathus lettiensis	Benthic inhabitant of outer continental shelf waters and has been captured from depths of 42-180 m. Trawl bycatch records in 150-180 m water depths in Australia.	42-180
Solenostomus cyanopterus	Inhabit protected coastal and lagoon reefs, deeper coastal reefs and deep, clear estuaries with seagrass or macro-algae in 4-21 m.	4-21
Solenostomus paegnius	Reef associated. Depth range 0-10 m.	0-10
Syngnathoides biaculeatus	Inhabits shallow, protected waters of bays, lagoons and estuaries including mangrove areas, in association with seagrass beds and macroalgae in depths at 0-10 m.	0-10
Trachyrhamphus bicoarctatus	Inhabits sheltered coastal lagoon and reef areas on sandy and rubble habitats amongst seagrasses and macroalgae at 1–30 m. Has been recorded to 42 m	1-42
Trachyrhamphus longirostris	Most specimens have been trawled or dredged from muddy to sandy-bottom habitats in depths of 16-91 m, in association with sand, rubble, seagrasses, algae, sponges, sea pens and hydroids.	16-91

Sources: [1] DoEE (2017); [2] Bray and Thompson (2017); [3] Austin and Pollom (2016); [4] Froese and Pauly (2017).

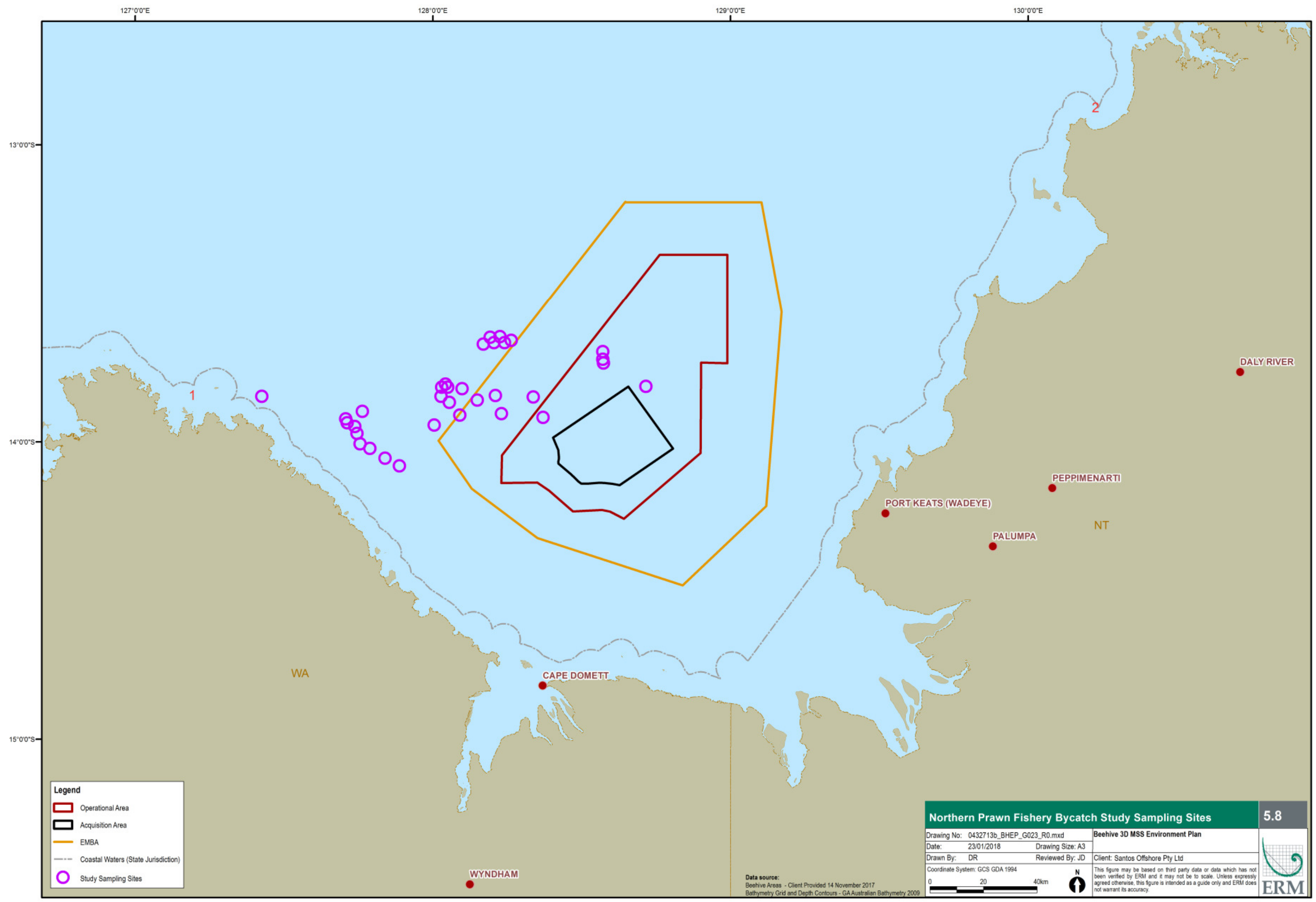

Figure 5.8 Northern Prawn Fishery bycatch study sampling sites

Based on the waters depths and benthic habitat likely to be present in the EMBA and that syngnathid species were not recorded in the NPF trawls near the EMBA, these species may present in the EMBA with more species abundance expected associated with the shoal/bank feature located in the western part of the Operational Area and EMBA.

Tonks et al. (2008) identified 112 teleost species from 61 families from 53 NPF commercial trawls over two years. The species with the highest mean catch rates were glassy bombay duck (*Harpadon translucens*), threadfin scat (*Rhinoprenes pentanemus*), largehead hairtail (*Trichiurus lepturus*), blackfin threadfin (*Polydactylus nigripinnis*) and smooth croaker (*Johnius laevis*).

As described in *Section 5.6.1* and shown in *Figure 5.7* above, the Operational and Acquisition areas predominantly overlap the infaunal plains habitat type, which is characterised by flat, soft substrates with occasional rocky outcrops, scattered epifauna, and a biota dominated by infauna (Przelawski et al. 2011). The Operational Area also overlaps three other benthic habitat types:

- Sponge gardens – characterised by hard and mixed substrates, relatively shallow water depths, raised geomorphic features, common sponge and octocoral gardens and localised aggregations of reef-forming hard corals.
- Deep valley communities – soft substrates, relatively deep water depths, scattered epifauna and moderate infauna.
- Barren sand banks – high disturbance, soft substrates and limited biota.

Hence, it is likely that the only habitat within the Operational Area that may support assemblages of site-attached fish are the sponge gardens that may occur on the shallow shoal/bank located in the western part of the Operational Area and EMBA.

5.6.5 Sharks

The Protected Matters Database search identified six species of threatened sharks that may occur within the EMBA: white shark, northern river shark, dwarf sawfish, largetooth sawfish, green sawfish and whale shark (*Table 5.6*). Of these, the white shark, whale shark, dwarf sawfish, freshwater sawfish and green sawfish are also migratory. The Protected Matters Database search also identified three additional migratory shark species: narrow sawfish, shortfin mako and longfin mako (*Table 5.6*).

White shark

The white shark is widely distributed, and located throughout temperate and sub-tropical waters with their known range in Australian waters including all coastal areas except the Northern Territory (DoEE 2017a). Studies of white sharks indicate that they appear to be largely transient, with a few longer-term residents; however, individuals are known to return to feeding grounds on a seasonal basis (Klimey and Anderson 1996). Observations of adult white sharks are more frequent around fur seal and sea lion colonies whilst juveniles are known to congregate in certain key areas. According to the National Conservation Values Atlas there are no biologically important aggregation, breeding or foraging areas near the EMBA, and given that the EMBA is at the extreme limit of the white shark's distribution, it is unlikely that white sharks will be encountered.

The Recovery Plan for the White Shark (*Carcharodon carcharias*) (DEWHA 2013) does not identify any threats or objectives that are relevant to the activity.

Northern river shark

The northern river shark is listed as endangered under the EPBC Act, based partly on its limited geographic distribution (TSSC 2014a). Within Australia, the northern river shark is known to occur in Western Australia and the Northern Territory, occupying both marine and freshwater environments including the JBG, Daly River, Adelaide River and the South and East Alligator Rivers (TSSC 2014a). Whilst northern river sharks have been observed well offshore, the extent to which this occurs is unknown (TSSC 2014a). The EMBA is adjacent to the area where adult northern river sharks may occur in the offshore waters of the Cambridge Gulf (*Figure 5.9*).

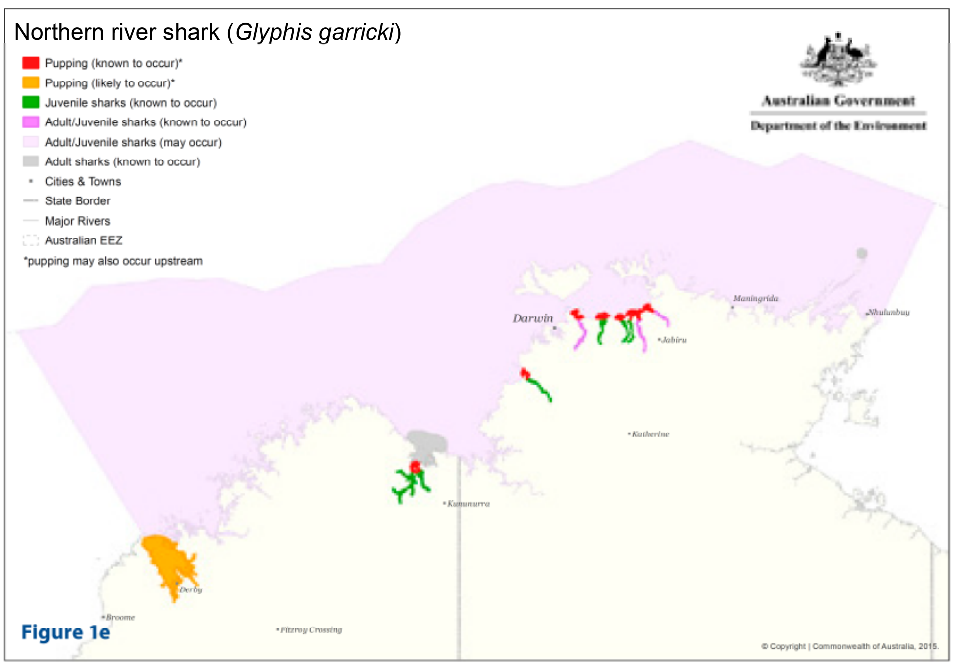

Figure 5.9 ***Distribution of northern river shark (DoE 2015a)***

Dwarf sawfish

The dwarf sawfish usually inhabits shallow (2–3 m deep) coastal waters and estuarine habitats. Its distribution is considered to extend north from Cairns around the Cape York Peninsula in Queensland, across northern Australian waters to the Pilbara coast in Western Australia (DoEE 2017b) (*Figure 5.10*). The

EMBA overlaps the area where adult dwarf sawfish are known to occur, however, it is unlikely they would be encountered given the distance from the EMBA to shallow coastal waters.

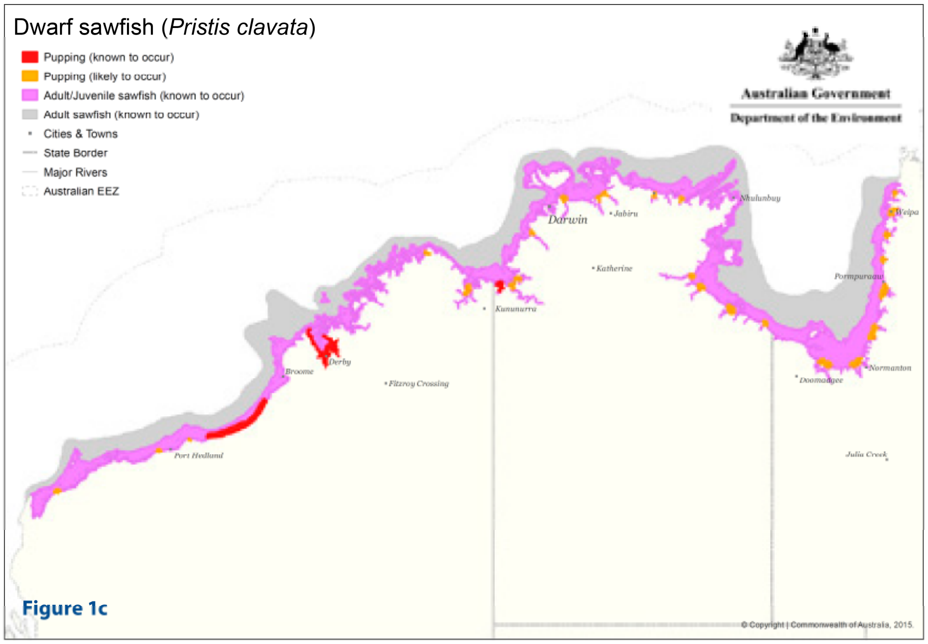

Figure 5.10 Distribution of dwarf sawfish (DoE 2015a)

Largetooth sawfish

Largetooth sawfish (formerly known as the freshwater sawfish) utilise both freshwater (juvenile) and marine (adult) environments during the different stages of its lifecycle (TSSC 2014b) Within Australia, largetooth sawfish have been recorded in numerous drainage systems across northern Western Australia, Northern Territory and northern Queensland (TSSC 2014b). The EMBA is within the area where adult largetooth sawfish are known to occur, and adjacent to an area where pupping is known to occur in the south-eastern part of the JBG (*Figure 5.11*). In addition, the largetooth sawfish is also likely to occur within the carbonate bank and terrace system of the Sahul Shelf KEF (DSEWPaC 2012a).

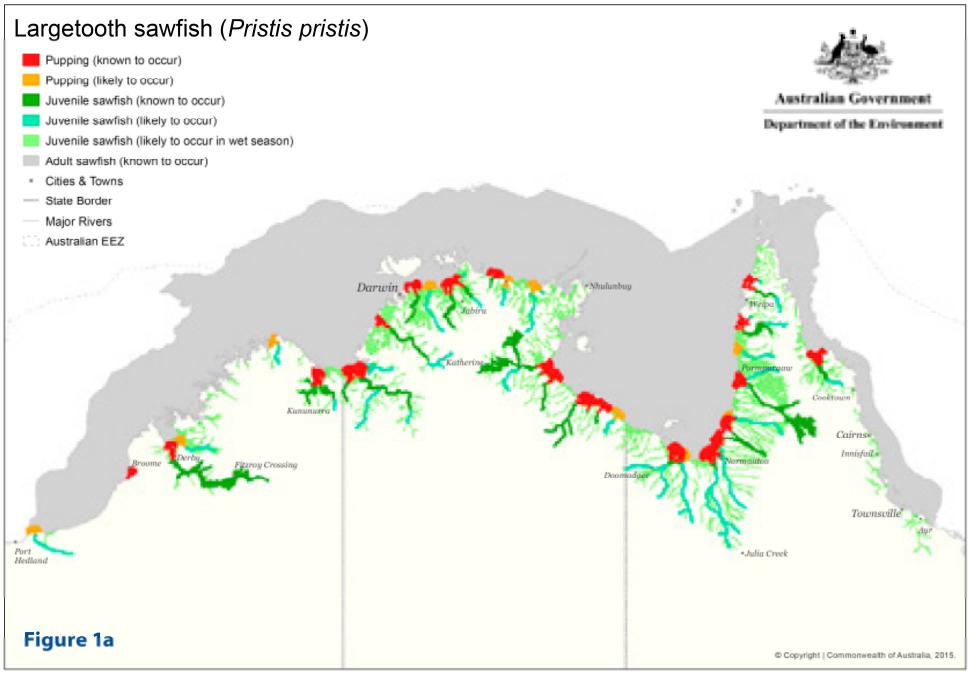

Figure 5.11 Distribution of largetooth sawfish (DoE 2015a)

Green Sawfish

The green sawfish occurs in both inshore and offshore marine coastal waters of northern Australia. Its current known distribution stretches from Broome in Western Australia around northern Australia and down the east coast as far as Jervis Bay, NSW (DoEE 2017r). The EMBA overlaps areas where both adult and juvenile sawfish are known to occur, and is adjacent to the inner waters of the southern JBG where pupping of this species is likely to occur (*Figure 5.12*). In addition, the green sawfish is also likely to within the carbonate bank and terrace system of the Sahul Shelf KEF (DSEWPaC 2012a). It has also been caught as bycatch from the NPF in the area overlapped by the EMBA and Operational Area (Tonks et al. 2008; see *Figure 5.21*).

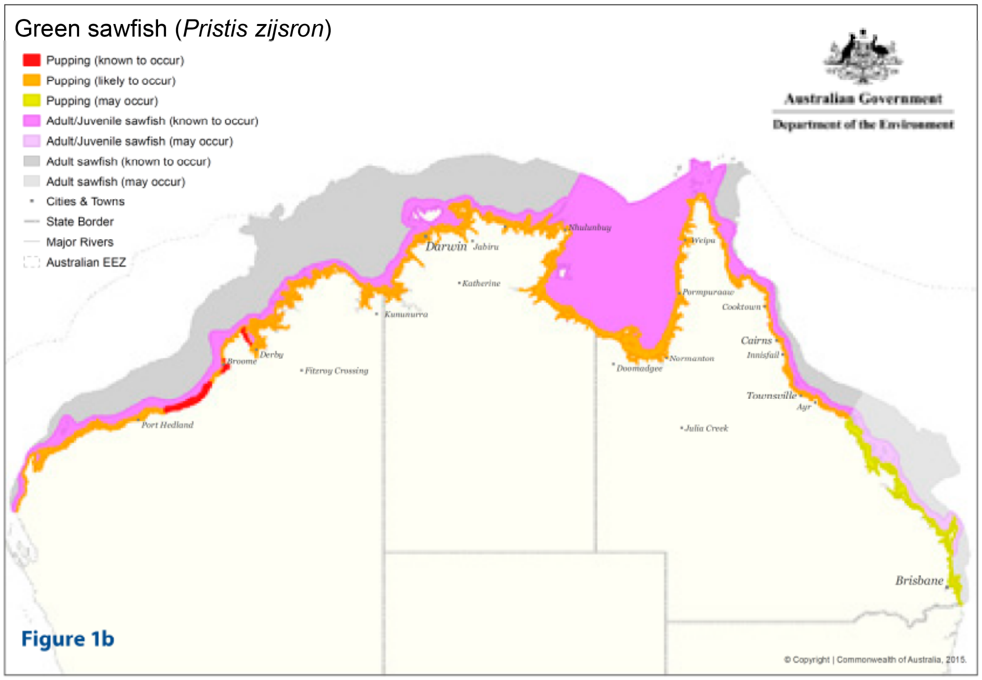

Figure 5.12 Distribution of green sawfish (DoE 2015a)

Narrow Sawfish

The narrow sawfish lives in coastal and estuarine habitats across northern Australia and is generally restricted to shallow waters (less than 40 m) (D'Anastasi et al. 2013). The species is known to occur in the Gulf of Carpentaria but its distribution and migration is largely unknown. The narrow sawfish has the potential to occur within the EMBA based on it has been caught as bycatch in the NPF in an area overlapping the EMBA and Operational Area (Tonks et al. 2008).

A review of the National Conservation Values Atlas did not identify any biologically important aggregation, breeding or foraging areas for river sharks or sawfish within the EMBA.

Due to their slow growth and maturation rates, longevity, low fecundity and low rates of natural mortality, sawfish are particularly vulnerable to human-induced pressures (DSEWPaC 2012a). The Sawfish and River Sharks Multispecies Recovery Plan (DoE 2015a) covers largetooth sawfish, green sawfish, dwarf sawfish, speartooth shark and the northern river shark. The primary objective of this recovery plan is to:

- *Improve the population status leading to the removal of the sawfish and river shark species from the threatened species list of the EPBC Act.*

Ensure that anthropogenic activities do not hinder recovery in the near future, or impact on the conservation status of the species in the future.

The recovery plan and specific conservation advices identify the principal threats to these sawfish and river shark species from: commercial fishing activities; recreational fishing, Indigenous fishing, illegal, unreported and unregulated (IUU) fishing, and habitat degradation and modification. Other potential threats to the species include the collection of animals for display in public aquaria and marine debris. Habitat degradation and marine debris are threats that are relevant to the Beehive 3D MSS and are detailed in *Table 5.10*

Table 5.10 ***Threats identified in the sawfish and river sharks' multispecies recovery plan relevant to the Beehive 3D MSS***

Relevant Threats	Objective	Actions Relevant to Activity
Marine debris	Reduce and, where possible, eliminate any adverse impacts of marine debris on sawfish and river shark species noting the linkages with the Threat Abatement Plan for the Impact of Marine Debris on Vertebrate Marine Life.	Management of marine debris is detailed in Section 7.6 Waste.
Habitat degradation	Implement measures to reduce adverse impacts of habitat degradation and/or modification.	The activity and any potential risks or impacts to sawfish and river shark habitat are assessed in Section 7. No impacts or risks to sawfish and river shark habitat were identified.

Currently, there are no adopted recovery plans or conservation advice documents for the narrow sawfish. The IUCN, however, identifies entanglement due to marine debris as a relevant key threat for this species (D'Anastasi et al. 2013).

Whale shark

The whale shark is a filter feeding shark and is the largest known species of fish in the world (DoEE 2017c). It is considered to be an oceanic and coastal species, commonly seen far offshore but also closer inshore near coral atolls (DoEE 2017c). Whale sharks generally prefer tropical to warm temperate waters where surface sea temperature ranges from 21° to 25 ºC (DoEE 2017c). In Australian waters the whale shark is commonly seen in waters off northern Western Australia, Northern Territory and Queensland with only very occasional sightings off Victoria and South Australia (Last and Stevens 1994). The movements of whale sharks are not well documented, however, they are known to seasonally aggregate (March / April) in shallow tropical waters off the North West Cape in Western Australia (DoEE 2017c). According to the National Conservation Values Atlas there is a foraging biologically important area (BIA) ~234 km to the west of the EMBA (*Figure 5.13*). Thus, due to their widespread distribution and highly migratory nature, individuals may transit through the EMBA.

The Whale Shark (*Rhincodon typus*) Recovery Plan 2005-2010 (DEH 2005a) ceased to be in effect from 2015. The DoEE SPRAT profile (DoEE 2017c) identifies increased noise from boats and boat strike as threats that are relevant to the activity (*Table 5.11*).

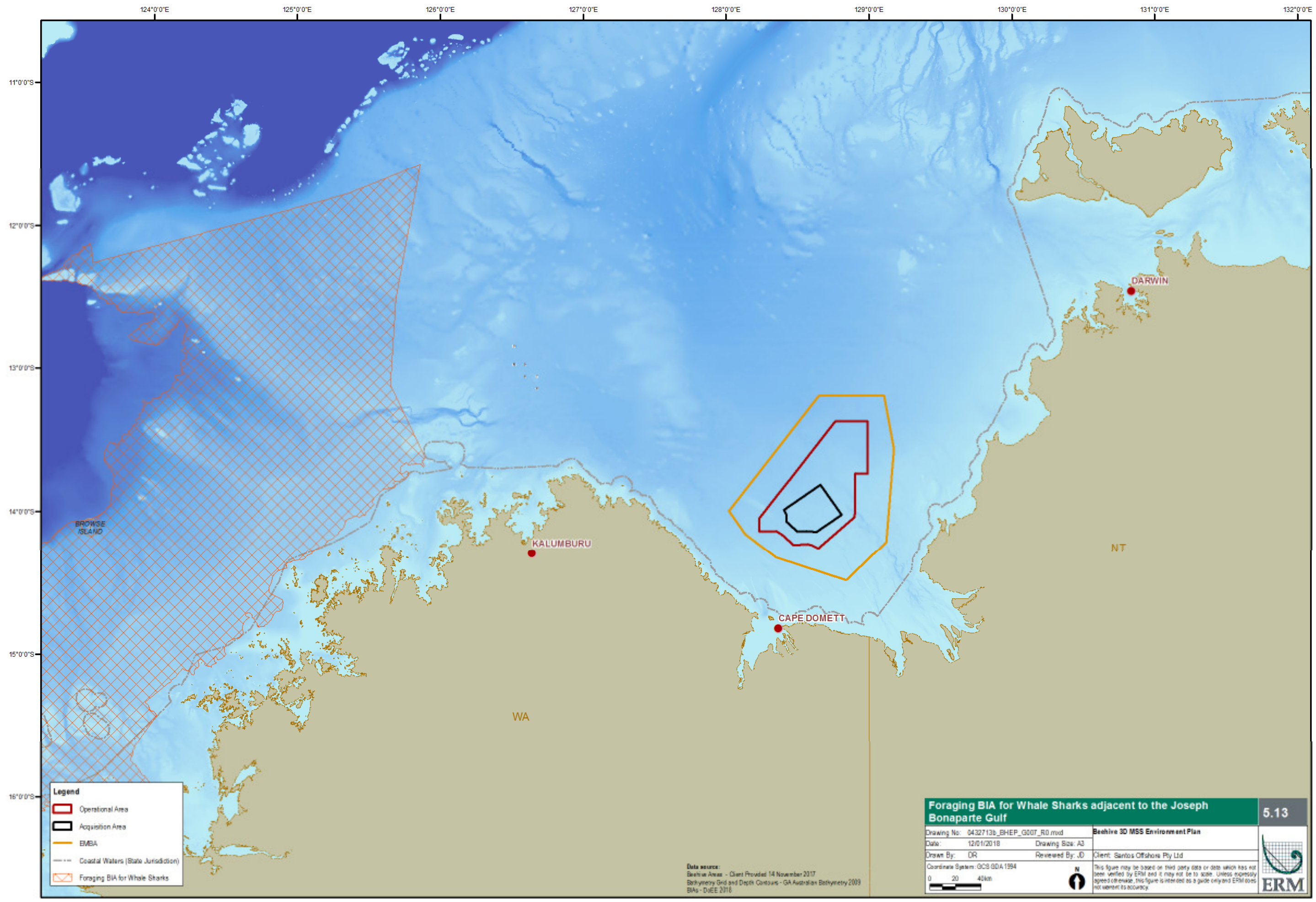

Figure 5.13 Foraging BIA for whale sharks adjacent to the JBG

Table 5.11 Threats to whale sharks relevant to the Beehive 3D MSS

Objective	Relevant Threats	Relevant Actions
To maintain existing levels of protection for the whale shark in Australia while working to increase the level of protection afforded to the whale share within the Indian Ocean and Southeast Asian region to enable population growth in order to remove the Whale Shark from the EPBC Act.	Increased levels of noise resulting from an increase in boat traffic may have a negative impact on the migration patterns	Management of noise impacts are detailed in Section 7.1 and 7.2.
	Boat strike	Management of fauna interaction is detailed in Section 7.8.

Shortfin mako

The shortfin mako is a pelagic species with a circumglobal, wide-ranging oceanic distribution in tropical and temperate seas (Mollet et al. 2000). It is widespread in Australian waters having been recorded in offshore waters all around the continent's coastline with exception of the Arafura Sea, the Gulf of Carpentaria and Torres Strait (TSSC 2014c). Shortfin makos are also highly migratory and travel large distances. Due to their widespread distribution in Australian waters, their presence in the EMBA is likely to be limited to transiting individuals.

Currently, there are no adopted recovery plans or conservation advice documents available for the shortfin mako. Though the IUCN does not identify any relevant threats (Cailliet et al. 2009) the listing advice for the shortfin mako identified fishing as a threat (TSSC 2014c).

Longfin mako

Longfin makos inhabit oceanic and pelagic habits, typically in tropical regions (DSEWPaC 2012b). They are a highly mobile species and have a wide-ranging distribution (DSEWPaC 2012b). Whilst assumed to be a deep-dwelling shark, sightings on the ocean surface, and the species' diet, suggest a greater depth range (Reardon et al. 2006). Though there is limited information about the longfin mako their presence in the EMBA is likely to be limited to transiting individuals.

Currently, there are no adopted recovery plans or conservation advice documents available for the longfin mako. In addition, the IUCN does not identify any relevant threats to this species (Reardon et al. 2006).

Scalloped hammerhead shark

On 15 March 2018 the scalloped hammerhead shark (*Sphyrna lewini*) was listed as Conservation Dependent under the EPBC Act. Currently, no information for this newly listed species is available from the National Conservation Values Atlas (NCVA).

The scalloped hammerhead has a circum-global distribution in tropical and sub-tropical waters (TSSC 2018). The scalloped hammerhead shows strong genetic population structuring across ocean basins as it rarely ventures into or across deep ocean waters, but ranges quite widely over shallow coastal shelf waters. Within Australian waters the scalloped hammerhead extends from New South Wales, around the north of the continent and then south into Western Australia to approximately Geographe Bay (TSSC 2018).

There is a low likelihood that scalloped hammerhead sharks will occur in significant numbers within or adjacent to the Beehive EMBA. A new PMST search for the Beehive EMBA was conducted on 4 April 2018, and this species of shark was not listed as potentially occurring in, or relating to, the EMBA.

Distribution data for scalloped hammerhead sharks in Northern Territory waters indicates that, in the JBG, this species largely restricted to shallow inshore waters along the eastern side of the gulf (*Figure 5.14*). Furthermore, according to NPF bycatch data for the JBG presented in Tonks et al. (2008) and Zhou et al. (2015), the only species of hammerhead shark taken as bycatch by prawn trawlers in this area is the winghead shark (*Eusphyra blochii*). There is no indication that the scalloped hammerhead occurs in offshore, deeper waters of the JBG. In the Listing Advice for this species (TSSC 2018), the Northern Prawn Fishery (NPF) is not listed as a fishery that captures scalloped hammerhead sharks, either as target species or as bycatch.

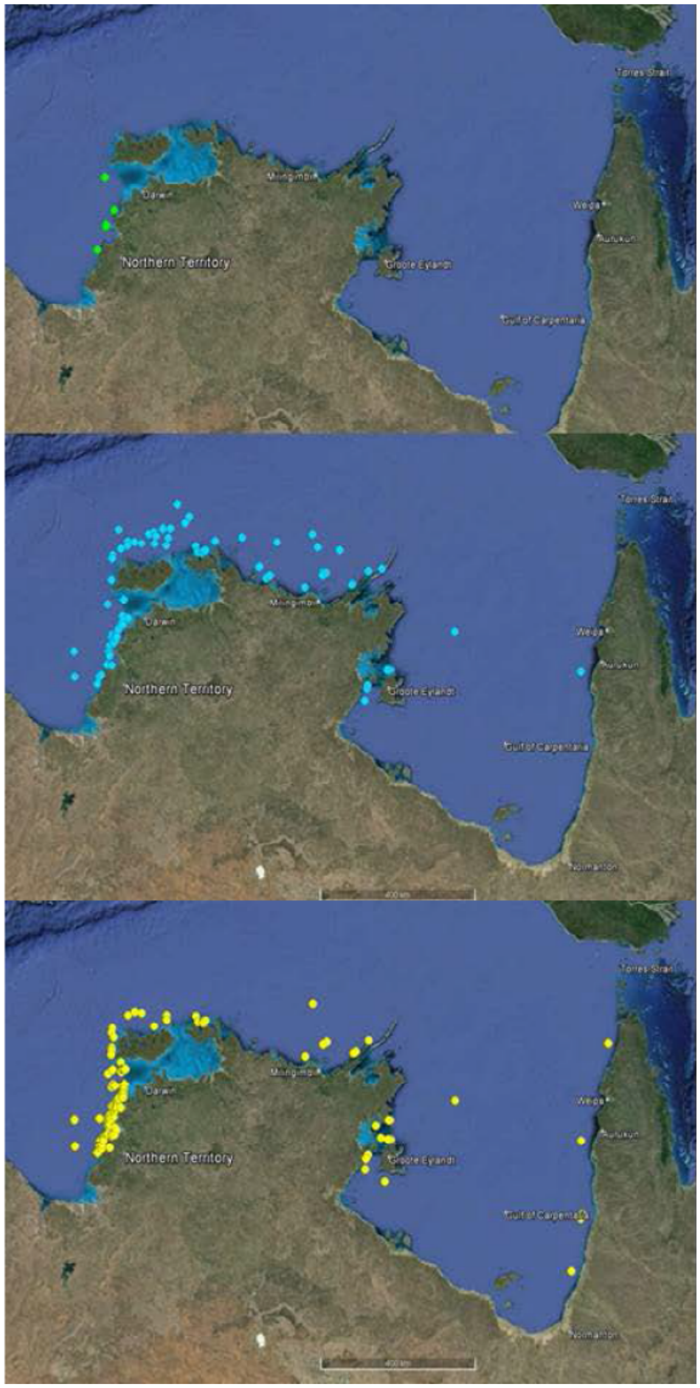

Figure 5.14 Distribution of scalloped hammerhead sharks (S. lewini) in Northern Territory (Heupel 2015)[1]

[1] Note: Green indicates adult females, blue indicates adult males, yellow and pink indicate immature and neonate individuals of both sexes.

5.6.6 *Rays*

The Protected Matters Database search identified two migratory ray species, the reef manta ray and the giant manta ray, which may occur within the EMBA.

The reef manta ray has a circumglobal range in tropical and sub-tropical waters with sightings between waters off Perth in Western Australia, all along the northern coastline of Australia to the waters off the Solitary Islands in New South Wales (Marshall et al. 2011a). Whilst this species tends to inhabit near-shore environments, it is known to have a lower depth limit of 300 m and has been sighted around offshore coral reefs, rocky reefs and seamounts (Marshall et al. 2011a). In addition, it makes seasonal migrations of several hundred kilometres (Marshall et al. 2011a). Despite there being no known aggregation sites within close proximity to the EMBA reef manta rays maybe present in the EMBA as transiting individuals.

Similar to the reef manta ray, the giant manta ray has a widespread distribution along the coast of Australia and is also known to seasonally migrate between aggregation sites (Marshall et al. 2011b). The giant manta ray is commonly sighted along productive coastlines with regular upwelling, oceanic island groups and particularly offshore pinnacles and seamounts (Marshall et al. 2011b). This species has been recorded within the Oceanic Shoals Marine Park (Nichol et al. 2013). Despite there being no known aggregation sites within close proximity to the EMBA giant manta rays maybe present in the EMBA as transiting individuals.

Currently, there are no adopted recovery plans or conservation advice documents available for the reef or giant manta ray. The IUCN identifies entanglement due to marine debris and boat strike as relevant key threats (Marshall et al. 2011a, b). These threats are discussed in Section 7.6 and 7.8, respectively.

5.6.7 *Reptiles*

The Protected Matters Database search identified six species of threatened and migratory marine turtle species, which may occur within the EMBA. The loggerhead, leatherback and olive ridley turtle are listed as endangered whilst the green, hawksbill and flatback turtle are listed as vulnerable. The salt-water crocodile was also identified as a migratory marine reptile species.

Based on data in the National Conservation Values Atlas, the EMBA is within foraging BIA for green and olive ridley turtles, and is located ~ 36 km from foraging BIA for flatback and loggerhead turtles (*Figure 5.15*).

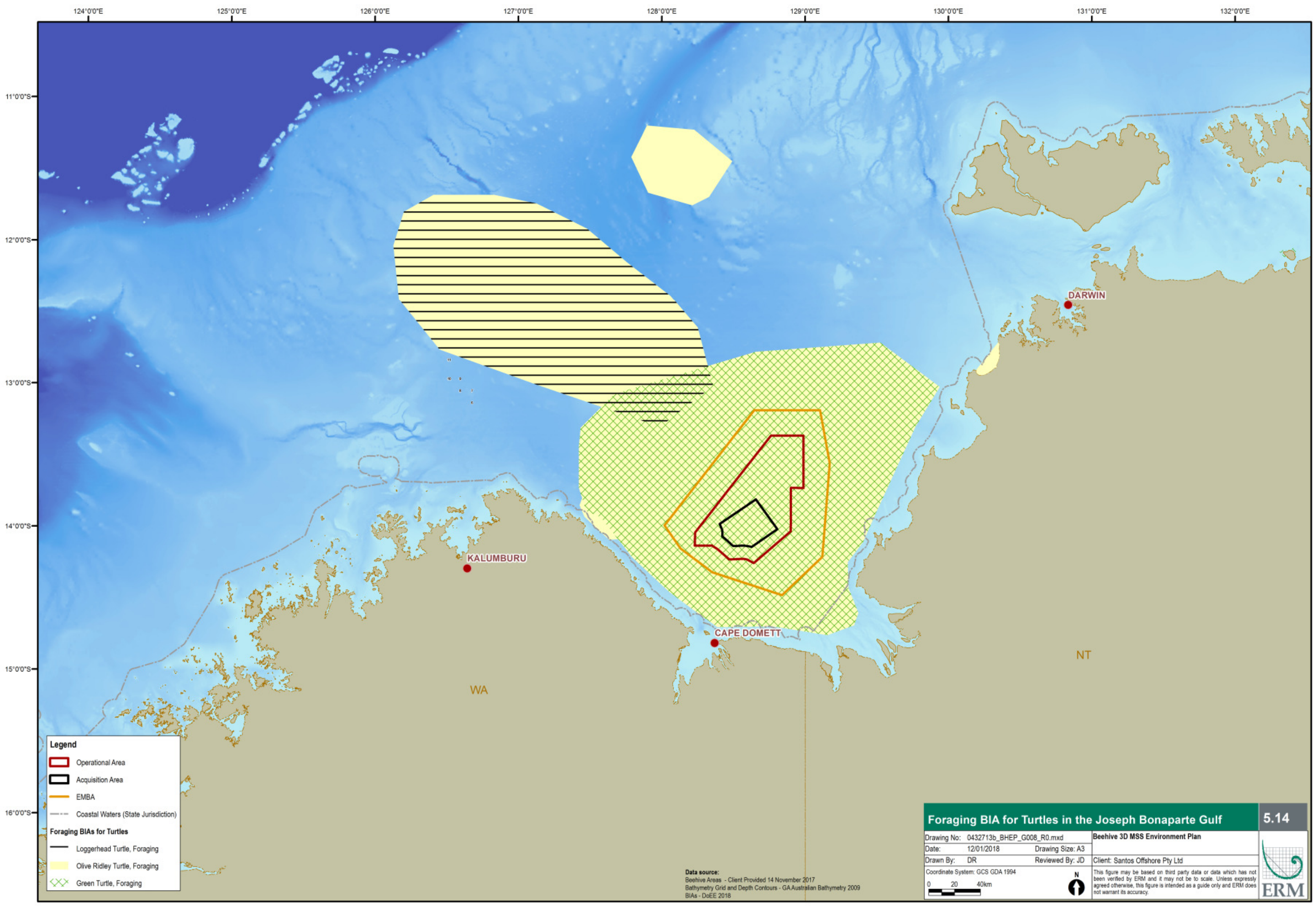

Figure 5.15 Foraging BIA for turtles within or adjacent to the EMBA

Green turtles nest, forage and migrate across tropical northern Australia (DoEE 2017g) and are commonly found foraging and nesting in the Gulf of Carpentaria (DSEWPaC 2012c). The closest biologically important internesting area is around the Cassini Island, approximately ~257 km west of the EMBA. In Western Australia, nesting is between November and March and green turtles can migrate over 2,600 km between their feeding and nesting grounds (DoEE 2017g). The pinnacles of the Bonaparte Basin are thought to be a key ecological feature where green turtles transverse between foraging and nesting grounds (DSEWPaC 2012a). The National Conservation Values Atlas identifies that the EMBA overlaps with a foraging BIA for this species, and hence it is possible that individuals could be encountered. Within such foraging areas, adult green turtles feed on seagrass, sponges and algae (DoEE 2017g).

The olive ridley turtle has a worldwide tropical and subtropical distribution and is known to occur in both Western Australia and Northern Territory (DSEWPaC 2012c). Whilst nesting has been recorded in Western Australia, it is far more common in the Northern Territory (DSEWPaC 2012a). Although olive ridley turtles nest all year round nesting activity peaks around April to November, with the majority of nesting occurring from the Arnhem Land coast (including Bathurst Island, a biologically important internesting area) to the north-western coast of Cape York Peninsula (DSEWPaC 2012c). After nesting, olive ridley turtles are known to migrate up to 1,050 km to various foraging areas (DoEE 2017h) including the pinnacles of the Bonaparte Basin and the carbonate bank and terrace system of the Sahul Shelf KEF (DSEWPaC 2012a). Adult turtles forage for crabs, shrimp, tunicates, jellyfish, salps and algae in depths ranging from several metres to over 100 m (DoEE 2017h). The National Conservation Values Atlas identifies that the EMBA overlaps with a foraging BIA for this species, and hence it is possible that individuals could be encountered.

The flatback turtle is only found in Australian waters and some nearby waters in Indonesia and Papua New Guinea. It is commonly found in the NWMR and NMR, nesting in northern Australia and foraging in the region. Breeding occurs all year round, however, in northern Australia most nesting occurs between June and August (DoEE 2017i). The nearest nesting beach for flatback turtles to the EMBA is at Cape Domett (~43 km south of the EMBA). The Cape Domett nesting population appears to be one of the largest known nesting populations of this species, with an estimated yearly population in the order of several thousand turtles (Whiting et al. 2008). Flatback turtles nest at Cape Domett throughout the year. Whiting et al. (2008) identified peak nesting as occurring during August and September. The Recovery Plan for Marine Turtles in Australia 2017 -2017 (DoEE 2017s) details the peak nesting period at Cape Domett as July to September (in Section 3.3 of the Recovery Plan) and as August to September (in Section 5.3).

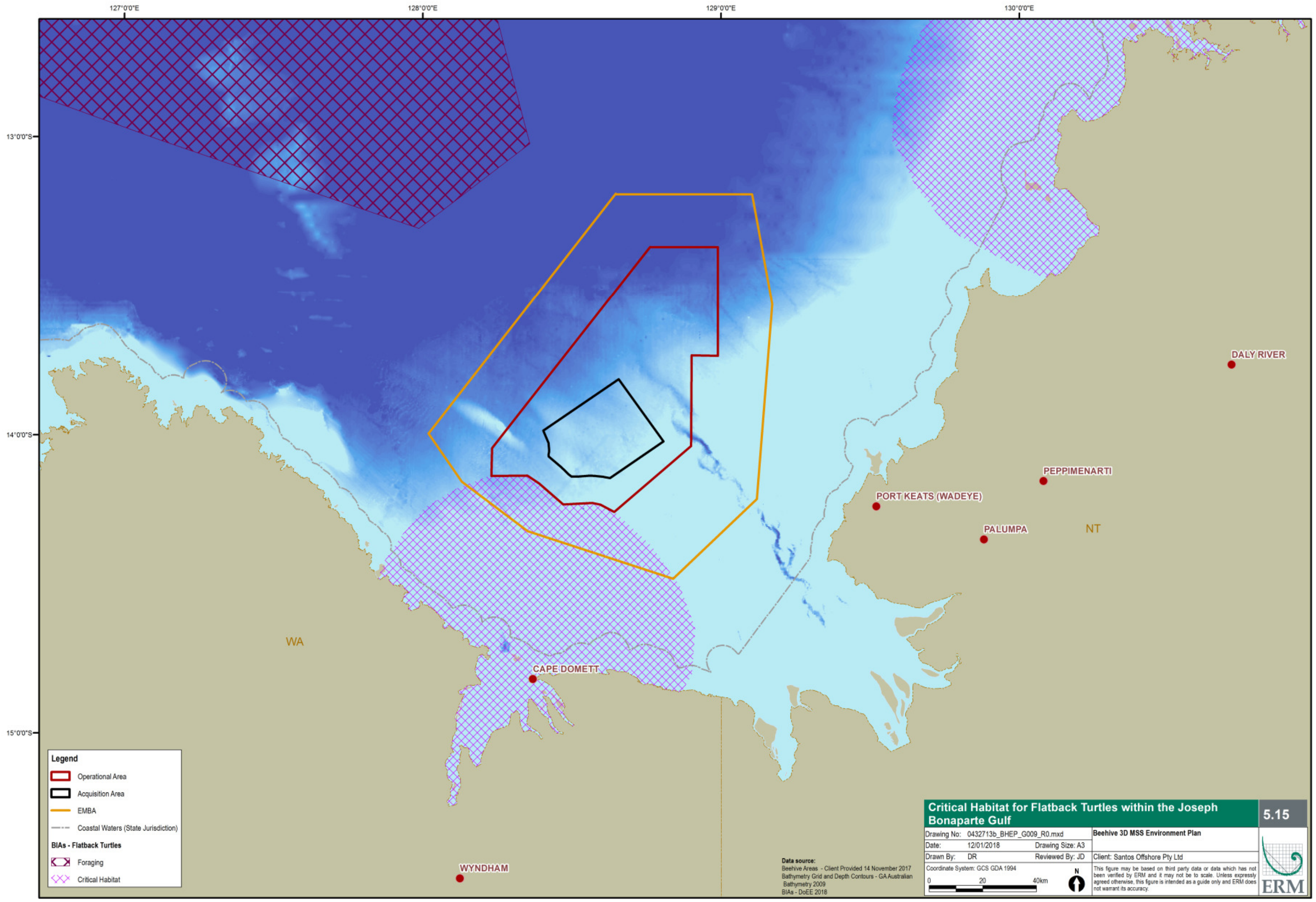

Figure 5.16 'Habitat critical to the survival of a species' for flatback turtles within the Joseph Bonaparte Gulf

The National Conservation Values Atlas identifies the area out to 60 km offshore from Cape Domett and Lacrosse Island in the Cambridge Gulf as a biologically important internesting area. The Recovery Plan for Marine Turtles in Australia 2017 -2017 (DoEE 2017s) has redefined this internesting area as Critical Habitat for flatback turtles ('Habitat critical to the survival of a species'). The southern boundary of the Operational Area is contiguous with the outer boundary of this 'habitat critical to the survival of a species', and the EMBA overlaps ~1,023 km^2 of the offshore portion of this internesting area for flatback turtles (*Figure 5.16*).

Flatback turtles lack an oceanic phase and remain in the surface waters of the continental shelf and once the pelagic stage of its life is completed, they move to sub-tidal soft bottomed habitats inshore, feeding on benthic organisms. Flatback turtles have a wide foraging range with individuals that nest on the Pilbara coast dispersing to feeding areas extending from Exmouth Gulf to the Tiwi Islands (DSEWPaC 2012a). Adult flatbacks are primarily carnivorous, feeding on soft-bodied invertebrates. Juveniles eat gastropod molluscs, squid, siphonophores, and limited data indicate that cuttlefish, hydroids, soft corals, crinoids, molluscs and jellyfish are also eaten (DoEE 2017s). The species has been recorded foraging in depths less than 10 m to over 40 m on the carbonate bank and terrace of the Sahul Shelf KEF and around the pinnacles of the Bonaparte Basin KEF. The National Conservation Values Atlas identifies the Western Joseph Bonaparte Depression, located ~36 km from the EMBA at the closest point, as a foraging BIA for flatbacks. Hence, it is possible that individuals could be encountered.

The loggerhead turtle has a global distribution throughout tropical, subtropical and temperate waters. In Australia, the loggerhead turtle occurs in waters of coral and rocky reefs, seagrass beds, and muddy bays throughout eastern, northern and western Australia (DoEE 2017d). Whilst nesting is mainly concentrated on sub-tropical beaches in southern Queensland and from Shark Bay to the North West Cape in Western Australia between November to March, foraging is more widespread. Loggerhead turtles show fidelity to both their foraging and breeding areas and can migrate over 2,600 km between the two (DoEE 2017d). The WA stock forage from Shark Bay through to Arnhem Land in the Northern Territory (DoEE 2017d). As a juvenile, this species feeds on algae, pelagic crustaceans, molluscs and flotsam whilst as an adult it feeds on gastropod molluscs, clams, jellyfish, starfish, coral, crabs and fish (DoEE 2017d). Loggerhead turtles are known to forage around the pinnacles of the Bonaparte Basin and the carbonate bank and terrace of the Sahul Shelf KEF (DSEWPaC 2012a, 2012c). The National Conservation Values Atlas identifies the Western Joseph Bonaparte Depression, located ~36 km from the EMBA at the closest point, as a foraging BIA for loggerheads. Hence, it is possible that individuals could be encountered.

The leatherback turtle is a pelagic feeder found in tropical, subtropical, and temperate waters throughout the world. Whilst it is less abundant off the northern Australian continental shelf, it is occasionally sighted in the Gulf of Carpentaria and near Cobourg Peninsula (DSEWPaC 2012c). No major nesting has been recorded in Australia, with isolated nesting recorded in Queensland and the Northern Territory (DSEWPaC 2012c). The closest confirmed internesting site for the leatherback turtle is at Cobourg Peninsula (DoEE 2017e) ~368 km north-east of the EMBA. Leatherback turtle forage on pelagic soft-bodied creatures (such as jellyfish, squid, salps, siphonophores and tunicates) all year round in Australian waters (DoEE 2017e), thus it is possible that this species may be present within the EMBA.

Hawksbill turtles are found in tropical, subtropical and temperate waters in all the oceans of the world (DoEE 2017f). The hawksbill turtle is commonly found in the NWMR and NMR, nesting extensively along the coasts and foraging in the region. As a juvenile, the hawksbill turtle feeds on plankton in the open ocean and then feeds on sponges, hydroids, cephalopods, gastropods, jellyfish, seagrass and algae as an adult (DoEE 2017f). The species is also highly migratory, moving up to 2,400 km between foraging and breeding areas (DSEWPaC 2012c). Due to genetic variability, Australia's population is considered to comprise of two distinct stokes; one in Western Australia and the other in the north-east of Australia (DSEWPaC 2012c). These distinct populations are also known to have significantly different breeding seasons. The north-east subpopulation breeds throughout the year with a peak nesting period during July to October (DSEWPaC 2012c), whilst breeding in the WA population peaks around October to January. In the NWMR, the closest internesting area to the EMBA is located at Ashmore Reef, ~562 km to the west-northwest. As this species is oceanic it is possible that it may be present within the EMBA.

A study of turtle bycatch of the NPF, which included the waters of the southern JBG overlapped by the EMBA, recorded five species: flatback, 59% of the total, loggerhead (10%), olive ridley (12%), green (8%) and hawksbill (5%). They identified that turtle catches varied with water depth: the highest catch rates were from trawls in water between 20 and 30 m deep, relatively few turtles (10%) were captured in water deeper than 40 m (Poiner and Harris 1996). Thus, it is unlikely that the Operational Area (water depth range of ~ 23 to 65 m) is a predominant foraging area for turtles.

Table 5.12 identifies the objectives and actions identified in the Recovery Plan for Marine Turtles in Australia 2017 – 2027 (DoEE 2017s), which are relevant to the Beehive 3D MSS.

Table 5.12 Recovery Plan for Marine Turtles in Australia 2017 – 2027 – objectives and actions relevant to the Beehive 3D MSS

Recovery Objective	Relevant Key Threats	Action Area	Relevant Actions to the Activity
Long Term Recovery Objective. Minimise anthropogenic threats to allow for the conservation status of marine turtles to improve so that they can be removed from the EPBC Act threatened species list.	4B Marine debris	Reduce the impacts from marine debris	Management of marine debris is detailed in *Section 7.6*.
	4C Chemical and terrestrial discharge	Minimise chemical and terrestrial discharge	Ensure spill risk strategies and response programs adequately include management for marine turtles and their habitats, particularly in reference to 'slow to recover habitats', e.g. nesting habitat, seagrass meadows or coral reefs. Management of oil spills is detailed in *Sections 7.11* and *7.12*.
Interim Recovery Objectives relevant to the activity. Interim Objective 3: Anthropogenic threats are demonstrably minimised. Target 3.1: Robust and adaptive management regimes that lead to a reduction in anthropogenic threats to marine turtles and their habitats are in place. Target 3.2: Threat mitigation strategies are supported by high quality information	4G Light pollution	Minimise light pollution	Artificial light within or adjacent to 'habitats critical to survival' of marine turtles will be managed such that marine turtles are not displaced from these habitats. Identify the cumulative impact on turtles from multiple sources of onshore and offshore light pollution. Management of light pollution is detailed in *Section 7.3*. *Section 7.1.5.7* does not identify any activities within 100 km of the Operational Area, thus cumulative light impacts would not occur from the activity.
	4J Vessel disturbance	No specific action	Management of vessel/fauna interactions is detailed in *Section 7.8*.
	4K Noise interference	Understand the impacts of anthropogenic noise on marine turtle behaviour and biology.	Implementation of EPBC Act Policy Statement 2.1 – Interactions between Offshore Seismic Exploration soft start procedures to afford protection for marine turtles. Management of noise is detailed in *Sections 7.1* and *7.2*.

The salt-water crocodile is distributed from King Sound in Western Australia throughout coastal Northern Territory to Rockhampton in Queensland, where it can be found in coastal waters, estuaries, lakes, inland swamps and marshes up to 150 km inland from the coast (DoEE 2017j). Whilst sightings of salt-water crocodiles far out to sea have been recorded it is very unlikely that it would be encountered within the EMBA.

5.6.8 *Marine Birds*

The Protected Matters Database search identified three listed threatened bird species, the red knot, the curlew sandpiper and the eastern curlew, as potentially occurring within the EMBA. It also identified the common noddy, streaked shearwater, lesser frigatebird and great frigatebird as migratory marine bird species that may occur within the EMBA.

The red knot is common in all the main suitable habitats around the coast of Australia (DoEE 2017s), and very large numbers are regularly recorded in north-west Australia, with Eighty Mile Beach and Roebuck Bay being particular strongholds. In WA, it is widespread on the coast from Ningaloo Reef and Barrow Island to the south-west Kimberley coastline. In the Northern Territory it is mainly recorded from Darwin, but also seen at various other sites. It is unlikely that this species would be present in the EMBA.

In Australia, curlew sandpipers occur around the coasts and are also quite widespread inland, though in smaller numbers. They are rarely recorded in the north-west Kimberley, around Wyndham and Lake Argyle (DoEE 2017k). No critical habitats for this species (e.g. wetlands of international importance) were identified within or near the EMBA (Bamford et al. 2008), and it is unlikely that this species would be present in the EMBA.

The eastern curlew has a primarily coastal distribution within Australia. It does not breed in Australia and is found foraging on soft sheltered intertidal sandflats or mudflats, open and without vegetation or covered with seagrass, often near mangroves, on saltflats and in saltmarsh, rockpools and among rubble on coral reefs, and on ocean beaches near the tideline (DoEE 2015). No critical habitats for this species (e.g. wetlands of international importance) were identified within or near the EMBA (Bamford et al. 2008). It is unlikely that this species would be present in the EMBA.

In Australia, the common noddy occurs mainly in ocean off the Queensland coast, but the species also occurs off the north-west and central Western Australia coast (DoEE 2017m). During the breeding season, it usually occurs on or near islands, on rocky islets and stacks with precipitous cliffs, or on shoals or cays of coral or sand. When not at the nest, individuals will remain close to the nest, foraging in the surrounding waters (DoEE 2017m). It is unlikely that this species would be present in the EMBA.

Following its winter migration from the northern hemisphere, the streaked shearwater occurs frequently in northern Australia from October to March, with some records as early as August and as late as May (Marchant and Higgins 1990). Whilst it does not breed in Australia, it is known to forage in the NMR, in particular north-west of the Wellesley Islands (over 1,100 km east-southeast of the EMBA) (DSEWPaC 2012c). Given the shearwaters migratory periods it is unlikely that this species would be present in the EMBA during the Beehive 3D MSS.

Lesser frigatebirds are usually observed in tropical waters around the coast of northern Western Australia, Northern Territory, Queensland and New South Wales (DSEWPaC 2012a). They are often found foraging far offshore, especially during the non-breeding season where some large movements have been recorded (DSEWPaC 2012b). During the breeding season (March - November), the lesser frigatebird’s range remains close to the breeding colonies. The National Conservation Values Atlas identifies a breeding BIA for this species located~130 km west of the EMBA. As the Beehive survey is planned to be undertaken during the breeding season when lesser frigatebirds remain close to their colony, it is unlikely that this species would be present in the EMBA.

The great frigatebird is widespread and breeds on numerous tropical islands including Adele Island and Ashmore Reef. Breeding mostly occurs between March and November. The species is pelagic, although breeding birds probably forage within 100 – 200 km of the colony during the early stages of the breeding season (DSEWPaC 2012a). Based on these distances it is unlikely that this species would be present in the EMBA.

The lesser crested tern was identified in the Protected Matters Database search as a listed marine species that may occur within the EMBA. This species inhabits tropical and subtropical sandy and coral coasts and estuaries, and breeds on islands off the north and west Kimberley coastlines. It breeds on low-lying offshore islands, coral flats, sandbanks and flat sandy beaches, and forages for small pelagic fish and shrimp in the surf and over offshore waters in both areas of reef and deeper shelf waters (Commonwealth of Australia 2012). The species forages in the NMR and breeds in adjacent areas. The National Conservation Values Atlas identifies a breeding BIA for this species that is located in the southern JBG adjacent to the south-west part of the EMBA (*Figure 5.17*). Given the lack of information as to how far this species may forage from their nesting areas it is possible that they may be encountered within the EMBA.

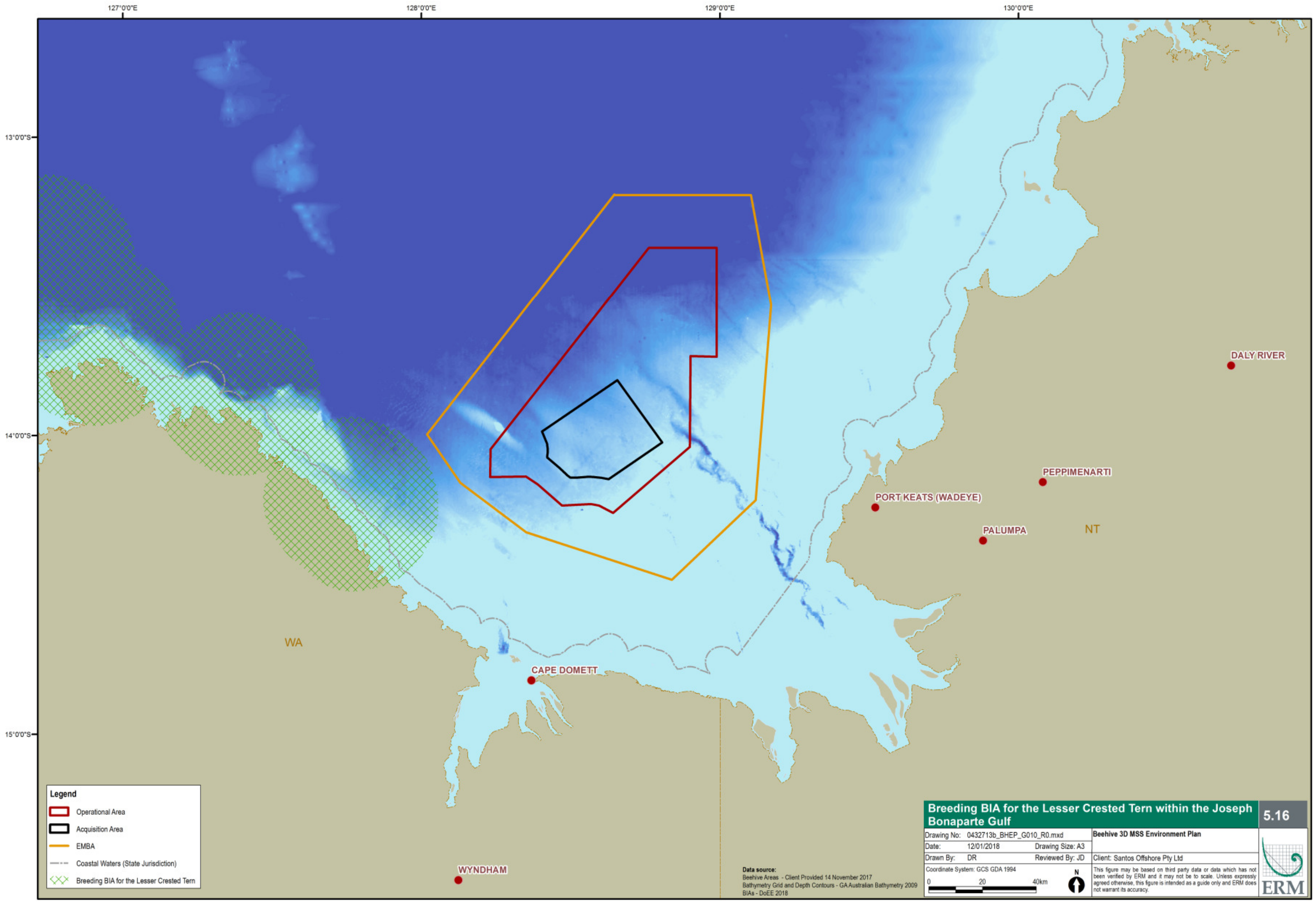

Figure 5.17 Breeding BIA for the lesser crested tern within the Joseph Bonaparte Gulf

No Recovery Plans have been prepared for these marine bird species, however, the North-west Marine Bioregional Plan and North Marine Bioregional Plan identify the following threats to a number of the bird species; marine debris, oil pollution and collision with vessels. These threats are discussed in *Sections 7.6*, *7.11*, *7.12* and *7.8*, respectively.

5.6.9 Mammals

The Protected Matters Database searches identified four species of threatened and migratory cetaceans as potentially occurring within the EMBA; the sei whale (vulnerable), blue whale (endangered), fin whale (vulnerable) and humpback whale (vulnerable). A further four species of listed migratory cetaceans (Bryde's whale, killer whale, Indo-Pacific humpback dolphin, spotted bottlenose dolphin and killer whale) were also identified as potentially occurring within the EMBA.

Sei whales are moderately large whales growing up to 18 m. It is less studied than other great whales and its population status, distribution and movements are not well known. They are similar in appearance to Bryde's whale, which has led to confusion as to their distribution, especially in warmer waters where Bryde's whales are more common (DEH 2005b). There are no known mating or calving areas in Australia, and Antarctic waters and the Bonney Upwelling are known feeding areas (DoEE 2017n). The movements and distributions of sei whales are unpredictable and not well documented with information suggesting that they have the same general pattern of migration as most other baleen whales, although it is timed a little later and they do not move to such high latitudes (DoEE 2017n). There are no important biological areas for sei whales near the EMBA. Given the EMBA location and relatively shallow water depths within it, it is unlikely that sei whales will be encountered in the area.

Blue whales are the largest living animals, growing to a length of over 30 m and weighing up to 180 tonnes (DEH 2005b). In Australia, there are two recognised sub-species of blue whale; the Antarctic or true blue whale (*Balaenoptera musculus intermedia*) and the pygmy blue whale (*B. m. brevicauda*). Blue whales have a worldwide distribution but tend to move between warm water (low latitudes) for breeding and cold water (high latitudes) for feeding. Pygmy blue whales are thought to migrate from Australian feeding areas to breeding grounds that include Indonesia (based on sightings in Indonesia in the austral winter), while Antarctic blue whale winter migratory destinations include lower latitudes of the Pacific and Indian Oceans (DoE 2015b). Thus, the pygmy blue whale is more likely to be encountered in tropical waters and hence the information provided is based on the pygmy blue whale.

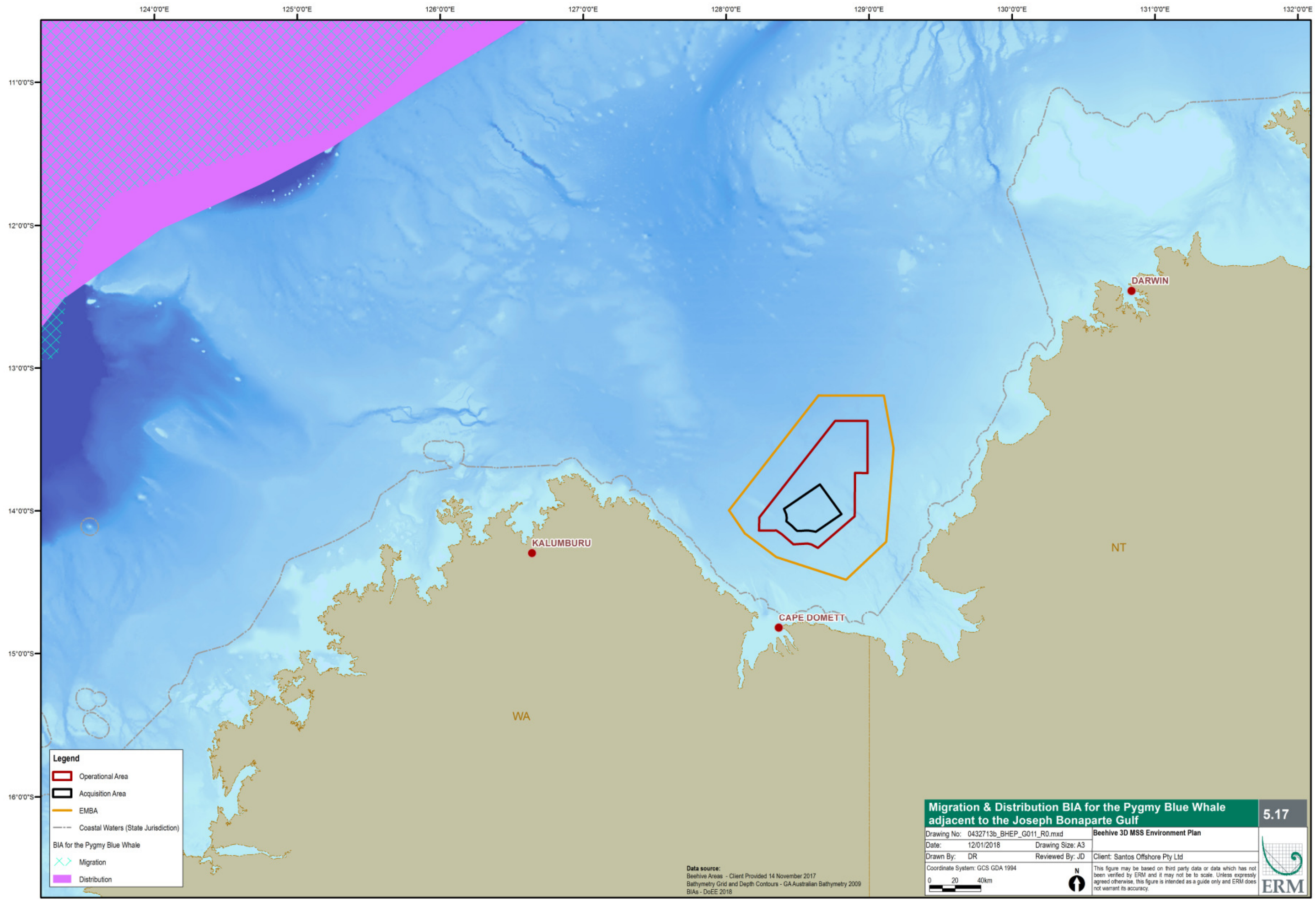

Figure 5.18 Migration and distribution BIA for pygmy blue whales adjacent to the Joseph Bonaparte Gulf

Tracking of pygmy blue whales identified that they migrate north from the Perth Canyon (known feeding area) in March/April reaching Indonesia by June where they remain until at least September. Southern migration from Indonesia may occur from September and finish by December after which the animals may make their way slowly northwards towards the Perth Canyon by March/April (Double et al. 2014). Blue whale migration is thought to follow deep oceanic routes, and a tagging study by Double et al. (2014) identified that the shallowest waters occupied was ~ 1,300 m. shows the migration and distribution BIA for pygmy blue whales adjacent to the JBG.

At the closest point, the EMBA is located ~375 km south-east of the boundary of the pygmy blue whale distribution BIA, and ~470 km from the boundary of the migration BIA. Given the EMBA location and relatively shallow water depths within it, it is unlikely that pygmy blue whales will be encountered in the area.

The Conservation Management Plan for the Blue Whale 2015-2025 (DoE 2015b) identified noise interference and vessel collision as threats which are relevant to the activity (*Table 5.13*).

Table 5.13 Conservation Management Plan for the Blue Whale 2015 – 2025 – objectives and actions relevant to the Beehive 3D MSS

Relevant Objectives	Relevant Threats	Relevant Actions
Anthropogenic threats are demonstrably minimised	Noise interference	EPBC Act Policy Statement 2.1—Interaction between offshore seismic exploration and whales is applied to all seismic surveys. Management of noise is detailed in *Sections 7.1* and *7.2*.
	Vessel disturbance – vessel collision	Ensure the risk of vessel strikes on blue whales is considered when assessing actions that increase vessel traffic in areas where blue whales occur and, if required, appropriate mitigation measures are implemented. Management of vessel/fauna interactions is detailed in *Section 7.8*.

The fin whale is the second-largest whale species, after the blue whale. Fin whales have been observed during aerial surveys in South Australian waters between November and May. Fin whale distribution in Australian waters is known primarily from stranding events and whaling records from Western Australia, South Australia, Victoria and Tasmania (DoEE 2017). There is no known mating or calving areas in Australian waters and feeding seems to be in more temperate waters (DEH 2005b). Based on this information it is unlikely that the fin whale would be present in the EMBA.

The Blue, Fin and Sei Whale Recovery Plan (DEH 2005b) is no longer in force. In this plan acoustic pollution from seismic survey was identified as a threat and is assessed in Sections 7.1 and 7.2. Minimising vessel collisions is identified as a relevant management action in the Conservation Management Plan for the Blue Whale 2015-2025 (DoE 2015b) and in the Conservation Advice for fin and sei whales provided by the Threatened Species Scientific Committee (TSSC). This threat is assessed in Section 7.8.

Humpback whales in the southern hemisphere undertake an annual migration during the austral winter from Antarctic feeding areas to tropical calving grounds (DoEE 2017p). In the NWMR, humpback whales are known to have breeding and foraging grounds between Broome and the northern end of Camden Sound (~425 km west-southwest of the EMBA), with the highest concentrations occurring between June and September (DEWHA 2008). Camden Sound appears to be the northernmost limit for the majority of the west coast whales (Jenner et al. 2001). The breeding and calving BIA for humpbacks off the west Kimberley coastline extends as far as Bigge Island (~318 km west-southwest of the EMBA). Based on this it is unlikely that humpback whales would be present in the EMBA.

The Humpback Whale Recovery Plan 2005 – 2010 (DEH 2005c) is no longer in force, however, applicable threats to the activity are detailed in *Table 5.14*. Additional actions from the Conservation Advice for *Megaptera novaeangliae* are also included in *Table 5.14*.

Table 5.14 Threats to the blue whale relevant to the activity and relevant actions

Relevant Threats	Relevant Actions
Acoustic pollution (e.g. commercial and recreational vessel noise, and seismic survey activity)	Assess and manage acoustic pollution – including the development and application of administrative guidelines under the EPBC Act such as the "Guidelines on the application of the EPBC Act to interactions between offshore seismic operations and larger cetaceans". All seismic surveys must be undertaken consistently with the EPBC Act Policy Statement 2.1 – Interaction between offshore seismic exploration and whales. Should a survey be undertaken in or near a calving, resting, foraging area, or a confined migratory pathway then Part B. Additional Management Procedures must also be applied. Management of noise is detailed in *Sections 7.1* and *7.2*.
Vessel disturbance and strike	Vessel strike incidents must be reported in the National Ship Strike Database. Enhance education programs to inform vessel operators of best practice behaviours and regulations for interacting with humpback whales. Ensure the risk of vessel strike on humpback whales is considered when assessing actions that increase vessel traffic in areas where humpback whales occur and, if required appropriate mitigation measures are implemented to reduce the risk of vessel strike. Management of vessel/fauna interactions is detailed in *Section 7.8*.

Relevant Threats	Relevant Actions
Entanglement – marine debris	Encourage best practice approaches that will reduce the likelihood of humpback whales being entangled in marine debris. Management of waste is detailed in *Section 7.6*.
Changing water quality and pollution (e.g. runoff from land based agriculture, oil spills, outputs from aquaculture)	Assess and manage physical disturbance and development activities (such as ship-strike, aquaculture, pollution, recreational boating, naval activities, and exploration and extraction industries) – including the application of environmental impact assessment and approvals and the development of industry guidelines and State/Commonwealth government regulations. Management of waste water discharges is detailed in *Section 7.5*. Management of oil spills is detailed in *Sections 7.11* and *7.12*.

There is some confusion regarding the taxonomy of Bryde's whales, as for many years the sei whale was recorded as Bryde's whale. Recently, smaller inshore and larger offshore forms have been identified, with the inshore form potentially being Omura's whale (*Balaenoptera omurai*) (DoEE 2017q).

Bryde's whale is restricted to tropical and temperate waters and has been recorded off all Australian states with exception of the Northern Territory (Bannister et al. 1996). Bryde's whales can be found in both oceanic (500 to 1000 m isobath) and inshore waters (<200 m isobath) (DoEE 2017q). Population estimates are not available for Bryde's whales, globally or in Australia, and no migration patterns have been documented in Australian waters (DoEE 2017q). Bryde's whale is considered to be a fairly opportunistic feeder and it appears that the coastal and offshore forms may be distinguished by their prey preferences, with the smaller coastal form feeding on schooling fishes, such as pilchard, anchovy, sardine, mackerel, herring and others. In contrast, the larger offshore form appears to feed on small crustaceans, such as euphausids, copepods, pelagic red crabs and cephalopods. Based on this information it is possible that Bryde's whales may transit through the EMBA.

Currently, there are no adopted recovery plans or conservation advice documents available for the Bryde's whale. In addition, the IUCN does not identify any relevant threats to this species (Reilly et al. 2008).

Indo-Pacific humpback dolphins occur in coastal lagoons and enclosed bays with mangrove forests and seagrass beds, but are also found in open coastal waters around islands and coastal cliffs in association with rock or coral reefs. The species usually occurs close to the coast, generally at depths of up to 20 m, but it has been seen 55 km offshore in shallow water. Indo-Pacific humpback dolphins eat a wide variety of coastal and estuarine-associated fishes, as well as reef, littoral and demersal fish species. Based on this information it is possible that Indo-Pacific humpback dolphins may transit through the EMBA.

Spotted bottlenose dolphins occur in coastal waters, primarily in continental shelf waters (less than 200 m deep), including coastal areas and oceanic islands

(DSEWPaC 2012b). They are found mainly in four regions around Australia, including the Arafura-Timor seas (DSEWPaC 2012b). Whilst knowledge of their seasonal migration and breeding is largely unknown, it is inferred that only the Arafura-Timor Sea population is migratory (DSEWPaC 2012b). BIAs identified for foraging and breeding during April to November, include the Darwin harbour (~200 km north-east of the EMBA) and near the Camden Sound (~425 km west-southwest of the EMBA). Bottlenose dolphins (*Tursiops truncatus*) have been recorded within the Oceanic Shoals Marine Park (Nichol et al. 2013) and therefore both spotted bottlenose and bottlenose dolphins may transit through the EMBA.

Whilst there is no specific management plan available for the spotted bottlenose dolphin, it is listed in the Marine Bioregional Plan for the NMR. This plan identifies marine debris, chemical and noise pollution to be of potential concern to the spotted bottlenose dolphin and oil pollution and collision with vessels to be less of a concern (DSEWPaC 2012b). These threats as assessed in *Sections 7.6*, *7.5*, *7.1*, *7.2*, *7.11*, *7.12* and *7.8*, respectively.

Whilst the Australian snubfin dolphin was no included in the results of the Protected Matters database search the National Conservation Values Atlas identifies a resting BIA for this species in Cambridge Gulf, ~31 km inshore from the EMBA. Snubfin dolphins have been recorded almost exclusively in coastal and estuarine waters, primarily in shallow waters less than 20 m deep (DoEE 2017r). Thus, it is unlikely to occur within the EMBA.

The killer whale is known to occur from polar to equatorial regions of all oceans and has been recorded off all states of Australia (Bannister et al. 1996). Killer whales appear to be more common in cold, deep waters; however, they have often been observed along the continental slope and shelf, particularly near seal colonies (Bannister et al. 1996). Though there are no BIA for killer whales near the EMBA, however they have been reported within the Oceanic Shoals Marine Park (Nichol et al. 2013), and therefore this species may transit through the EMBA.

Currently, there are no adopted recovery plans or conservation advice documents available for the killer whale. The IUCN, however, identifies bioaccumulation due to chemical pollution, noise pollution, boat strike and oil spills as relevant key threats (Taylor et al. 2013). These threats are assessed in Sections *7.5*, *7.1*, *7.2*, *7.8*, *7.11* and *7.12*, respectively.

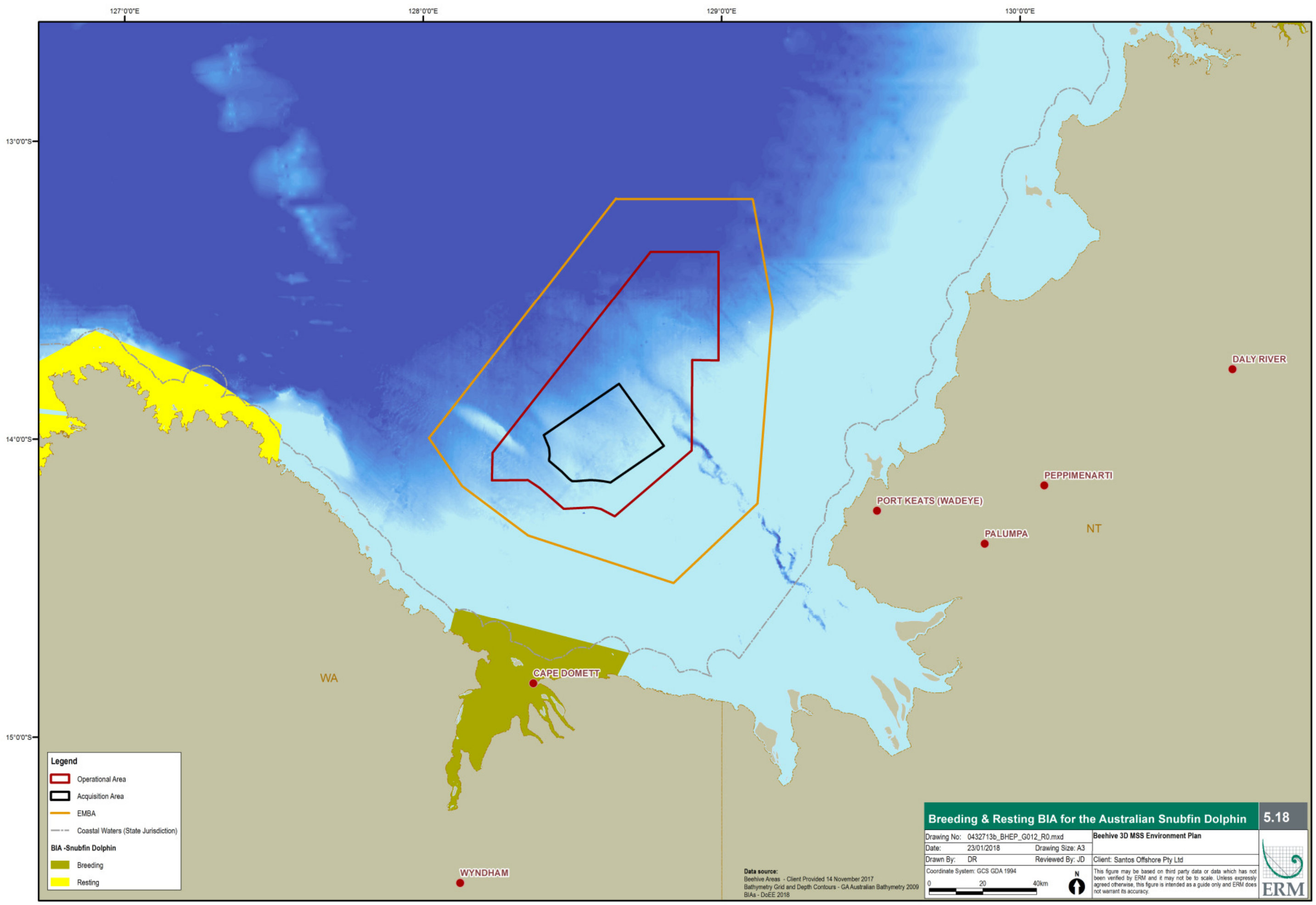

Figure 5.19 Resting and breeding BIA for the Australian snubfin dolphin in the Cambridge Gulf

Dugongs inhabit protected shallow coastal areas, such as wide shallow bays and mangrove channels. They feed on seagrass, and major concentrations of dugongs tend to coincide with sizeable seagrass beds. However, observations by Whiting (2002) revealed that dugongs also feed on macro algae on rocky reefs in tropical Australia, expanding the number of habitats utilised by dugongs.

Research undertaken in Northern Territory, including aerial surveys, has focused on dugong populations in the Gulf of Carpentaria and in the northern parts of the NT, such as the Tiwi Islands and Coburg Peninsula. No surveys have been undertaken in the JBG, therefore little is known about the distribution of dugongs in the Gulf. However, as high turbidity in the JBG limits the development of seagrass beds, dugongs are not expected to be abundant (Woodside 2004).

Though not abundant in the JBG, dugongs have been reported to occur along the coastline from Cape Hay to Point Pearce, with the main populations concentrated around Dorcherty Island (Woodside 2004), ~ 34 km to the east of the EMBA. Therefore, this species may transit through the EMBA.

5.7 SOCIO-ECONOMIC ENVIRONMENT

5.7.1 Settlements

The closest major community to the EMBA is Wyndham, which is located ~130 km to the south. Darwin is ~205 km north-east of the EMBA. At the closest point, the EMBA is located ~44 km west of the Wadeye (Port Keats) community.

5.7.2 Commonwealth Managed Fisheries

Commonwealth fisheries are managed by the Australian Fisheries Management Authority (AFMA) under the *Fisheries Management Act 1991* (Commonwealth). AFMA's jurisdiction covers the area of ocean from 3 nm from the coast out to the 200 nm limit (the extent of the Australian Fishing Zone - AFZ). Fisheries with jurisdictions to fish within area overlapped by the EMBA are given in *Table 5.15*. Based on discussions with AFMA and information from the ABARES Fishery Status Report 2017 (Patterson et al. 2017) it was identified that only the Northern Prawn Fishery (NPF) actively fishes in the area.

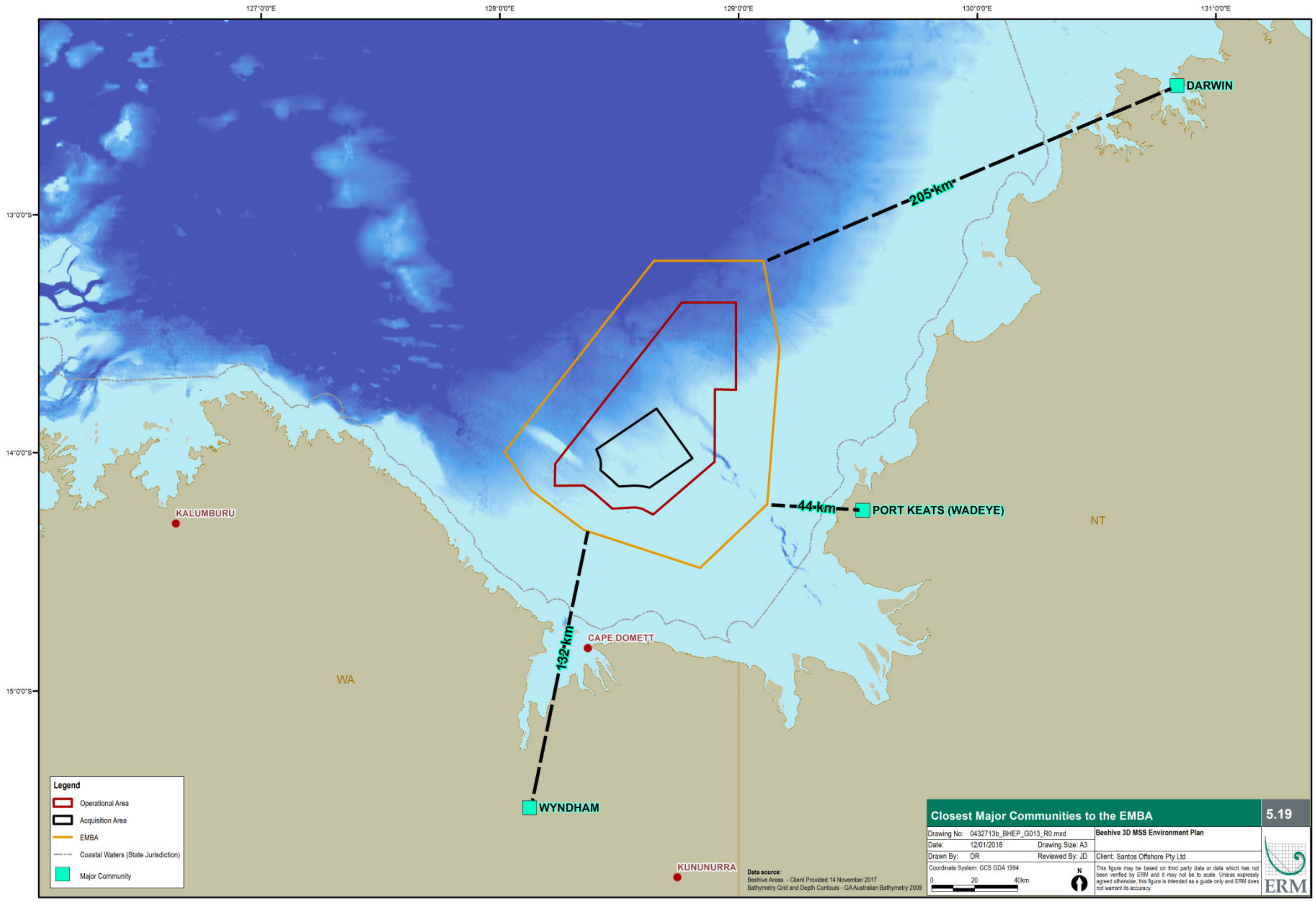

Figure 5.20 Closest major communities to the Beehive 3D MSS EMBA

Table 5.15 Commonwealth managed fisheries within the EMBA

Fishery	Actual Catch Effort within Permit Area/s	Comments
Western Tuna and Billfish Fishery	No	Effort has been concentrated off south-west WA over recent years.
Western Skipjack Fishery	No	No fishing effort since 2008-2009.
Southern Bluefin Tuna Fishery	No	Since 1992 juvenile Southern Bluefin Tuna have been targeted in the Great Australian Bight (GAB) and waters off South Australia. Spawning area is off the north-west of WA outside of Joseph Bonaparte Gulf. The spawning area is located >500 km from the Beehive 3D MSS Acquisition Area.
Northern Prawn Fishery	Yes	Known to fish at a low (<0.1 days/km^2) to medium (0.1-0.25 days/km^2) intensity within the Joseph Bonaparte Gulf (Patterson et al. 2017).
North West Slope Trawl Fishery	No	Fishery is located in deep water from the coast of the Prince Regent National Park to Exmouth between the 200 m depth contour to the outer limit of the AFZ. This area is not near the Beehive 3D MSS Acquisition Area.

Northern Prawn Fishery

The Northern Prawn Fishery (NPF) operates off Australia's northern coast from Cape York (QLD) to Cape Londonderry (WA) (AFMA 2017). The NPF is restricted to 52 vessels. The area of the NPF and fishing intensity for 2016 is shown in *Figure 5.21*. The main fishing area for the NPF is the Gulf of Carpentaria, with low intensity within the Joseph Bonaparte Gulf.

Figure 5.22 shows the area of fishing activity in the southern JBG for 2013-2016, based on data presented in the annual ABARES Fishery Status Reports.

The following information in regards to the NPF in general is from the ABARES 2017 Fishery Status Report (Patterson et al. 2017) except where noted. Information relating to the activities of the NPF within the JBG has been sourced from:

- Loneragan et al. (2002);
- AFMA (2017);
- Laird (2017);
- Jarrett et al. (2015); and
- a response from the NPFI received during the stakeholder consultation process (see *Section 4.3*).

The NPF is managed through a combination of input controls (limited entry, seasonal closures, permanent area closures, gear restrictions and operational controls) that are implemented under the *Northern Prawn Fishery Management Plan 1995*.

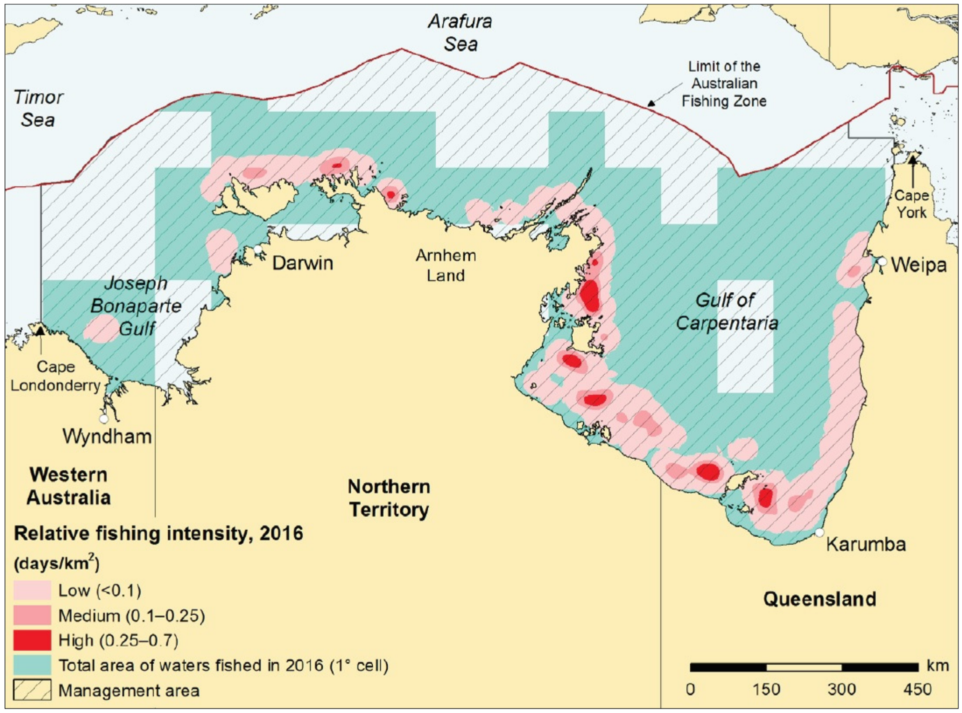

Figure 5.21 Northern Prawn Fishery Management Area and 2016 fishing intensity (Patterson et al. 2017)

The NPF uses otter trawl gear to target a range of tropical prawn species. White banana prawn and two species of tiger prawn (brown and grooved) account for around 80% of the landed catch. In recent years, many vessels have transitioned from using twin gear to mostly using a quad rig comprising four trawl nets—a configuration that is more efficient.

White banana prawn (*Fenneropenaeus merguiensis*) is mainly caught during the day on the eastern side of the Gulf of Carpentaria, whereas red-legged banana prawns (*F. indicus*) is mainly caught in the Joseph Bonaparte Gulf. Byproduct species include endeavour prawns (*Metapenaeus* spp.), scampi (*Metanephrops* spp.), bugs (*Thenus* spp.) and saucer scallops (*Amusium* spp.).

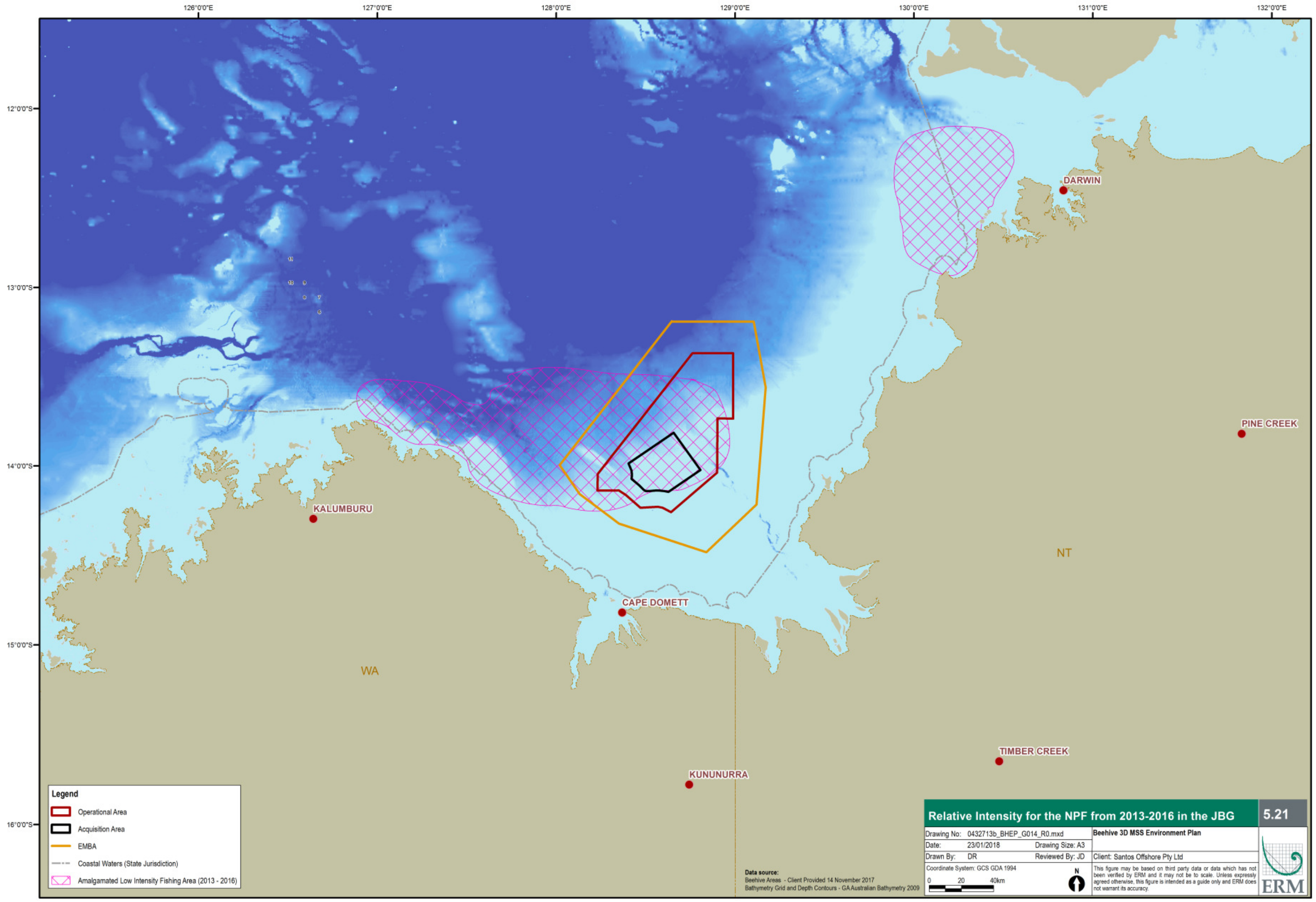

Figure 5.22 Northern Prawn Fishery main area of activity nearest to the EMBA

The total catch in 2016 for the NPF was 5,807 t at a value of $124.0 million, and in 2015 it was 7,825 t at a value of $106.8 million. Annual catches tend to be quite variable from year to year because of natural variability in the banana prawn component of the fishery.

The NPF operates during two seasons. The first season is from 1 April to 15 June, and during this time banana prawns are mainly caught. Conversely, during the second season (1 August – 1 December) tiger prawns are predominately caught. Either season has the potential to end early depending on the total catch.

The following information has been obtained from the AFMA website (http://www.afma.gov.au/portfolio-item/prawns/) except where noted.

Banana prawns inhabit tropical and subtropical coastal waters. They are found over muddy and sandy bottoms in coastal waters and estuaries. Juveniles inhabit small creeks and rivers in sheltered mangrove environments. White banana prawns can generally be found at depths of 16-25 m but can occur to depths of 45 m. Red-legged banana prawns are found at depths of 35-90 m.

Tiger prawns inhabit coastal waters to depths of 200 m. Adult brown tiger prawns are found over coarse sediments. Adult grooved tiger prawns are found in fine mud sediments. Juvenile tiger prawns are found in shallow waters, often in association with seagrass beds, and sometimes on top of coral reef platforms. Spawning occurs throughout the year, in both inshore and offshore areas for brown tiger prawns and in offshore areas for grooved tiger prawns. Brown tiger prawns have a spawning peak between July and October. Grooved tiger prawns have a spawning peak in August-September, with a secondary peak in February.

Endeavour prawns inhabit tropical coastal waters. Blue endeavour prawns can be found over sandy or mud-sand substrates to depths of about 60 m. Red endeavour prawns prefer muddy substrates and have been found to depths of 95 m. Juveniles blue endeavour prawns are commonly associated with seagrass beds in shallow estuaries, while juvenile red endeavour prawns are more widely distributed across seagrass beds, mangrove banks, mud flats and open channels. Spawning occurs throughout the year. Blue endeavour prawns have spawning peaks in March and September. Red endeavour prawns have a spawning peak in September-December. Based on the endeavour prawns spawning habitat preferences it is unlikely that they would spawn in the offshore area of the survey location.

Advice from the NPFI during the development of the Santos Fishburn EP is that prawn species reach a commercial size at six months, and can live for up to two years. Larger sized prawns have a higher price tag. Growth rates vary considerably between species and sexes, with females generally growing faster and to a larger size than males. Most species are sexually mature at six months, but fecundity increases with age. A twelve-month-old female can produce hundreds of thousands of eggs at a single spawning and may spawn more than once in a season. The eggs sink to the bottom after release, where they hatch into larvae within about 24 hours. Less than 1% of these offspring survive the two to four week planktonic larval phase to reach suitable coastal nursery habitats where they may settle. After one to three months on the nursery grounds, the young prawns move offshore onto the fishing grounds.

During the 2016 season, a total of 2,904 tonnes of banana prawns, 2,158 tonnes of tiger prawns and 374 tonnes of endeavour prawns were caught.

NPF Activity in the Joseph Bonaparte Gulf

In the JBG the NPF the catch is comprised primarily of banana prawns (mainly *F. indicus* and some *F. merguiensis*), with a very minor catch of tiger and endeavour prawns (Laird 2017).

The JBG comprises about 30,000 km² of the westernmost portion of the NPF (*Figure 5.23*). Fishing for the *F. indicus* is permitted day and night in both NPF fishing seasons. Fishing takes place in waters 35–70 m deep, with most fishing effort between 50 and 60 m. The trawling regime for this species is similar to the tiger prawn subfishery in other regions of the NPF, where the total duration of individual trawls are usually long (~3 h). Although the JBG fishery comprises less than 5% of the area of the NPF, it contributes about 65% of the NPF's red-legged banana prawn catch and around 20% of the NPF's total banana prawn catch (combined *F. merguensis* and *F. indicus*) (Loneragan et al. 2002).

Advice from the Northern Prawn Fishery Industry (NPFI) obtained during consultation for the Santos Fishburn 3D MSS EP is that there is not much known about the spawning season for *F. merguiensis*, but research to date indicates that *F. indicus* prawns spawn offshore near to the fishing area throughout the year with two spawning peaks: the late dry season (September-November) and the late wet season (March-May). The larvae move inshore and then wash out as juveniles with the wet season floods.

As described in Loneragan et al. (2002), the offshore fishery for red-legged banana prawns (*F. indicus*) takes place in the north-western offshore waters of the JBG (in water depths of 50-80 m). Thus, the juvenile phase of *F. indicus* is found in estuarine habitats up to 120 km south and 240 km east-southeast of the southern and eastern limits of the JBG *F. indicus* fishery. The juvenile phase of *F. merguiensis* is found in estuarine habitats in the western JBG, about 50 km to the south west of the *F. indicus* fishery, offshore. Although these mangrove habitats are the closest inshore habitats to the fishery, they are not used by *F. indicus*. These results suggest that the larvae of *F. indicus* resulting from spawning in the fishing, are advected large distances to the south and east to their nursery habitats (*Figure 5.23*). They also imply that the emigrating juveniles and sub-adults migrate from the mangrove nursery habitats, north and west, across shallower sand substrates (30 – 40 m deep) to the deeper-water fishery (on mud substrates about 50-80 m deep).

The migration of juvenile *F. indicus* in the JBG appears to be split into two periods, with the migration of the main cohort occurring between November and March, with a possible second cohort migrating from April to June (Neil Loneragan, CSIRO Division of Marine Research, pers. comm., April 2000). Migration of the juveniles is thought to be triggered by rainfall and river discharge.

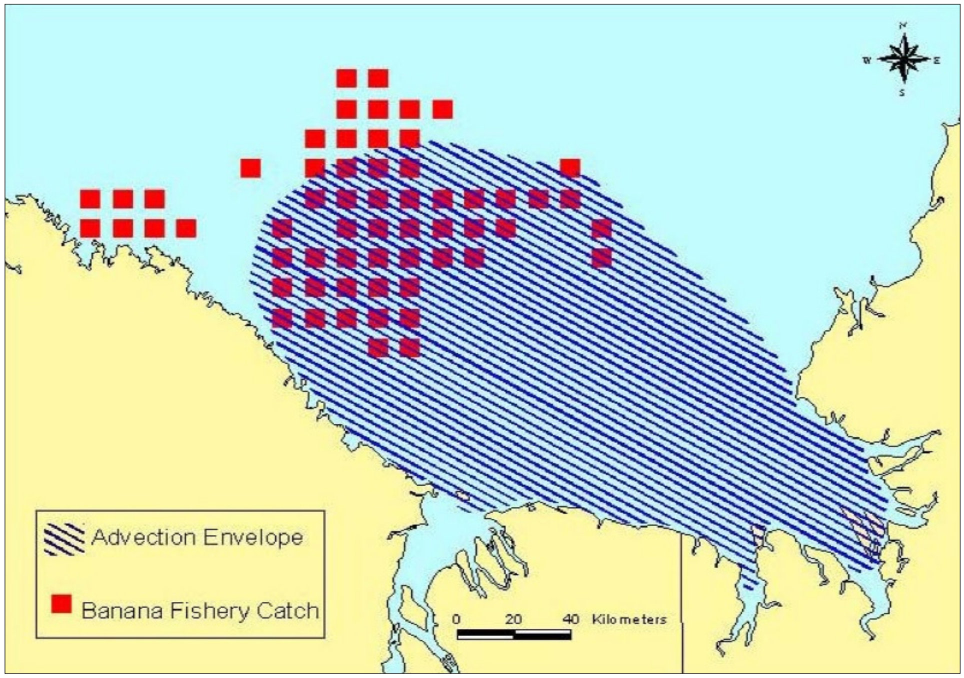

Figure 5.23 ***Size of the probable advection envelope for postlarval F. indicus in the Joseph Bonaparte Gulf (Loneragan et al. 2002)***

A seasonal closure for the NPF in the JBG exists in the period 31 March – 15 June (*Figure 5.24*) (AFMA 2017). The seasonal closure is an exclusion zone in place for all licence holders within the NPF, and the purpose of this closure is to protect small juvenile prawns as they migrate offshore to deeper waters in the southern JBG, where the adults are targeted during the trawling operations (see *Figure 5.22*). Any catch south of the seasonal closure line is taken in the second fishing season only (August to November), whereas catch taken north of the closure line is taken during both the first and second seasons.

The Beehive 3D MSS is mostly located within this exclusion zone (~ 11% of the Acquisition Area is outside of this exclusion zone). According to the Northern Prawn Fishery Directions and Closures (AFMA 2017), the seasonal closure in the JBG will be implemented for the 2018 season.

Due to the large tidal range (6–8 m) in the JBG and its reputed influence on prawn abundance in the region, *F. indicus* are fished on the neap tides, when tidal range and currents are minimal (Tonks et al. 2008). Thus, over a tide cycle, fishing effort is high on the late spring-neap, neap and early neap-spring tides, and low to non-existent at other times when the fleet moves to fishing grounds north of Melville Island and Port Essington, outside the JBG. The extra steaming time that this fishing pattern generates, together with the remoteness of the JBG and the lower price of *F. indicus* in comparison to other species of prawns, makes the JBG a less attractive area to fish than other parts of the NPF. As a result, the annual fishing effort in the JBG fishery is mostly dependent on the catch levels elsewhere in the NPF; if catches are good elsewhere, effort in JBG is low (Loneragan et al. 2002).

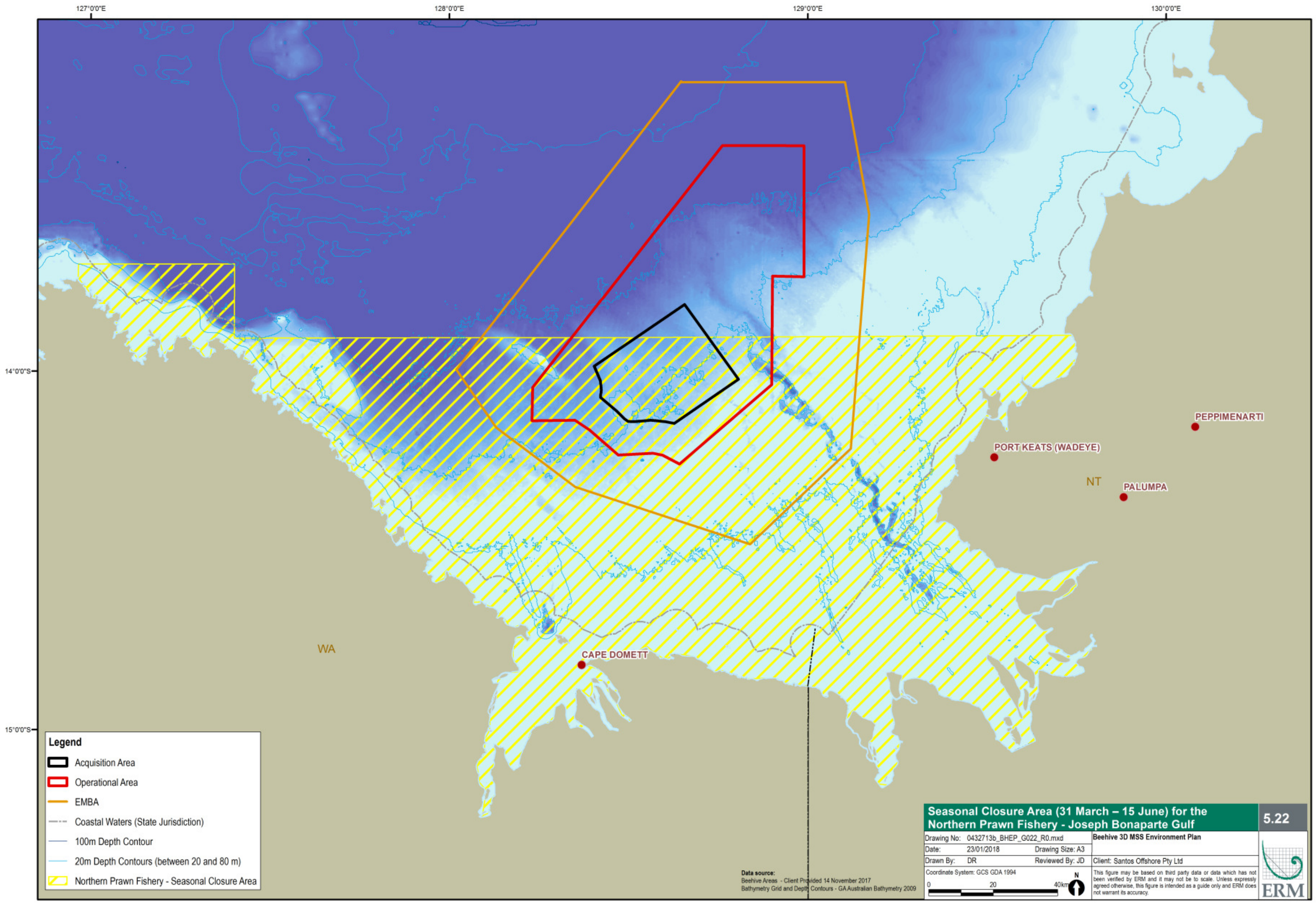

Figure 5.24 Northern Prawn Fishery closure area – Joseph Bonaparte Gulf

5.7.3 *Western Australian Managed Fisheries*

Western Australian fisheries are managed by the WA Department of Primary Industries and Regional Development (Fisheries) (DPIRD) under the *Fish Resources Management Act 1994* (WA). Although WA state waters extend from the coastal baseline (generally the high water mark) out to 3 nm, WA's fisheries extend into Commonwealth waters.

The DPIRD advised that the fisheries in *Table 5.16* exist in, or are in close proximity to, the areas associated with the proposed Beehive 3D MSS. A review of data from the 2014/2015 Fisheries Status Report as well as consultation with the DPIRD and licenced fishes identified two WA commercial fisheries that operate within the EMBA – the Mackerel Managed Fishery (MMF) and the Northern Demersal Scalefish Managed Fishery (NDSMF) (*Figure 5.25*).

Table 5.16 Relevant WA managed fisheries within the EMBA

Fishery	Actual Catch Effort within Permit Area/s	Comments
Beche-de-mer Fishery	No	The WA beche-de-mer fishery is only permitted to operate in Western Australian waters (Hart et al. 2015). It is a hand harvest fishery unlikely to be in EMBA due to water depths of 60 - 100 m. The EMBA does not encroach on state waters.
Joint Authority Northern Shark Fishery (JANSF)	No	Confirmation from DPIRD during the Santos Fishburn EP that the fishery has not operated since 2009 and unlikely to operate in 2017.
Mackerel Managed Fishery (MMF)	Yes	Targets Spanish mackerel using near-shore trolling gear around reefs, shoals and headlands. The fishery is divided into three zones, Area 1 - Kimberley (121°E to WA/NT border), Area 2 -Pilbara (114°E to 121°E) and Area -3 Gascoyne (27°S to 114°E) (Fletcher and Santoro 2015). The Kimberley area is the prime catching area and accounts for 50% of the allowable quota. A total of 11 vessels operated during 2014 with three within the Kimberley area (Fletcher and Santoro 2015). Feedback from WAFIC during the Santos Fishburn EP (see *Section 4*) is that Mackerel licence holder's fish in water depths below 100 m. Fishing tends to be around headlands and reefs and also shoal areas (which are not necessarily close to the coast). The Beehive 3D MSS EMBA is within the fisheries area of known operation.
Marine Aquarium Managed Fishery	No	The fishery currently only operates in WA state waters and is active in waters from Esperance to Broome (Fletcher and Santoro 2015). In 2014, 10 licences operated in the fishery (Fletcher and Santoro, 2015). The fishery targets more than 250 species of finfish and also takes coral, live rock, invertebrates, seagrass and algae. It does so using divers and hand held nets. This limits the fishery's area and the number of catches. The Beehive 3D MSS EMBA is not within the fisheries area of known operation.
Northern Demersal Scalefish Managed Fishery (NDSMF)	Yes	Operates off the north-west coast of WA in the waters east of 120°E and targets predominately red emperor and goldband snapper. Although permitted to use handlines, droplines and traplines, since 2002 the fishery has been essentially trap based (Fletcher and Santoro 2015). This has allowed fishing to occur in depths greater than 200 m. In 2014, eight vessels operated using between 18-36 fish traps per day and resulting in a catch of 1,111 tonnes (Fletcher and Santoro 2015). The Beehive 3D MSS is located in Area 2, Zone A.

Fishery	Actual Catch Effort within Permit Area/s	Comments
Pearl Oyster Managed Fishery	No	Dive fishery operated in shallow coastal waters along the North West Shelf. The fishery is separated into four zones: NW Cape to longitude 119°30’E (Zone 1), east of Cape Thouin (118°20’E) and south of latitude 18°14’ (Zone 2), west of longitude 125°20’E and north of latitude of 18°14’S (Zone 3) and east of longitude 125°20’E to the WA/NT border (Zone 4) (Fletcher and Santoro 2015). The Beehive EMBA is located in Zone 4 and all licences have access to this zone. However, stocks in the area are not currently economically viable (Fletcher and Santoro 2015). Consultation with the Pearl Producers Association (PPA) during the Santos Fishburn EP confirmed no activity in the area. No response was received from the PPA with regards to the Beehive survey.
Specimen Shell Managed Fishery	No	Fishery covers entire WA coastline, however, concentrates its efforts in areas adjacent to population centres (Fletcher and Santoro 2015). In 2014, over 200 different specimen shell species were collected using methods ranging from diving to wading to remote controlled underwater vehicles (Fletcher and Santoro 2015) Although there are 32 licences in the fishery, only 11 are regularly active (Fletcher and Santoro 2015). The Beehive EMBA is not within the fisheries area of known operation.

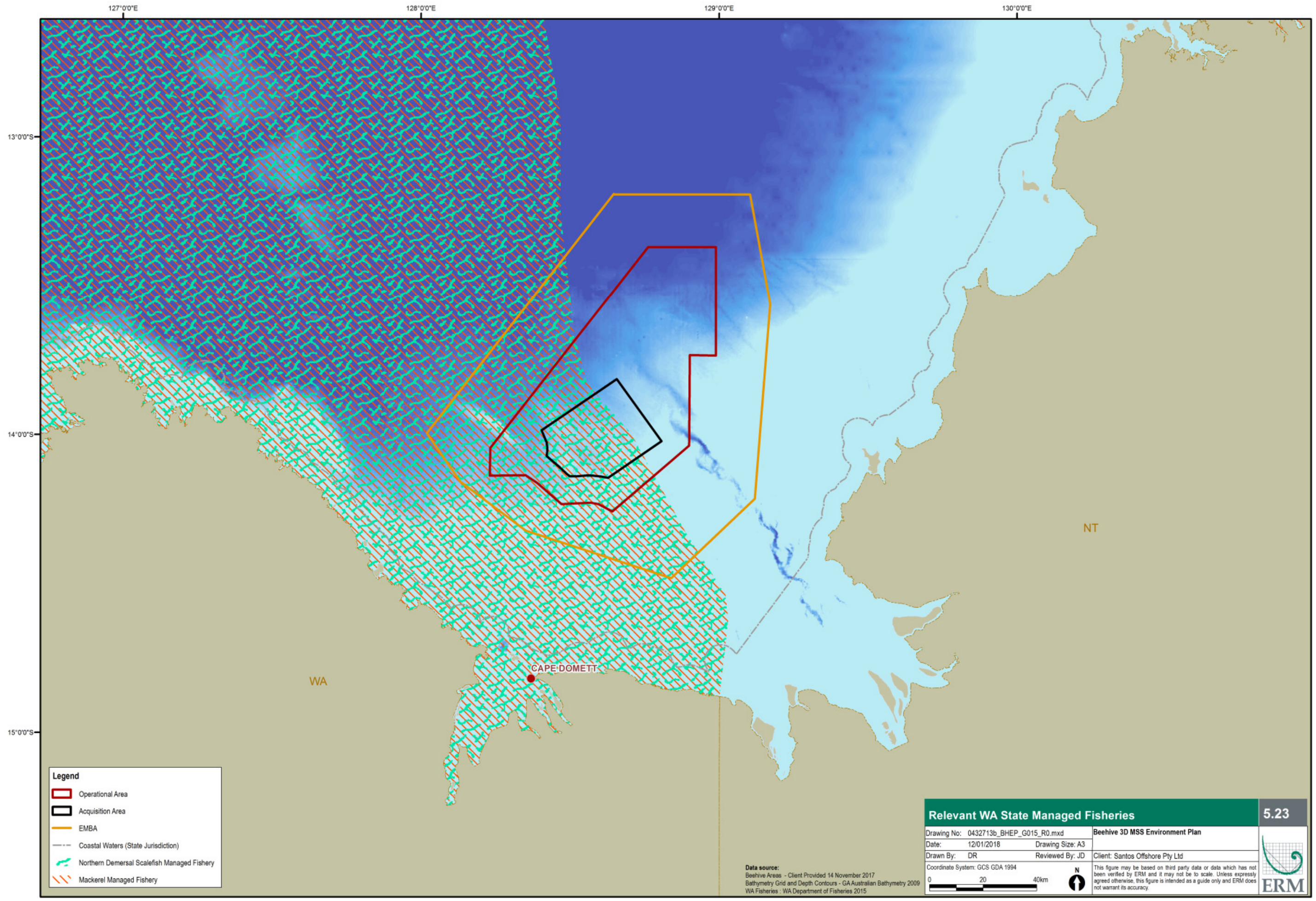

Figure 5.25 Relevant WA managed fisheries

5.7.3.1 *Mackerel Managed Fishery*

The MMF is divided into three zones, Area 1 - Kimberley (121°E to WA/NT border), Area 2 -Pilbara (114°E to 121°E) and Area - 3 Gascoyne (27°S to 114°E), which encompass the entire coastline of WA from the Northern Territory (NT) border to Cape Leeuwin in the south west (Fletcher and Santoro 2015).

The primary species of the MMF is the Spanish mackerel (*Scomberomorus commerson*), which is fished commercially between Geraldton (in the Gascoyne/West Coast Sector) and the Northern Territory border (Kimberley Sector).

The MMF was made a fully managed fishery in 2012 and operates under an Individual Transferable Quota (ITQ) system which includes the setting of Total Allowable Commercial Catches (TACCs) for each area of the fishery, allocation of the entitlement to take quota in the form of units, and establishment of minimum unit holding requirements to operate in the Fishery.

Licence holders may only fish for mackerel by trolling or handline. There are currently only 14 licences in the Kimberley management area. A total of 14 vessels operated during the 2014 season with three vessels within the Kimberley area (Fletcher and Santoro 2015). A total of 673 fishing days of effort were reported targeting Spanish mackerel in 2014, with more than 53% of effort days reported from the Kimberley Area.

Estimates of catches are monitored through mandatory logbook systems with the total catch of Spanish mackerel in the 2014 season estimated at 322 tonnes. The target catch (and effort) for Spanish mackerel is between 246 – 410 tonnes for the three management zones. The reported catch from the Kimberley Area of 193.8 t was within the area’s acceptable catch range (110 – 205 t).

5.7.3.2 *Northern Demersal Scalefish Managed Fishery*

In the Kimberley, the NDSMF operates off WA’s coast in waters east of 120° E longitude. The NDSMF is managed primarily through input controls in the form of an annual fishing effort capacity, with supplementary gear controls and area closures.

The fishery is permitted to use hand lines, droplines and fish traps, although the NDSF has essentially operated as a trap based fishery since 2002. The NDSF principally targets red emperor and goldband snapper, with a number of species of snappers (Lutjanidae), cods (Epinephelidae) and emperors (Lethrinidae) comprising the majority of the remainder of the catch (Fletcher and Santoro 2015).

The fishery is further divided into two fishing areas; an inshore sector (Area 1) and an offshore sector (Area 2). The *Northern Demersal Scalefish Managed Fishery Management Plan 2000* was amended in 2013 to formalise the previous voluntary industry agreement which further divides the offshore sector (Area 2) into three zones; A, B and C. Zone B comprises the area with most of the historical fishing activity. Zone A is an inshore developmental area and Zone C is an offshore deep slope developmental area representing waters deeper than 200 m (Fletcher and Santoro 2015). The Beehive 3D MSS is located within Area 2, Zone A.

In 2014, the total catch for the NDSMF was reported at 1,111 t, of which Zone B contributed 960 t. The total catch of goldband snapper in 2014 in the NDSMF (499 t) was similar to that reported in 2013 (493 t). Catch levels of goldband snapper have remained high (> 450 t) since the peak catch of 523 t reported in 2010. The last five years represent the highest reported landings of this species, continuing an overall trend of increasing catches since 2005. The total catch of red emperor in 2014 was 132 t, which is similar to the red emperor catch levels reported over the past four years (2010-2013).

5.7.3.3 Pearl Oyster Managed Fishery

During consultation with the Pearl Producers Association (PPA) for the Santos Fishburn EP, the PPA noted that at the proposed depths where the Fishburn survey is to be acquired, will most likely have a variable distribution of *Pinctada maxima* (silver lipped pearl oyster), which are known to be present to less dense quantities in the Joseph Bonaparte Basin out to the 100 m isobath.

There are no current or future fisheries of *P. maxima* in or near the Beehive EMBA and *P. maxima* have a wide distribution throughout northern Australia and into Asia. No response was received from the PPA with regards to the Beehive survey (see stakeholder records in *Section 4* and Appendix 2).

5.7.4 Northern Territory Managed Fisheries

Northern Territory fisheries are managed by the NT Department of Primary Industry and Resources (DPIR) (Fisheries). Although NT waters extend from the coastal baseline (generally the high water mark) out to 3 nm, NT fisheries extend into Commonwealth waters.

The DPIR advised that the fisheries in *Table 5.16* exist in, or are in close proximity to, the areas associated with the proposed survey. A review of data from the DPIR website (https://nt.gov.au/marine/commercial-fishing) and as well as consultation with the DPIR and licenced fishes identified one NT commercial fishery that operates within the Beehive 3D MSS EMBA – the Demersal Fishery (*Figure 5.26*).

Table 5.17 Relevant NT managed fisheries within the EMBA

Fishery	Actual Catch Effort within Permit Area/s	Comments
Aquarium Fishery	No	The Aquarium Fishery is a small-scale, multi-species fishery. It includes freshwater, estuarine and marine habitats to the outer boundary of the AFZ, which is 200 nm offshore. Most marine species are collected within 100 km of Nhulunbuy and Darwin (NT Government 2016). According to the NTSC, the fishery has 11 licences and around 3 boats are active each year (NTSC 2017). Information from Chair of the Aquarium Fishery Licence Committee obtained during consultation for the Santos Bethany EP is that they scuba dive to a maximum of 30 m and one operator operates at Evan Shoal, east of Lyndoch Shoal, Blackwood Shoal and Money Shoal in Arufura and within Timor Reef Fishery Area. This fishery is not considered relevant
Timor Reef Fishery	No	The Timor Reef Fishery operates offshore north-west of Darwin in a specific area of the Timor Sea. The harvest by this fishery is limited through a set of TACs applied to goldband snappers (900 t), red snappers (1300 t) and “group fish” (415 t). The composition of these groups is the same as those for the Demersal Fishery. A total of 806 t of fishes was harvested by licensees in 2015, with goldband snappers and red snappers constituting most of the harvest (38% and 31% of the total, respectively) (NT Government 2016). The Timor Reef Fishery (TRF) operates offshore in a zone covering roughly 8,400 nm^2 to the north-west of Darwin. The Beehive EMBA is not within or adjacent to the Timor Reef Fishery area. Therefore, this fishery is not considered relevant.
Demersal Fishery	Yes	The Demersal Fishery operates in waters from 15 nm out to the AFZ boundary, excluding the area of the Timor Reef Fishery. In 2016, seven vessels were active in the Demersal Fishery with a reported total catch of 3,463 t, including 2,510 t of red snappers and 318 t of goldband snappers. The Demersal Fishery currently has 18 license holders. The Beehive EMBA overlaps the Demersal Fishery area in the southern Joseph Bonaparte Gulf.
Spanish Mackerel Fishery	No	The Spanish Mackerel Fishery operates in waters from the higher water marks to the outer boundary of the AFZ. Most Spanish mackerel are caught off the western and eastern mainland coasts and near islands including Bathurst Island, Groote Eylandt and the Wessel Islands. The Spanish Mackerel Fishery is restricted to 15 license holders with the main methods to catch Spanish mackerel include; troll lines, floating hand lines and rods. The primary fishing grounds include waters near Bathurst Island, New Year Island, the Wessel Islands around to Groote Eylandt and the Sir Edward Pellew Group of islands. A total 346 t of fish were harvested by Spanish Mackerel Fishery licensees in 2015 (NT Government 2016). The Beehive EMBA does not overlap the main area of fishing for the mackerel fishery. Therefore, this fishery is not considered relevant.
Offshore Net and Line Fishery	No	The NT Offshore Net and Line Fishery extends seaward from the high water mark to the outer limit of the AFZ and targets Australian blacktip shark (*Carcharhinus tilstoni*), common blacktip shark (*C. limbatus*) and grey mackerel (*Scomberomorus semifasciatus*). A total of 522 t of fishes were harvested by Offshore Net and Line Fishery licensees in 2015 (NT Government 2016). Demersal longlines can be used throughout the fishery whereas pelagic gillnets and pelagic longlines can only be used beyond 2 nm and 3 nm off the coast, respectively. Pelagic gillnets are the primary gear used by this fishery and are generally set within 15 nm of the coast, in the Gulf of Carpentaria. Longlines have not been used in the fishery since 2013, primarily as a result of the drop in shark fin price. The fishery is restricted to 17 license holders. The Beehive EMBA does not overlap the main area of fishing for the offshore net and line fishery. Therefore, the fishery is not considered relevant.

5.7.4.1 *Demersal Fishery*

The NT Demersal Fishery extends from 15 nm from the low water mark to the outer limit of the AFZ (excluding the area of the Timor Reef Fishery) and targets a range of tropical snappers (*Lutjanus* spp. and *Pristipomoides* spp.). In 2016, seven vessels were active in the Demersal Fishery with a reported total catch of 3,463 t, including 2,510 t of red snappers and 318 t of goldband snappers.

The harvest by the Demersal Fishery is limited through a set of total allowable catches (TACs) applied to goldband snappers (*Pristipomoides* spp.) (400 t), red snappers (*L. malabaricus* and *L. erythropterus*) (2,500 t) and a "grouped fish" category (915 t). The latter group includes all fishes other than barramundi (*Lates calcarifer*), king threadfin (*Polydactylus macrochir*), Spanish mackerel, shark and mud crabs (*Scylla* spp.) (NT Government 2016).

The north-eastern portion of the Acquisition Area overlaps the Demersal Fishery Area 2, where line and fish-trap gear are permitted and demersal trawls nets are excluded (*Figure 5.26*). The northern extent of the Operational Area and EMBA overlap Area 1 of the Demersal Fishery where line, fish-trap and finfish trawl gear are all permitted (*Figure 5.26*).

Traps used in the fishery are set on the seabed with an identifying float on the sea surface. The fishery is monitored primarily through logbook returns, which operators are required to fill out on a daily basis during fishing operations. The logbooks provide detailed catch and effort information, as well as information on the spatial distribution of the fishing operations (NT Government 2014).

Catch and effort for trap vessels varies from year to year. NT Government (2014) states that the substantial variability in trap effort since 2009 generally reflects movement between the Demersal Fishery and the nearby Timor Reef Fishery. NT Government (2014) states that Stock Reduction Analysis evidence suggests that this is not due to changes in fish abundance or sustainability concerns that the fluctuating CPUE reflects the small number of operators and their developing knowledge of the fishery.

The Demersal Fishery covers an area of ~ 100,000 nm^2 (~ 343,000 km^2). The Beehive Operational Area covers ~ 2,895 km^2 of the Demersal Fishery (0.84%) and the Beehive Acquisition Area covers ~ 300 km^2 of the Demersal Fishery (0.09%).

Santos, via engagement with the NTSC and NT DPIR has tried to obtain more recent and more detailed information about where the Demersal Fishery licensees actively fish to be able to undertake a more robust assessment of impacts, however, to date this information has not been made available.

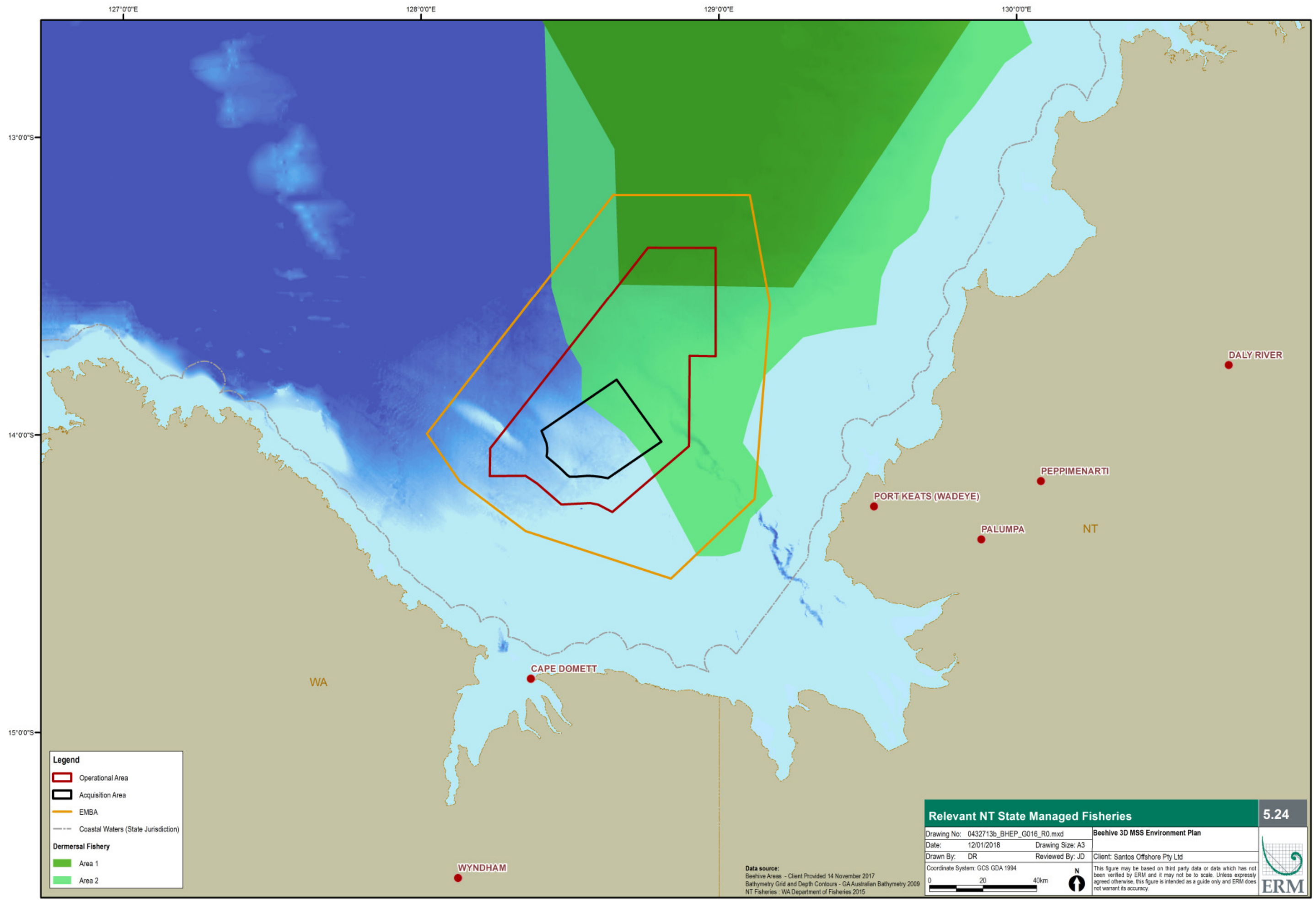

Figure 5.26 Relevant NT managed fishery - Demersal Fishery

5.7.5 *Recreational Activities*

Based on stakeholder consultation during the Santos Fishburn EP with the WA DPIRD, WA Department of Aboriginal Affairs, Kimberley Land Council, Recfishwest and Amateur Fishermen's Association of NT, no recreational activities or customary fishing was identified to occur within the EMBA. See *Section 4* for stakeholder engagement records.

5.7.6 *Oil and Gas Activities*

The Bonaparte Basin is an established hydrocarbon province with a number of commercial operations such as the Bayu-Undan gas and condensate field, which is operated by ConocoPhillips and processed at their Darwin LNG plant, and the Blacktip Field operated by Eni Australia B.V.

Figure 5.27 shows the oil and gas permits within the broader Bonaparte Basin and the Joseph Bonaparte Gulf. To identify if any cumulative impacts could occur with other oil and gas activities those permits within 100 km of the WA-488-P permit where identified and the titleholders contacted. *Section 4* details the stakeholder records and *Table 5.18* details the potential activities in the area.

Table 5.18 Oil and gas permits within 100 km of the WA-488-P permit

Permit	Permit Type	Titleholder/ Operator	Activity in 2018/2019	Distance from WA-488-P
WA-454-P	Exploration Permit	Origin Energy Resources Ltd	No planned acquisition in 2018/19.	18 km N
NT/P84	Exploration Permit	Origin Energy Resources Ltd	Gulpener 2D seismic survey acquired in 2017.	0 km (adjacent)
WA-33-L	Production License	Eni Australia B.V	Blacktip Operations.	0 km (adjacent)
WA-69-R	Retention Lease	Eni Australia B.V	No response received during consultation process.	23 km N
WA-27-R	Retention Lease	Engie Bonaparte Pty Ltd	No response received during consultation process.	74 km NW
WA-40-R	Retention Lease	Engie Bonaparte Pty Ltd		93 km NW
NT/RL1	Retention Lease	Engie Bonaparte Pty Ltd		96 km N
WA-6-R	Retention Lease	Engie Bonaparte Pty Ltd		97 km N
WA-522-P	Exploration Permit	Woodside Energy Ltd	Acquiring a multi-client seismic survey in March-April 2018.	77 km NW

Permit	Permit Type	Titleholder/ Operator	Activity in 2018/2019	Distance from WA-488-P
WA-459-P	Exploration Permit	Santos Limited	No activity. Fishburn EP was acquired in 2017.	105 km NW

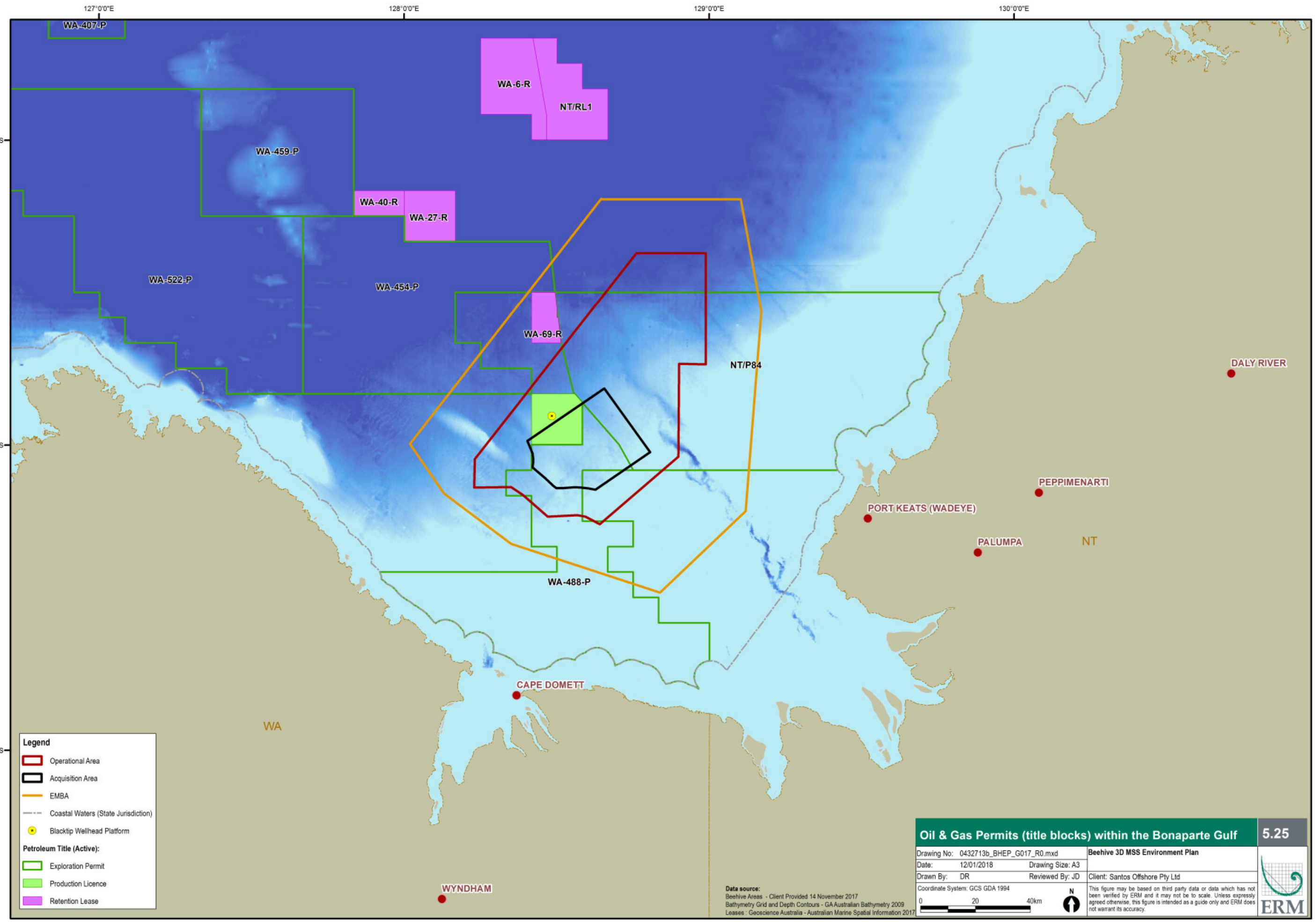

Figure 5.27 Oil and gas permits within the Bonaparte Gulf

5.7.7 *Commercial Shipping*

Darwin's close proximity to South-east Asia makes the surrounding area a key shipping region. AMSA has identified high traffic shipping volumes in close proximity to the Darwin Harbour, around operating petroleum fields and along key shipping routes to and from South-East Asia and to and from petroleum fields (*Figure 5.28)*. As shown in *Figure 5.28*, there is some low level shipping traffic passing through the EMBA.

5.7.8 *Defence Activities*

The Beehive 3D MSS Acquisition and Operational areas overlap with the North Australian Exercise Area (NAXA) a maritime military zone administered by the Australian Defence Force (*Figure 5.29*). The NAXA is used by the Royal Australian Air Force and the Royal Australian Navy for military operations including live weapons and missile firings.

The NAXA is the primary location of the KAKADU training exercise that operates biannually, with the 2018 exercise scheduled for 31 August – 15 September 2018. The exercise involves numerous naval ships from various countries participating in the waters off Darwin and Northern Australia. Exercise KAKADU is Australia's premier international maritime exercise, bringing together navies and air forces from the Asian, Pacific and Indian Ocean regions to test integration and war fighting abilities. Access will be restricted to all vessels and aircraft within the Due Regard Area (DRA).

During consultation with the Department of Defence (DoD), the DoD informed Finniss that the Beehive 3D MSS would potentially impact the scale of manoeuvre of surface units during the exercise. The proximity to the Blacktip Wellhead Platform (WHP) makes this portion of the NAXA valuable in terms of training scenarios (*Section 4.3*).

The DoD proposed that the Beehive 3D MSS is completed no later than 30 August 2018, or alternatively commencing after the 16 September 2018, as this would be of mutual benefit to both Finniss/Santos and Defence by removing the possibility of unintended impacts on each other's activities. Additionally, DoD also advised that unexploded ordinance (UXO) may be present on and in the sea floor in the area of proposed activities, and that Finniss/Santos must inform itself of the risks associated with conducting activities in the area.

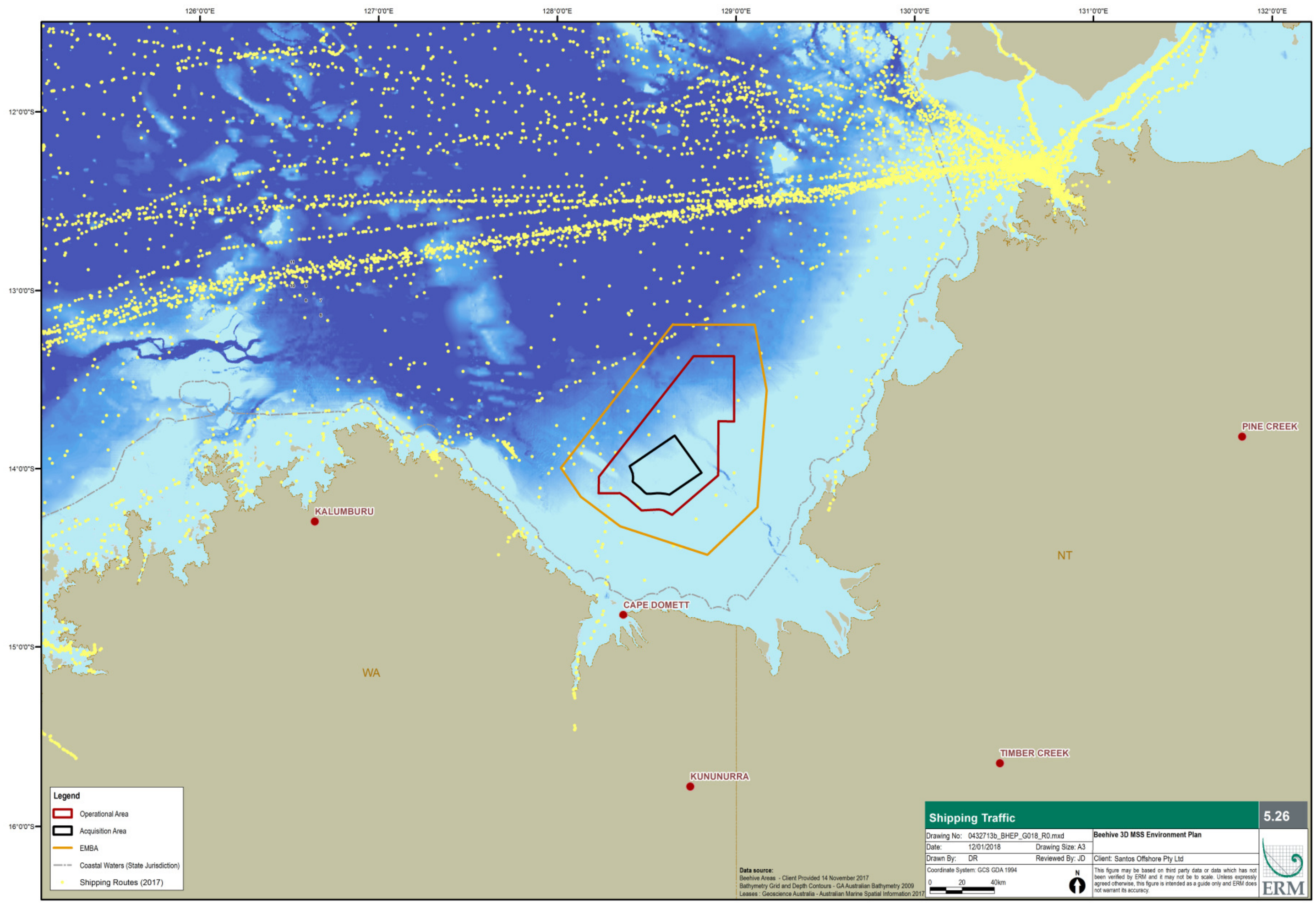

Figure 5.28 Shipping traffic

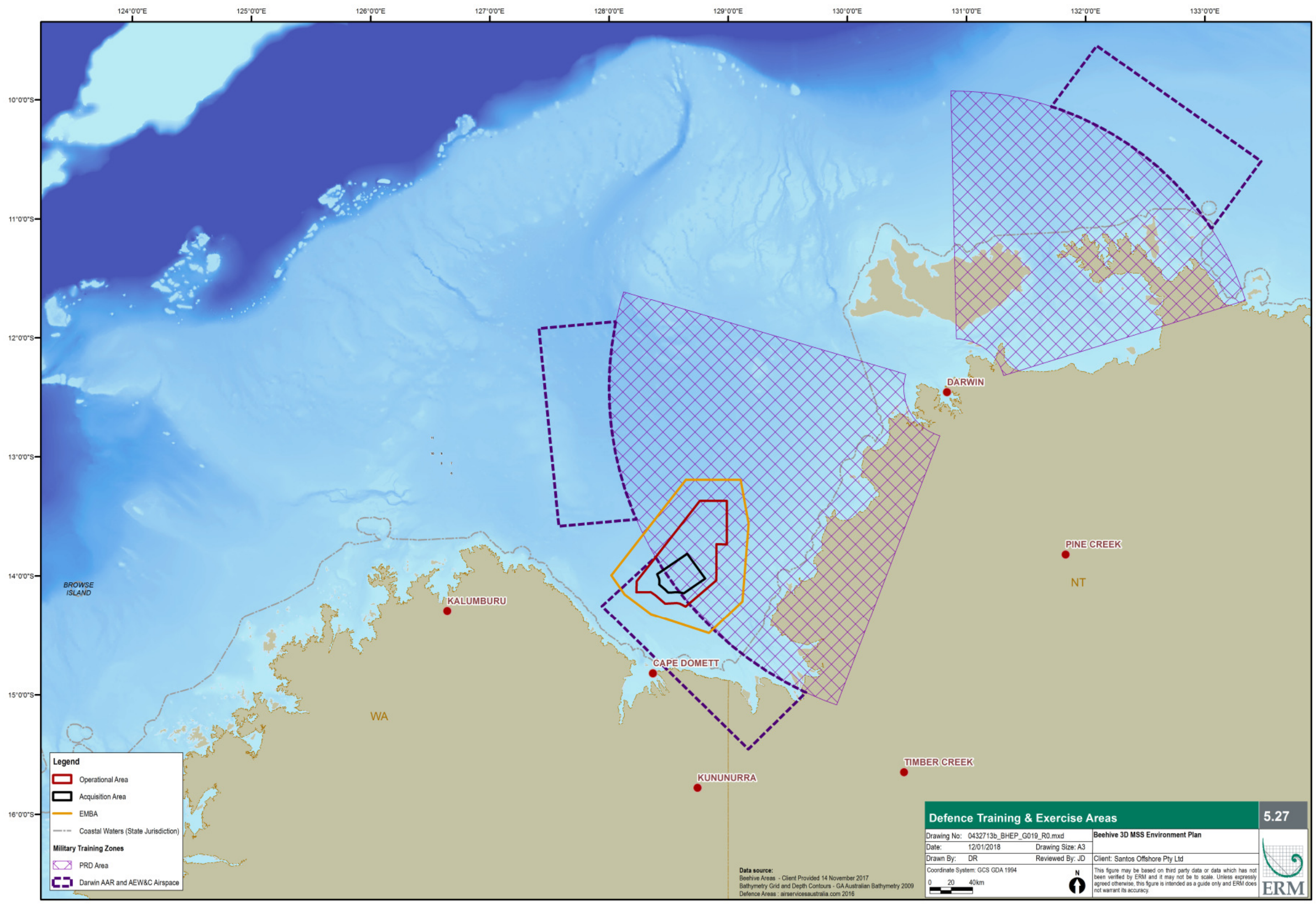

Figure 5.29 Department of Defence training areas

5.8 *INDIGENOUS HERITAGE*

A search of the Department of Aboriginal Affairs' (WA) Aboriginal Heritage Inquiry System did not identify any registered Aboriginal heritage sites, other heritage sites or Aboriginal heritage survey areas within the EMBA.

A search of the Australian Heritage Database did not identify any indigenous heritage areas within the EMBA.

5.9 *MARITIME HERITAGE*

Historic shipwrecks are recognised and protected under the *Historic Shipwrecks Act 1976* that protects historic wrecks and associated relics. Under the Act, all wrecks more than 75 years old are protected, together with their associated relics regardless of whether their actual locations are known. The Commonwealth minister responsible for the environment can also make a declaration to protect any historically significant wrecks or articles and relics that are less than 75 years old.

A search of the National Shipwreck and Relic database did not identify any shipwrecks or relics within the EMBA.

5.10 *WORLD HERITAGE AND NATIONAL HERITAGE SITES*

There are no World Heritage Properties or National Heritage Sites within or adjacent to the Beehive EMBA.

The only Commonwealth Heritage Area in the vicinity of the Joseph Bonaparte Gulf is the Bradshaw Defence Area (Bradshaw Field Training Area), located ~ 120 km south-east of the Beehive Operational Area. The Bradshaw Defence Area is located outside of the EMBA.

5.11 *WETLANDS OF INTERNATIONAL IMPORTANCE*

There are no marine or coastal Wetlands of International Importance in the vicinity of the Beehive 3D MSS. The nearest Wetland of International Importance is the Ord River Floodplain Ramsar Site, located on the eastern side of Cambridge Gulf (WA), over 100 km to the south-west of the Operational Area. The Ord River Floodplain is located outside of the EMBA and therefore will not be impacted by the proposed activity.

5.12 *COMMONWEALTH PROTECTED AREAS*

A network of Australian Marine Parks (AMPs) has been formed around Australia as part of a national representative system of marine protected areas. The AMPs are currently under review and transitional arrangements apply until new management plans come into effect. Draft management plans were released for comment on 21st July 2017 (DoNP 2017a; 2017b).

As described in *Section 5.2*, a search of the DoEE Protected Matters Database identified that the EMBA overlaps part of the Joseph Bonaparte Gulf Marine Park Multiple Use Zone (VI-6,345 km^2) and the Special Purpose Zone (VI-2,251 km^2) (*Figure 5.30*). The Operational Area and Acquisition Area do not overlap either zone of the Joseph Bonaparte Gulf Marine Park.

Commercial activities, such as fishing, tourism, and oil and gas exploration, are permitted within the Joseph Bonaparte Gulf Marine Park Multiple Use Zone and Special Purpose Zone.

The Joseph Bonaparte Gulf Marine Park major conservation values are:

- Important foraging area for threatened and migratory marine turtles (green and olive ridley turtles).
- Important foraging area for snubfin dolphins.
- Examples of the shallow water ecosystems and communities of the Northwest Shelf Transition Province, the second largest of all the provincial bioregions on the shelf, which includes the extensive banks that make up the Van Diemen Rise and the Sahul Shelf, broad shelf terraces and the shallow basin in the Joseph Bonaparte Gulf (including the Cambridge-Bonaparte, Anson Beagle and Bonaparte Gulf meso-scale bioregions

One key ecological feature is represented in the marine park:

- Carbonate bank and terrace system of the Sahul Shelf (see *Section 5.4*).

Where there is no specific management plan in place for a Commonwealth reserve the IUCN reserve management principles must be considered. The IUCN has identified seven categories that form the basis of the reserve management principles. The Joseph Bonaparte Gulf is categorised as IUCN VI Protected area with sustainable use of natural resources under the IUCN Management Principles for Commonwealth Marine Protected Areas (Environment Australia 2002). The management principles relevant to this category and how they will be met for the Beehive 3D MSS are detailed in *Table 5.19*.

As shown in *Figure 5.30*, the Beehive EMBA is located ~ 82 km south-east of the Oceanic Shoals Marine Park.

A review of the Australian Marine Parks did not identify any changes to these marine reserve boundaries or any changes to the Joseph Bonaparte Gulf Marine Park zones that overlaps the EMBA (Buxton and Cochrane 2015).

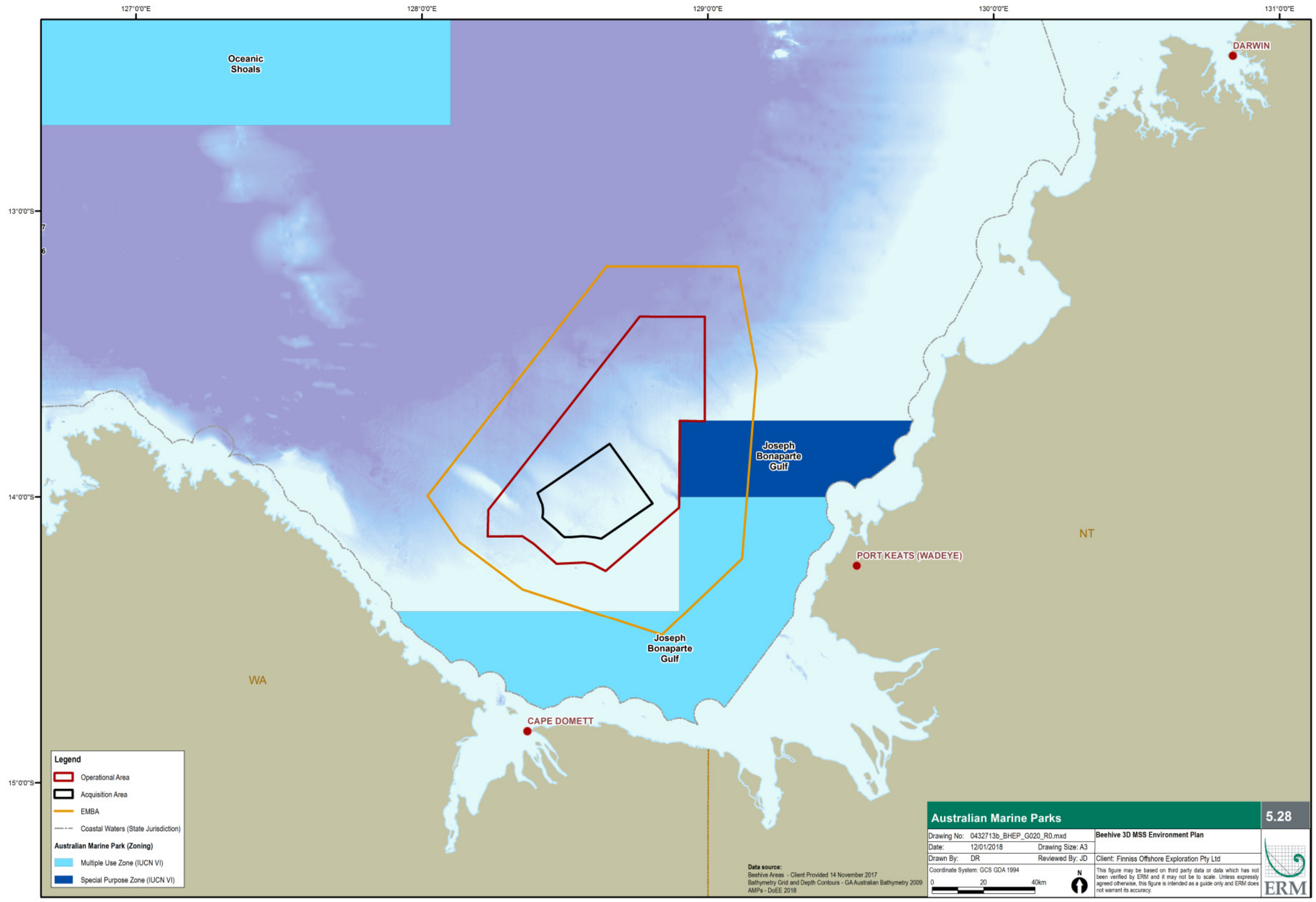

Figure 5.30 Australian Marine Parks

Table 5.19 ***Australian IUCN Reserve Management Principles for Australian Marine Protected Area Category VI and management of the activity consistent with these principles***

Reserve Management Principles for IUCN VI	Management of the Activity Consistent with the Principles
The reserve or zone should be managed mainly for the sustainable use of natural ecosystems based on the following principles.	*Section 7*of the EP details the risk assessment process undertaken for the activity and identifies potential impacts and risks to the Joseph Bonaparte Gulf Marine Park conservation values. The risk assessment process includes demonstrating that environmental impacts and risks of the activity will be of an acceptable level. The assessment did not identify any impacts or risks to the Joseph Bonaparte Gulf Marine Park conservation values that were unacceptable.
The biological diversity and other natural values of the reserve or zone should be protected and maintained in the long term.	*Section 7* of the EP details the risk assessment process undertaken for the activity and identifies potential impacts and risks to the Joseph Bonaparte Gulf Marine Park conservation values. The assessment identifies appropriate controls to manage potential impacts and risks to ALARP and an acceptable level. No long term impacts to the Joseph Bonaparte Gulf Marine Park conservation values were identified.
Management practices should be applied to ensure ecologically sustainable use of the reserve or zone.	*Section 7*of the EP details the risk assessment process undertaken for the activity and identifies potential impacts and risks to the Joseph Bonaparte Gulf Marine Park conservation values. The risk assessment process includes demonstrating that environmental impacts and risks of the activity will be of an acceptable level. One of the criteria for this demonstration is have the principles of ecologically sustainable development met? All impacts and risks identified from the activity demonstrated that the principles of ecologically sustainable development can be met.
Management of the reserve or zone should contribute to regional and national development to the extent that this is consistent with these principles.	The activity is proposed to identify gas resources in the region. This could lead to potential development which would contribute to regional and national development. As detailed via the principles above the survey will be undertaken consistent with the reserve management principles.

5.13 STATE PROTECTED AREAS

A review of the WA Marine Parks and Reserve did not identify any current or proposed marine parks or reserves within or adjacent to the EMBA.

The proposed North Kimberley Marine Park is located within State waters, ~ 25 km south of the EMBA (*Figure 5.31*). The King Shoals Sanctuary Zone, located ~ 34 km from the EMBA, includes some of the Kimberley's only mapped tidal sand waves and sand banks, as well as carbonate banks (a designated KEF) and deep waters. The zone also provides protection for threatened species such as green and freshwater sawfish, which occur in the area (DPaW 2016).

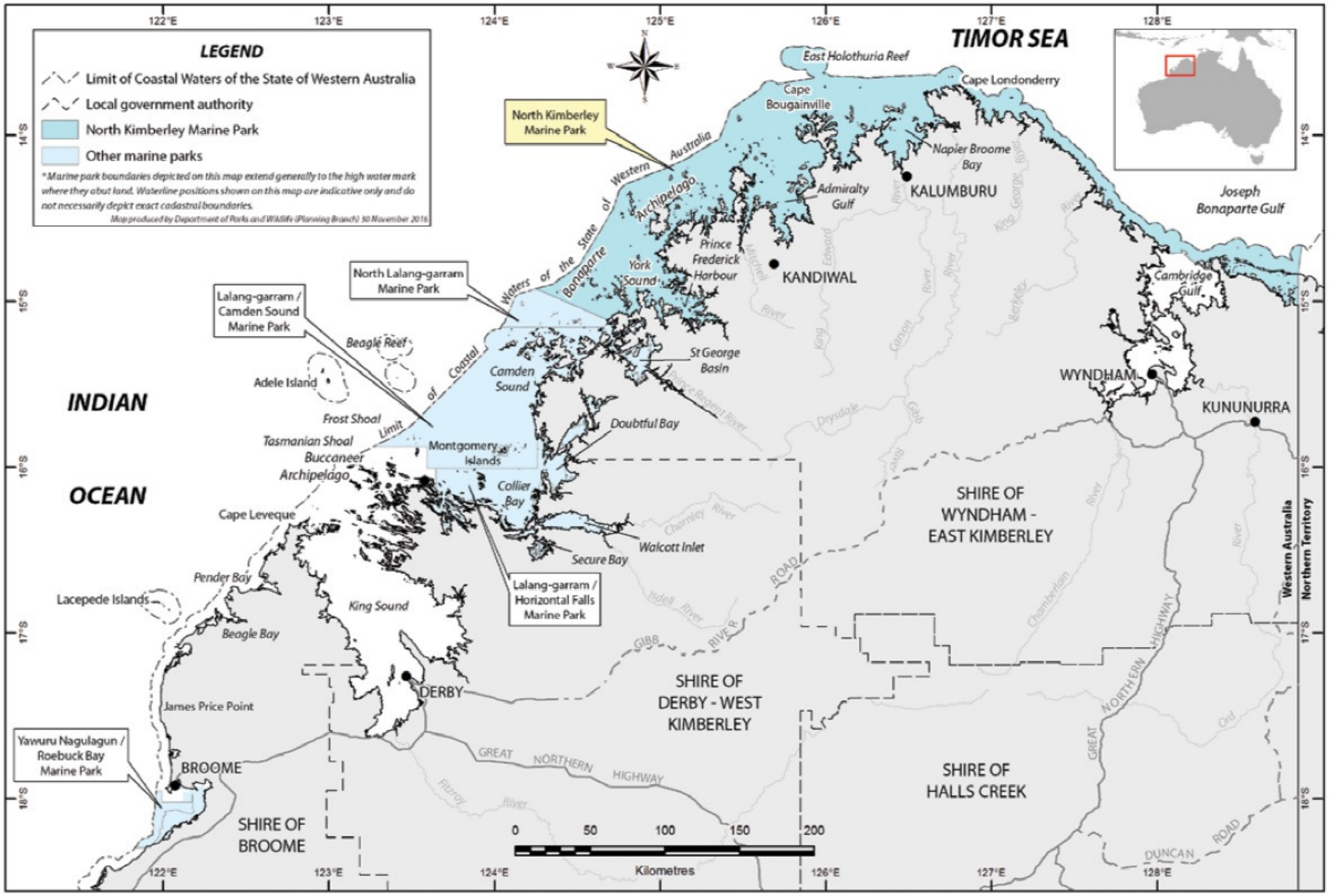

Figure 5.31 Location of the proposed North Kimberley Marine Park

6 *ENVIRONMENTAL RISK ASSESSMENT METHODOLOGY*

The environmental risk assessment process undertaken for the seismic survey comprised of the following components that are discussed further in the following sections:

1. Identification of environmental hazards
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. Control measure identification and ALARP decision framework
6. Determine severity of consequence
7. Determine likelihood
8. Determine residual risk ranking
9. Determination of Acceptability

The outcome of the risk assessment process is detailed in *Section 7* - Environmental Risk Assessment.

6.1 *IDENTIFICATION OF ENVIRONMENTAL HAZARDS (ASPECTS)*

Environmental hazards or aspects are those elements of the activity that can interact with the environment. Environmental hazards were identified for operations and emergency conditions. An assessment of each component of the activity was undertaken and the environmental hazards (aspects) identified.

6.2 *IDENTIFICATION AND DESCRIPTION OF THE ENVIRONMENT THAT MAY BE AFFECTED*

Following the identification of environmental hazards, the likely extent of each hazard, the environment that may be affected (EMBA) was determined. Based on the risk assessment undertaken in *Section 7* the EMBA by a diesel spill resulting from a vessel collision was identified as the largest for the survey. *Section 5* describes the existing environment within this area including any relevant cultural, social and economic aspects.

6.3 *IDENTIFICATION OF PARTICULAR VALUES AND SENSITIVITIES*

Based on Santos' and publicly available information a review of the existing environment (*Section 5*) was undertaken to identify the environmental values and / or sensitivities with the potential to occur within the EMBA. *Table 6.1* provides a summary of these values and sensitivities. These were used to inform the risk assessment as they provide the potential worst case consequence.

Table 6.1 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: 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.

6.4 *IDENTIFICATION AND EVALUATION OF POTENTIAL ENVIRONMENTAL IMPACTS*

Based on Santos' and publicly available information, the known and potential impacts to the identified receptors were identified. These were then evaluated and specifically considered:

- receptor sensitivity to identified hazard; and
- extent and duration of the potential impact.

6.5 *CONTROL MEASURE IDENTIFICATION AND ALARP DECISION FRAMEWORK*

Based upon the identified assessment technique used to demonstrate ALARP, 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.

6.5.1 *ALARP Decision Framework*

In alignment with NOPSEMA's ALARP Guidance Note (GN0166), Santos have adapted the approach developed by Oil and Gas UK (OGUK) (formerly UKOOA) for use in an environmental context to determine the assessment technique required to demonstrate that potential impacts and risks are ALARP (*Figure 6.1*). Specifically, the framework considers impact severity and several guiding factors:

- Activity type;
- Risk and uncertainty; and
- 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 *Table 6.1*.

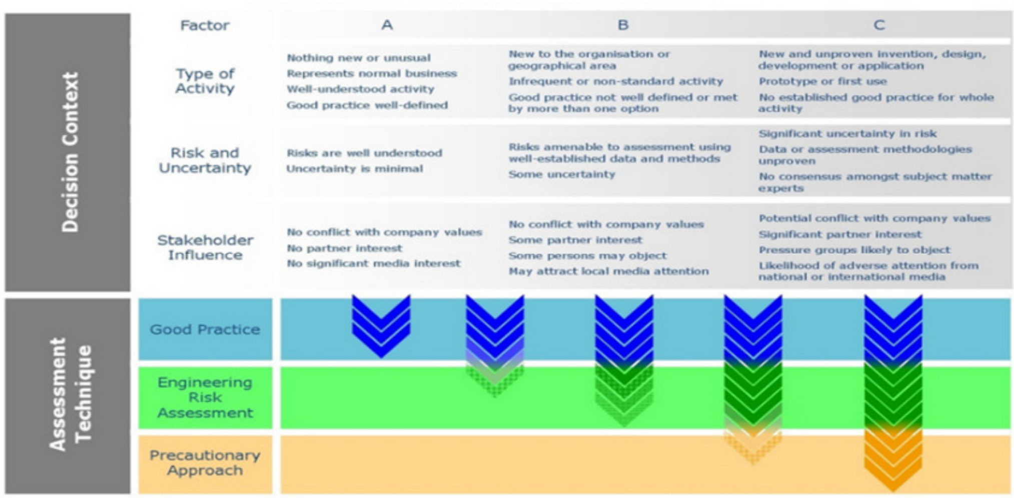

Figure 6.1 *Impact and Risk 'Uncertainty' Decision Making Framework*

6.5.2 *Control Measure Identification*

Control measures were identified for each hazard with the aim of eliminating the hazard, or if this is not reasonably practicable, to minimise the risk to as low as reasonably practicable (ALARP). The process of identifying control measures is an iterative process of:

- Identifying a risk control
- Assessing the risk control

- Deciding whether residual risk levels are tolerable
- If not tolerable, identifying a new risk control
- Assessing the effectiveness of that control

Santos uses a hierarchy of control (*Table 6.2*) where you start at the top of the list and ask "Is there any reasonably practicable way that we can eliminate the hazard?" If the answer is yes then this is the most effective way of managing the hazard. If the answer is no then you move down to the next option in the list. This process of working down the list is repeated until a control measure/s can be found.

Once the control measures were determined performance outcomes, performance standards and measurement criteria were established. Terms used for measuring the environmental performance for each hazard are defined as:

- *Control measure* – a system, an item of equipment, a person or a procedure that is used as a basis for managing environmental impacts and risks.
- *Performance outcome* – a statement of the measurable level of performance required for the management if environmental aspects of an activity to ensure that the environmental impacts and risks will be of an acceptable level.
- *Performance standard* – performance required of a control measure.
- *Measurement criteria* – defines how environmental performance will be measured and determine whether the outcomes and standards have been met.

Table 6.2 Santos Hierarchy Control

Control	Effectiveness	Example
Eliminate	↓	*Removal of the risk.* Refueling of vessels at port eliminates the risks of an offshore refueling.
Substitute		*Change the risk for a lower one.* The use of low-toxicity chemicals that perform the same task as a more toxic additive.
Engineering		*Engineer out the risk.* The use of oil-in-water separator to minimise the volume of oil discharged.
Isolation		*Isolate people or the environment from the risk.* The use of bunding for containment of bulk liquid materials.
Administrative		*Provide instructions or training to people to lower the risk.* The use of Job Hazard Analysis to assess and minimise the environmental risks of an activity.
Protective		*Use of protective equipment.* Containment and recovery of spilt hydrocarbons.

6.6 DETERMINATION OF SEVERITY OF CONSEQUENCE

Once the potential hazards and receptors were identified the potential level of impact (consequence) was assessed and assigned. Consequence is defined using the Santos Environmental Consequence Classification (*Table 6.3*) from the Santos Operational Risk Matrix. The consequence level for each hazard is documented in the risk assessment tables in *Section 7*.

Table 6.3 *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 Operational Area
Medium Term: Less than 12 months	Extensive: Within the EMBA
Long Term: Greater than 12 months	Regional: Outside of the EMBA

6.7 DETERMINATION OF LIKELIHOOD

Likelihood is defined as the likelihood of the consequence occurring, this includes the likelihood of the event occurring and the subsequent likelihood of the consequence occurring. Likelihood is defined using the Santos Likelihood Descriptors (*Table 6.4*) from the Santos Operational Risk Matrix.

Table 6.4 Santos Likelihood Descriptors

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”

6.8 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 (*Figure 6.2*) 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 (*Figure 6.3*) 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 6.6.

	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

Figure 6.2 Santos Risk Matrix

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 residual risk to level 4 or lower - Dedicated multi-disciplinary incident investigation team - Management involvement in the investigation
4	- Assess risk to determine if ALARP - If ALARP, activities related to maintenance of controls/ barriers prioritised & managed - If not ALARP, improve existing controls and/or implement new control/s - Dedicated multi-disciplinary incident investigation team
3	- Assess risk to determine if ALARP - If ALARP, activities related to maintenance of controls/ barriers prioritised & managed - If not ALARP, improve existing controls and/or implement new control/s - Full incident investigation
2	- Assess risk to determine if ALARP - If ALARP, activities related to maintenance of controls/ barriers prioritised & managed - If not ALARP, improve existing controls and/or implement new control/s - Incident investigations using simple tools
1	- Managed as stipulated by the related work processes - No incident investigation required

Figure 6.3 Santos Risk Significance Rating

6.9 DETERMINATION OF IMPACT AND RISK ACCEPTABILITY

The model Santos used for determining acceptance of residual risk is detailed in *Figure 6.4*. 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 offshore 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 (See Section 2)
- Legal and other requirements (See Section 2)
- Santos policies and standards (See Section 8.1)
- Stakeholder expectations (See *Section 4*)

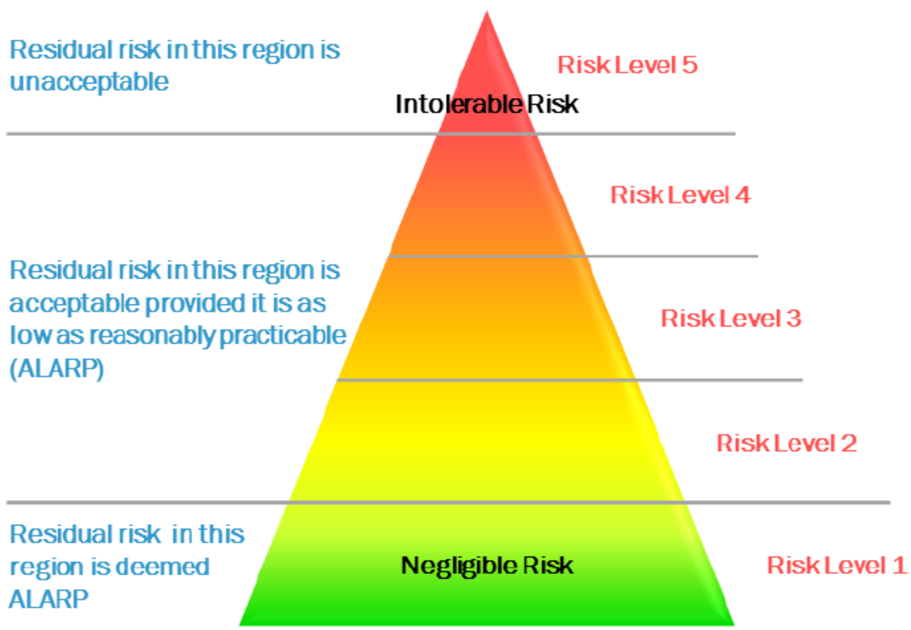

Figure 6.4 Santos Residual Risk Acceptance Model

7 ENVIRONMENTAL RISK ASSESSMENT

7.1 SEISMIC UNDERWATER NOISE

7.1.1 Hazard

When the seismic source is operating sound pulses will be generated from the source array.

7.1.2 Environment that May Be Affected by the Hazard

Maine seismic surveys involve the use of seismic source arrays that produce high intensity, low frequency impulsive sounds at regular intervals. Though the aim of a seismic survey is to direct the seismic sound energy downwards towards the sea floor, energy will also radiate at angles close to horizontal potentially propagating this sound energy over long distances. The rate at which the sound energy attenuates with distance from the source is based on the oceanography, bathymetry and seabed properties of the area (Carroll et al. 2017).

JASCO Applied Sciences (JASCO) conducted an assessment of underwater noise levels for the Beehive 3D MSS. The study used three sound propagation models to predict the acoustic field around the airgun array for frequencies of 10 Hz to 2 kHz. The full report (McPherson and Quijano 2017) is available in Appendix 3 to this EP.

The modelling approach accounted for the acoustic emission characteristics of a 2,380 in^3 seismic source array and considered source directivity and the range-dependent environmental properties in the area. The sound level results are presented as sound pressure levels (SPL), zero-to-peak pressure levels (PK), peak-to-peak pressure levels (PK-PK), and either single-impulse (i.e. per-pulse) or accumulated sound exposure levels (SEL) as appropriate.

The airgun array that will be utilised for the Beehive 3D MSS is an 11.2 × 15 m, ~ 2,380 in^3 seismic array consisting of three strings towed at a 6 m depth. The firing pressure will be 2000 psi. The modelling was based on 12.5 m shot point interval (based on triple source mode), and a 600 m line space interval. The underwater acoustic signature of the array was predicted with JASCO's Airgun Array Source Model (AASM) that accounts for individual airgun volumes and array geometry. Predicted source sound levels are shown in *Table 7.1*.

Table 7.1: Source level specifications for the 2,380 in^3 array, for a 6 m tow depth

Direction	Peak pressure level (dB re 1 µPa @ 1 m)	SEL (dB re 1 µPa^2·s @ 1 m)	
		10–2,000 Hz	2,000–25,000 Hz
Broadside	248.0	223.2	182.7
Endfire	245.9	223.1	187.4
Vertical (with ghost)	254.6	230.5	197.4

Complementary underwater acoustic propagation models were used in conjunction with the modelled array signature to estimate sound levels over a large area around the source. Single-impulse sound fields were predicted at a defined location, and accumulated sound exposure fields were predicted for one likely scenario of survey operations over 24 hours. A conservative sound speed profile that is most supportive of sound propagation conditions for the period of the survey was defined, and applied at each of the modelling locations to determine both single-impulse and accumulated sound exposure fields. The modelling methodology considered source directivity and range-dependent environmental properties in each of the areas assessed.

The modelling study for Beehive assessed:

- one single-impulse site for water column SPL, PK, PK-PK, and per-pulse SEL;
- one single-impulse site for seafloor PK, PK-PK and seafloor per-pulse SEL; and
- one scenario for accumulated SEL over 24 hours (SEL_{24h}).

The analysis considered several effects criteria, with the corresponding results summarised for the representative single-impulse sites and accumulated multiple-impulse SEL scenarios.

Per-pulse Sound Fields

For the Beehive survey a single shot site approximately in the centre of the survey Acquisition Area was assessed (*Figure 7.1*). This site in 42.6 m water depth, and was selected as representative of the survey area, which is relatively flat.

SEL modelling was conducted to assess the sound field at receiver depths spanning the entire water column over the modelled areas, from 1 m to a maximum of 300 m, along radials separated by 2.5°. For fauna which typically utilise the entire water column (cetaceans, turtles, pelagic fish) the predicted distances to specific levels were computed from the maximum-over-depth sound fields, with the distance along each modelled radial being that to the maximum value over all modelled depths at that location.

Table 7.2 details the estimated distances to the SEL and SPL isopleths in the water column.

Table 7.2: ***Distances from the Beehive source to modelled maximum-over-depth per-pulse isopleths***

Isopleth	SPL (dB re 1 µPa)		SEL (dB re 1 µPa^2·s)	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
200	-	-	-	-
190	0.24	0.24	0.05	0.05
180	0.37	0.37	0.14	0.14
170	0.63	0.60	0.30	0.30
160	1.40	1.35	0.88	0.83
150	3.02	2.78	1.51	1.43
140	5.65	5.03	3.18	3.02
130	14.21	12.31	6.25	5.46
120	50.94	42.70	14.94	13.11

Note: A dash indicates the threshold is not reached.

Table 7.3 details the estimated distances to modelled seafloor PK and PK-PK levels from four transects.

Table 7.3: ***Maximum (R_{max}) horizontal distances (in m) from the 2,380 in^3 array to modelled seafloor PK and PK-PK from four transects***

Isopleth	PK (dB re 1 µPa)	PK-PK (dB re 1 µPa)
230	-	-
225	-	18
220	18	43
215	47	63
213	58	
210	66	123
207	78	
205	110	208
200	220	313

Note: A dash indicates the threshold is not reached.

Table 7.4 details the estimated distances to modelled seafloor SEL from four transects.

Table 7.4 ***Maximum (R_{max}) horizontal distances (in m) from the 2,380 in^3 array to modelled seafloor per-pulse SEL from four transects***

SEL (dB re 1 µPa^2 s)	Distance R_{max} (m)
200	-
195	29
190	49
185	74
180	139
175	209
170	306

Note: A dash indicates the threshold is not reached.

Therefore, when modelling of PK levels to assess mortality and potential mortal injury to fish, turtles, fish eggs and larvae, the horizontal distances to the level at the seafloor for this survey will also predominantly represent the maximum-over-depth distance.

For species which live at or close to the seafloor, the modelling approach for assessing the distance to PK levels associated with fish is appropriate.

The modelling approach applied is appropriate to determine the relevant sound levels (PK, SEL or SPL), and therefore the distances to thresholds, for all fauna of concern, be they at the seafloor or within the water column.

<u>Multiple Pulse Sound Fields</u>

During a seismic survey, a new portion of sound energy is introduced into the environment with each pulse from the airgun array. While some impact criteria are based on per-pulse energy released, others, such as the fish and marine mammal and SEL criteria used in this impact assessment (*Sections 7.1.5.1* and *7.1.5.6*) account for the total acoustic energy marine fauna is subjected to over a specified period of time, defined in this report as 24 hours. An accurate assessment of the cumulative acoustic field depends not only on the parameters of each impulse, but also on the number of impulses delivered in a period and the relative positions of the impulses.

When there are many seismic pulses, it becomes computationally prohibitive to perform sound propagation modelling for every single event. The offset between the consecutive seismic impulses is small enough, however, that the environmental parameters that influence sound propagation are virtually the same for many impulse points. The acoustic fields can, therefore, be modelled for a subset of seismic pulses and estimated at several adjacent ones. After sound fields from representative impulse locations are calculated, they are adjusted to account for the source position for nearby impulses.

The modelling study for Beehive considered a single 24 hour period of seismic operation, along three sequential lines in the acquisition pattern to assess a conservative scenario in terms of 24 hour SEL. The three sequential acquisition lines assessed are 37.026, 28.361 and 37.226 km long, the spacing between sequential lines is 13.805 km, and between adjacent lines 600 m apart (*Figure 7.1*).

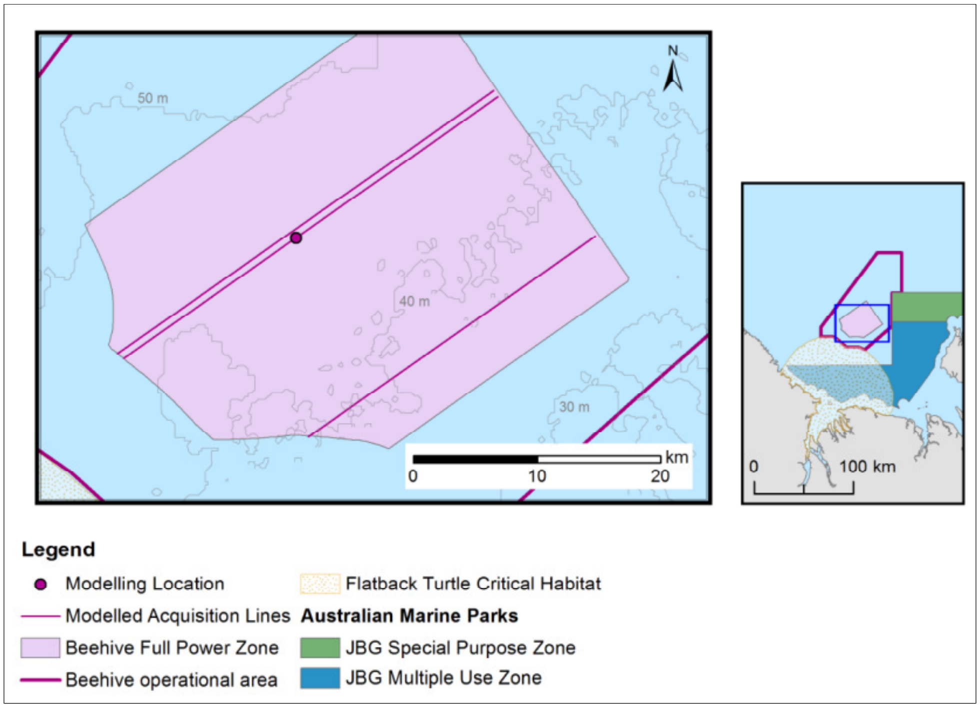

Figure 7.1 Acquisition lines considered for SEL_{24h} calculations

The seismic vessel is assumed to start at the eastern end of the northern line, and traverse the survey lines at ~4.5 knots, with an impulse interval of 12.5 m. The survey has been modelled considering a triple source array, with a source separation of 37.5 m, with each source being activated individually according to a set sequence. The modelling accounts for the location of the active source for each seismic impulse. In total, 8,204 impulses are accounted for in the scenario.

Because modelling the thousands of impulses needed to represent 24 hours of seismic operation is time consuming, JASCO estimated the acoustic fields based on single-impulse model sites from representative source locations which formed the library of representative footprints. As the geoacoustics are the same throughout the region, only the bathymetry needs to be considered when determining the location of the representative source locations. An analysis of the bathymetry along the acquisition lines in the modelled scenario determined that consideration of one representative site, covering the entire survey region, would provide a sufficient representation. Therefore, all survey lines within the 24 hour exposure calculation were classified as this impulse point, based on geographic similarity.

To produce maps of cumulative received sound level distributions and calculate distances to specified sound level thresholds, the maximum-over-depth level and level at the seafloor are calculated at each sampling point within the modelled region. The radial grids of maximum-over-depth and seafloor sound levels for each impulse are then resampled (by linear triangulation) to produce a regular Cartesian grid. The sound field grids from all impulses were summed to produce the cumulative sound field grid with cell sizes of 40 m. The contours and threshold ranges are calculated from these flat Cartesian projections of the modelled acoustic fields.

The single-impulse SEL fields are computed over model grids ~200 km × 200 km in range, which encompass the full area of the cumulative grid (the entire survey area). The unweighted (fish) and frequency-weighted SEL_{24h} results are rendered as contour maps, including contours that focus on the relevant criteria-based thresholds. Only contours at ranges larger than the nearfield of the airgun array are rendered.

7.1.3 *Sensitive Environmental Receptors with the Potential to occur within the EMBA*

Receptors that could potentially be impacted by seismic sound pulses are:

- Plankton including commercially important fish larvae/eggs.
- Invertebrates including commercial species.
- Fish.
- Sharks and rays.
- Turtles.
- Marine mammals – whales and dolphins (cetaceans).

7.1.4 *Known and Potential Environmental Impacts*

Potential biological and ecological impacts from seismic sound pulses are:

- Physical such as mortality or injury including temporary or permanent hearing loss.
- Physiological such as changes in metabolic rate or biochemical stress indicators.
- Behavioural such as disturbance or displacement or impairment/mask the ability to navigate, find food or communicate.
- Local abundance and catch which may occur from physical, physiological and/or behavioural changes.

7.1.5 *Evaluation of Environmental Impacts*

7.1.5.1 *Plankton*

Receptor Sensitivity

Plankton includes fish eggs and larvae which are transported by currents and winds and hence cannot take evasive behaviour to avoid seismic sources. Larval fish species studied appear to have hearing frequency ranges similar to those of adults and similar acoustic startle thresholds (Popper et al. 2014). Swim bladders may develop during the larval stage and may render larvae susceptible to pressure-related injuries such as barotrauma. Effects of sound upon eggs, and larvae containing gas bubbles, is focused on barotrauma rather than hearing (Popper et al. 2014).

Larval stages are often considered more sensitive to stressors than adult stages, but exposure to seismic sound reveals no differences in larval mortality or abundance for fish, crabs or scallops (Carroll et al. 2017).

The effects of an operating 3D seismic array on plankton was investigated by Parry et al. (2002), alongside their work on scallops. Vertical plankton tows (0 – 20 m depth) were taken along transects running parallel and adjacent to seismic survey lines. A last-minute change to the seismic vessel track meant the initial balanced sampling design became five control transects (5 net tows ~500 m apart along each transect) and one impact transect (10 net tows). Plankton tows along the impact transect were made within 30–60 min of the seismic pass. Parry et al. (2002) found no detectable impacts on plankton based on their species composition and live/dead state but did concede that their statistical power to detect any impacts was low, requiring decreases in abundance of > 30–40% for copepods and > 80–90% for most other taxa.

Day et al. (2016a) found no effects on the mortality, abnormality, competency, or energy content of lobster larvae (*Jasus edwardsii*) after exposure of early embryonic stages to SELs of 190 – 197 dB re µPa^2.s. Pearson et al. (1994) exposed larvae of the Dungeness crab (*Cancer magister*) to single discharges from a seven-airgun array. For immediate and long-term survival and time to moult, this study did not reveal any statistically significant differences between the exposed and unexposed larvae, even those exposed within 1 m of the seismic source.

Impacts to larvae have been identified at intense and lengthy periods of exposure to low-frequency sound. Tank experiments by Aguilar de Soto et al. (2013) showed evidence of morphological abnormalities in early stage scallop larvae from simulated airgun signals. The lengthy exposure period of 3 s shot intervals for an exposure duration of 90 h, 1 m distance from sound source is not realistic in an actual survey. Christian et al. (2003) found major developmental differences between control and treatment groups of snow crab eggs exposed to peak sound level of 216 dB re 1 µPa every 10 s for 33 min. Again, the exposure period of a consistent peak sound level is not realistic of an actual survey.

The recently published study by McCauley et al. (2017), conducted in temperate waters of south-east Tasmania, is the first large-scale field experiment on the impact of seismic activity on zooplankton. This study measured zooplankton abundance and the proportion of the population that was dead at three distances from a single 150 in^3 airgun—0, 200 and 800 m. The experiment estimated the proportion of the zooplankton that was dead, both before and after exposure to airgun noise, using net samples to measure zooplankton abundance, and bioacoustics to identify the distribution of zooplankton. In this study, copepods dominated the mesozooplankton (0.2-20 mm), and impacts were not assessed on microzooplankton (0.02-0.2 mm) or macrozooplankton (> 20 mm). There was movement of water through the experimental area, which made interpreting their results more difficult (Richardson et al. 2017).

McCauley et al. (2017) provide three findings from the experiment to show that zooplankton were affected by the seismic source:

(i) the proportion of the mesozooplankton community that was dead increased two- to three-fold;

(ii) the abundance of zooplankton estimated by net samples declined by 64%; and

(iii) the opening of a "hole" in the zooplankton backscatter observed via acoustics.

They found that exposure to airgun noise significantly decreased zooplankton abundance, and increased the mortality rate from a natural level of 19% per day to 45% per day (on the day of exposure, and that these impacts were observed out to the maximum range assessed (1.2 km) (Richardson et al. 2017).

Scientists from CSIRO's Oceans and Atmosphere Business Units were contracted by APPEA to undertake a desktop study that: a) critically reviewed the methodologies and findings of the McCauley et al. (2017) experiment; and b) simulated the large scale impact of a seismic survey on zooplankton in the Northwest Shelf region, based on the mortality rate associated with airgun noise exposure reported by McCauley et al. (2017).

The CSIRO review of the McCauley et al. (2017) study found that there were three primary questions raised by the results of the experiment, all of which warrant further investigation (Richardson et al. 2017):

1. *Why was there no attenuation of the impact with distance?*

   There is no consistent decline in the proportion of zooplankton that are dead with increasing distance away from the airgun. The energy of the sound waves at a distance of 1.2 km is substantially lower than at the source.

2. *Why was there an immediate decline in abundance?*

   It is unclear why there would be a near immediate drop in zooplankton abundance as measured by net samples and acoustic data. If zooplankton were killed, they would not immediately sink from the surface layers, or be rapidly eaten. A drop in abundance would be more likely once the dead zooplankton either sunk to the bottom or were removed by predation. Richardson et al (2017) conclude it is difficult to explain this immediate decline in zooplankton abundance.

3. *Was there sufficient replication to be confident in the study findings?*

   The conclusions were based on a relatively small number of zooplankton samples. A total of 24 samples were collected – 2 tows each sampling time x 3 distances from the gun (0 m, 200 m, 800 m) x 2 levels (Control, Exposed) x 2 replicate experiments (Day 1, Day 2). This means that there were only 12 samples collected under conditions exposed to the airgun, six on each day of the two experiments. The main potential confounding explanation in the study would be that a different water mass entered the area on each day of the experiment and had lower abundance and higher quantities of dead zooplankton. Richardson et al. (2017) conclude that: "although this is relatively unlikely it cannot be discounted because of the relatively few samples collected and only two replicate experiments conducted."

Independently of the APPEA/CSIRO study, the International Association of Geophysical Contractors (IAGC) conducted its own review of the McCauley et al. (2017) paper. This review came to the following conclusion:

> "*While we found the study interesting, we are also troubled by the small sample sizes, the large day-to-day variability in both the baseline and experimental data, and the large number of speculative conclusions that appear inconsistent with the data collected over a two-day period. Both statistically and methodologically, this project falls short of what would be needed to provide a convincing case for adverse effects from geophysical survey operations*." (IAGC 2017)

The second component of the CSIRO study was to estimate the spatial and temporal impact of seismic activity on zooplankton on the Northwest Shelf from a large-scale seismic survey, considering mortality estimates of McCauley et al. (2017), and accounting for typical growth rates, natural mortality rates, and the ocean circulation in the region The approach modelled a hypothetical 3D survey (2,900 km^2 in size, over a 35-day period, in water depths of 300-800 m) on the edge of the Northwest Shelf during summer. To simulate the movement of zooplankton by currents, the researchers used a hydrodynamic model that seeded 0.5 million particles into CSIRO's Ocean Forecast Australia Model. Zooplankton particles could be hit multiple times by airgun pulses if they were carried by currents into the future survey path. The greatest limitation in this approach was accurate knowledge of the natural growth and mortality rates of zooplankton, and to address this the CSIRO researchers tested the sensitivity of the model to different recovery (growth-mortality) rates, and also the sensitivity of the results to ocean circulation by undertaking simulations with and without water motion (Richardson et al. 2017).

The results of the simulations that included ocean circulation showed that the impact of the seismic survey on zooplankton biomass was greatest in the Survey Region (defined as the survey acquisition area with a 2.5 km impact zone around it) (22% of the zooplankton biomass was removed) and declines as one moves beyond it to the Survey Region + 15 km (14% of biomass removed), and the Survey Region + 150 km (2% of biomass removed). The time to recovery (to 95% of the original level) for the Survey Region and Survey Region + 15 km recovery was 39 days (38-42 days) after the start of the survey and three days (2-6 days) after the end of the survey (Richardson et al. 2017).

The major findings of the CSIRO study were that there was substantial impact of seismic activity on zooplankton populations on a local scale within or close to the survey area, however, on a regional scale the impacts were minimal and were not discernible over the entire Northwest Shelf Bioregion. Additionally, the study found that the time for the zooplankton biomass to recover to pre-seismic levels inside the survey area, and within 15 km of the area, was only three days following the completion of the survey. This relatively quick recovery was due to the fast growth rates of zooplankton, and the dispersal and mixing of zooplankton from both inside and outside of the impacted region (Richardson et al. 2017).

Whilst the CSIRO modelling was carried out for the Northwest Shelf IMCRA Meso-scale Bioregion the findings of this study are directly applicable in determining the potential impacts of the Beehive survey on zooplankton communities. The Bonaparte Gulf Meso-scale Bioregion, within which the survey area is located, and the Northwest Shelf Meso-scale Bioregion are both located within the North West Marine Bioregion. The North West Marine Bioregion is distinguished from the other marine regions around Australia by its unique combination of features. These include a wide continental shelf, very high tidal regimes, very high cyclone incidence, unique current systems and its warm oligotrophic surface waters (Brewer et al. 2007). Whilst the Bonaparte Gulf Meso-scale Bioregion is located further to the northeast than the Northwest Shelf Bioregion, it also covers tropical waters of the continental shelf and has broad-scale ocean circulation dominated by the Indonesian Throughflow current system (Brewer et al. 2017).

Popper et al. (2014) identified a fish eggs and larvae mortality and potential mortality injury peak pressure level threshold of 207 dB re 1 µPa (PK) (*Table 7.5*). Based on the modelling this threshold would be within 78 m (R_{max} distance) of the sound source.

Table 7.5 Fish eggs and larvae mortality and potential mortal injury peak pressure threshold

Receptor	Mortality and Potential Mortal Injury Peak pressure level threshold (dB re 1 µPa)	Distance R_{max} (m)
Fish eggs and larvae	207	78

Extent and Duration of Exposure and Identified Potential Impact

Based on information from the Northern Prawn Fishery commercial prawn species such as banana, tiger and endeavour prawns may spawn within the survey area. These species spawn throughout the year with their peak spawning season outside the timing of the survey, with the exception of brown tiger prawns whose peak spawning period is between July and October. However, the survey area has not been specifically identified as a significant area of spawning, and no other spawning areas were identified within or adjacent to the EMBA.

Based on the noise modelling, the area where the Popper et al. (2014) sound source levels exceed the mortality or mortal injury threshold for fish eggs and larvae is restricted to a distance of < 78 m from the seismic source at full power (*Table 7.5*). The area where the seismic source will be at full power is within the Acquisition Area (946 km^2) and one kilometre at each end of the survey area, as the source ramps up on entering and ramps down on leaving the survey area. To be conservative, an additional 2 km, either end of the Acquisition Area, is applied giving a total area of 975 km^2. Thus, the area where the sound source levels are above the Popper et al. (2014) mortality or mortal injury threshold for fish eggs and larvae would equate to 985 km^2 (975 km^2 plus buffer zone of 78 m).

However, to be conservative, for this assessment the impact regions as applied in the CSIRO modelling study (Richardson et al. 2017) have been used – i.e. survey acquisition area + 2.5 km (1,301 km^2), and survey acquisition area + 15 km (3,517 km^2).

However, this has to be viewed in the context of:

- The broader area in which the survey is being undertaken. For plankton the Bonaparte Gulf Meso-scale Bioregion would be representative of the broader area in which the survey is being undertaken as it is representative of water depths, habitats and hydrodynamics within the survey area.

- Based on the area for the Bonaparte Gulf Meso-scale Bioregion (57,589 km^2; DoEE 2018), the area of potential impact of 1,301 km^2 represents 2.6% of this bioregion and for 3,517 km^2 represents 6.1%. This aligns with the CSIRO model that showed that impact of the seismic survey on zooplankton biomass was greatest in the Survey Region with no discernible effect on the broader bioregion.

- Within these areas the impact on zooplankton biomass was 22% within the Survey area + 2.5 km and declined to 14% within the Survey Region + 15 km. Within the broader Survey Region + 150 km 2% of biomass was predicted to be removed.

- The CSIRO modelling was undertaken for a larger seismic survey area (2,900 km^2) and for a longer period (35 days) compared to the Beehive survey, which is 975 km^2 and up to 30 days. Thus, the percentage zooplankton biomass removed (22%) may be lower for the Beehive survey. There is no indication that the area of potential impact includes any locations where significant fish or invertebrate aggregations / spawning occurs, thus it is unlikely that large numbers of fish eggs and larvae will be present in the survey area during acquisition.

- For comparison to the level reported in McCauley et al. (2017) for potential effects on plankton, the distance to 178 dB re 1 µPa PK-PK in the water column was assessed via the noise modelling study for Beehive. The range to this sound level was predicted to be a maximum of 1.95 km.

- Any plankton, including fish eggs and larvae, present in the water column within the area of potential impact will not be evenly distributed, and are likely to exhibit substantial spatial patchiness and will be moving with the currents in the area.

- The area of potential impact is not identified as an important area for fauna that rely on plankton as a food source such as whale sharks, rays or cetaceans. Though the area of impact is within a biologically important area for foraging olive ridley and green turtles (*Figure 5.15*) neither of these two species rely on plankton as a food source (DoEE 2017s).

- Zooplankton populations recover quickly due to their fast growth rates, and the dispersal and mixing of zooplankton from both inside and outside of the impacted area. The CSIRO model (Richardson et al. 2017) identified that the time for the zooplankton biomass to recover to pre-seismic levels inside the survey area, and within 15 km of the area, was only three days following the completion of the survey.

- Any mortality or mortal injury effects to fish eggs and larvae resulting from seismic noise emissions are likely to be inconsequential compared to natural mortality rates of fish eggs and larvae, which are very high (exceeding 50% per day in some species and commonly exceeding 10% per day). For example, in a review of mortality estimates (Houde and Zastrow 1993), the mean mortality rate for marine fish larvae was M = 0.24, a rate equivalent to a loss of 21.3% per day.

Thus, based on this analysis, though mortality or mortal injury may occur to plankton, including fish eggs and larvae, potential impacts are localised (within the Operational Area) and short term (survey timing of 30 days and 3 days for recovery). These potential impacts are not significant when compared to rates of natural mortality in planktonic populations (on average 10 - 50% per day) and impacts are not expected at a regional scale base on the area of predicted impact being 6.1% of the Bonaparte Gulf Meso-scale Bioregion where 2% of the plankton biomass may be impacted.

Summary

Consequence Level: If the activity results in mortality or mortal injury effects to fish eggs and larvae, there is potential for localised and short term impacts - (I).

Likelihood Level: For this activity, localised and short term impacts to fish eggs and larvae from seismic noise is considered Possible (c).

7.1.5.2 Invertebrates

Marine invertebrates lack a gas-filled bladder and are thus unable to detect the pressure component of sound waves. However, all cephalopods as well as some bivalves, echinoderms and crustaceans have a sac-like structure called a statocyst which includes a mineralised mass (statolith) and associated sensory hairs (Carroll et al. 2017). Cephalopods have epidermal hair cells which help them to detect particle motion in their immediate vicinity (Kaifu et al. 2008). Decapods have similar sensory setae on their body (Popper et al. 2001) and antennae which may be used to detect low-frequency vibrations (Montgomery et al. 2006).

The statocyst organs, found in a wide range of invertebrates, are utilised by animals to maintain their equilibrium and orientation and to direct their movements through the water. Their functions include the detection of gravitational forces and linear accelerations. Although there is little information available on the functioning of these sensory organs, it has been suggested that marine invertebrates are sensitive to low-frequency sounds and that this sensitivity is not directly linked to sound pressure but to particle motion detection (André et al., 2016; Roberts et al., 2016; Edmonds et al., 2016). The statocysts may play a key role in controlling the behaviour responses of invertebrates to a wide range of stimuli.

Prawns

Receptor Sensitivity

There has recently been a number of comprehensive reviews of seismic noise impacts to invertebrates; Carroll et al. (2017), Edmunds et al. (2016) and DoF (2016). Studies specific to prawn species are limited, however, a number of studies have been undertaken on decapods with a range of effects to no effects identified. As such studies of species in the same scientific order (Decapoda) have been used to provide an indication of how sensitive prawns are when exposed to sound waves

Edmonds et al. (2016) undertook a review and critical evaluation of crustacean sensitivity to loud impulsive, low frequency underwater noise typically produced by seismic surveys. They identified that sensitivity to underwater noise is shown by the Norway lobster and closely related crustacean species, including juvenile stages. They concluded that current evidence supports physiological sensitivity to local, particle motion effects of sound production. The DoF review (2016) also supported that there was no evidence in the current literature of direct mortality of crustaceans from seismic exposure. A range of physiological responses have been identified in some studies, however, the received sound levels are typically at levels that would be received within a few hundred metres from the sound source or have been from repeated exposure at the same sound levels which is not realistic in an actual survey.

Day et al. (2016b) found airgun exposure caused damaged statocysts in rock lobsters (*Jasus edwardsii*) up to a year later. However, no such effects were detected in snow crabs after exposure to 200 shots at 10 s intervals and 17–31 Hz) (Christian et al. 2003). For these studies, measured received noise levels were 209-212 dB re 1 µPa (PK-PK) and 197-237 dB re 1 µPa (PK-PK), respectively.

Day et al. (2016b) also found that the rock lobster showed delayed time to right itself after exposure to airguns and that 2 out of 3 experiments found no difference in tail extension reflex, while one showed exposed lobsters had a 23% decrease 14 days after exposure. In contrast, no differences in righting time were detected in the American lobster (*Homarus americanus*) 9, 65, or 142 days after exposure to airgun noise (Payne et al., 2007). For these studies, measured received noise levels were 209-212 dB re 1 µPa (PK-PK) and 202 dB re 1 µPa (PK-PK), respectively.

Day et al. (2016b) also identified no changes to haemolymph biochemistry in rock lobsters up to 120 days post exposure, though a reduction in haemocyte cell numbers was identified. Seismic exposure also had a consistent and prolonged negative effect on lobster total haemocyte count (THC) for up to 120 days post-exposure, with decreases in THC ranging from 23% to 60% in the four experiments potentially compromising their immune system. THC is commonly used as an assessment of stress and is suggested to be related to immune competency and health status of crustaceans. Payne et al (2007) found no effects of seismic surveys on American lobster haemolymph biochemistry but possible reduction in calcium. In contrast, Christian et al (2003, 2004) found no chronic or long-term effects on stress bioindicators in haemolymph. Andriguetto-Filho et al (2005) also carried out histopathological studies on gonadal and hepatopancreatic tissue and reported that there was no damage that could be associated with exposure to a four airgun array with a source peak pressure of 196 dB re 1 µPa at 1 m within shallow waters (2-15 m).

Extent and Duration of Exposure and Identified Potential Impact

It is likely that the mechanism of impacts for invertebrates, such as prawns, are not from sound pressure, but rather from particle motion. However, what is unknown is what particle motion levels lead to a behavioural response, as described in Day et al. (2016b), or mortality. Water depth and seismic source array size are related to the particle motion levels at the seafloor, with larger arrays and shallower water being related to higher levels, which can then be related to effects on prawns. Despite the results presented in Day et al. (2016b), the science around which metrics relate to an effect, and the relationship therefore to impact, is still an area of ongoing research. While the pressure related metrics identified in Day et al. (2016b) have been used to estimate the area of potential impact from seismic surveys in some impact assessments, the literature available does not clearly define either the metric which should be used, or any associated level to use while conducting an assessment.

In lieu of a suitable proxy, and because prawns have the potential to be in either the water column or on the substrate, an understanding of level for pressure related metrics at which impacts were identified gives some mechanism for being able to understand the area of potential impact from the Beehive survey. As Payne et al. (2007) identified no effects on righting time in lobster at 202 dB re 1 µPa (PK-PK), and Day et al. (2016b) found effects at 209 dB re 1 µPa (PK-PK), the level of 202 dB re 1 µPa (PK-PK) has been applied in this assessment as a precautionary threshold to determine potential impacts. The noise modelling conducted for Beehive indicates that received levels will be below 202 dB re 1 µPa (PK-PK) at approximately 265 m from the source. The higher sound pressure level, 209 dB re 1 µPa (PK-PK), where physiological impacts have been identified would be within ~ 125 m of the Beehive noise source.

As the Acquisition and Operational areas are overlapped by the main NPF fishing area in the southern JBG (*Figure 5.22*), there could potentially be prawns within these areas.

Based on the noise modelling, the area where the conservative threshold, where physiological impacts have not been identified, is within a distance of < 265 m from the seismic source at full power. The area where the seismic source will be at full power is within the survey area (946 km^2) and one kilometre at each end of the survey area, as the source ramps up on entering and ramps down on leaving the survey area. To be conservative an additional 2 km, either end of the survey area, is applied to the survey area giving a total area of 975 km^2.

Thus, the area in which prawns could experience noise levels above threshold levels would equate to 1,008 km^2 (975 km^2 plus buffer zone of 265 m). However, this has to be viewed in the context of:

- The area of potential impacts is small in context of the NPF fishing area in the JBG where prawns could be present.

- Based on a spatial extent of 13,594 km^2 for the actively fished NPF area in the JBG[2], the area of potential impact (1,008 km^2) represents 7.4% of the NPF area in the JBG.
- Any prawns present within the area of potential impact will not be evenly distributed, and are likely to exhibit substantial spatial patchiness.
- Acquisition of the survey will not commence until after the 15th June, hence the survey period does not overlap the main migration of juvenile prawns in the Joseph Bonaparte Gulf, with the migration of the main cohort occurring between November and March, with a possible second cohort migrating from April to June (see *Section 5.7.2*).
- The area of potential impact assumes that the area will receive the same sound levels at the same time, which is not the case, sound levels will change as the seismic vessel moves through the area during the survey for up to 30 days.
- Physiological impacts identified are unlikely to result in significant impacts to prawns or prawn populations in light of the small area of impact (7.4% of the NPF area in the JBG) and prawns typically become sexually mature at six months and spawn more than once a year which would negate any impacts on such a small scale.

Thus, based on this analysis, physiological impacts are unlikely to result in significant impacts to prawns or prawn populations as impacts would be localised (7.4% of the NPF area in the JBG) and medium term (6 months) based on the prawns sexual maturity.

<u>Summary</u>

Consequence Level: If the activity results in physiological impacts to prawns, there is potential for localised and medium term impacts - (III).

Likelihood Level: For this activity, localised and medium term impacts to prawns is considered Unlikely (b).

Molluscs

<u>Receptor Sensitivity</u>

Other invertebrate species that may potentially occur in the area are molluscs (cephalopods and bivalves) including the silver lipped pearl oyster (*Pinctada maxima*). As detailed in *Section 5.6.1*, there are no current or future fisheries of *P. maxima* in or near the EMBA and they have a wide distribution throughout northern Australia and into Asia.

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[2] Based on 4-years relative fishing intensity data (2013-2016) published in the annual Fishery Status reports 2013-2017 (see *Figure 5.21*).

Cephalopods have been found to respond to sound between 30 and 600 Hz, being most sensitive between 100 and 200 Hz, suggesting that they detect sound similarly to most fish, with the statocyst acting as an accelerometer through which they detect the particle motion component of a sound field (Kaifu et al. 2008, Mooney et al. 2010).

There have been no observed cephalopod mortalities directly associated with seismic survey exposure in the field (DoF 2016). Though there is anecdotal data from the strandings of giant squid (*Architeuthidae* spp.) that showed tissue, statolith and organ damage after seismic surveys (Guerra et al. 2004), there was no direct evidence to link the suggested cause and effect (CMST 2016). Laboratory studies that exposed two species of squid to seismic noise showed that *Alloteuthis sublata* was tolerant to a sound level up to 260 dB, *Loglio vulgaris* was fatally injured at levels of 246 – 252 dB within 3 – 11 minutes of exposure (Norris and Mohl 1983, in DoF 2016). André et al. (2011) demonstrated that they can be injured by sweeping waves 50-400 Hz at levels of 157 dB SPL produced continuously for up to two hours. However, the exposure experiments in both of these studies are complicated to relate to commercial seismic surveys due to either the exposure levels or the duration of the exposure event.

Studies have shown that seismic sounds can elicit a behavioural response in cephalopods. McCauley et al. (2003) and Fewtrell and McCauley (2012) described behavioural responses of squid (*Sepioteuthis australis*) such as squid inking at a sound exposure level of 163 dB re $1\mu Pa^2.s$ and an increase in movement away from the seismic source at a sound exposure level of 140 – 150 dB re $1\mu Pa^2.s$. They also noted that the squid showed fewer alarm response with subsequent exposure to the seismic source.

The potential effects on catch rates or abundances have been tested on cephalopods with no significant differences detected between sites exposed to seismic operations and those not exposed (Carroll et al. 2017). Thus it is likely that cephalopods in the area of the survey may show a behavioural response to the seismic noise and move away from the source. There is not enough information to gauge the scale of this movement, and the displacement distance, however, it is likely that they would move back to the area once the seismic source has passed.

The majority of studies undertaken on seismic impacts to molluscs have been on commercial scallops. As for other invertebrate studies results show mixed results of impacts and no impacts. Typically impacts are seen in laboratory studies or in field studies where there has been repeated exposure.

Harrington et al. (2010) conducted a scallop (*Pecten fumatus*) dredge before and two months after exposure to a 2000 psi air gun array. No evidence of short or long term impacts on the survival or health of adult specimens was detected. This study was undertaken following a die-off of scallops that fisherman claimed was the result of a seismic survey but neither the fisherman nor the study could definitively attribute the scallop die-off to the survey (CMST 2016).

Przeslawski et al. (2016) also recorded no impact of seismic exposure on adult scallop mortality rates or a range of physiological attributes two months after exposure to maximum sound exposure levels of 146 dB re 1µPa^2.s. Day et al. (2016) found that exposure to a seismic source (191 – 213 dB re 1µPa) did not cause any incidence of immediately mass mortality, however, repeated exposure (54 – 393 shots) significantly increased mortality, and the risk of mortality significantly increased with time as the majority of mortality was recorded at the day 120 sample point. Day et al. (2016) also found that exposed scallops has faster recessing times, elicited a novel velar flinch and had substantial disruptions in the biochemistry of the hemolymph. In one experiment there was some indication that righting time might be slowed.

Although studies have not necessarily looked at the effects of seismic sources on the pearl oyster directly, it is apparent that several species of bivalve, including two oyster species, are remarkably resilient to the shock waves created by the detonation of high explosives underwater. The one study that examined the effects of underwater explosions on the pearl oyster (LeProvost et al. 1986) found that no mortality occurred in the exposed animals over a 13-week period and at a minimum exposure range of 1 m from the blast centre.

As previously outlined, seismic sources cause less impacts on benthic invertebrates than explosives, hence it is likely that bivalves, such as *P. maxima*, would have to be within a very close range of a seismic source to experience pathological damage or mortality: available evidence would suggest ~ 1–2 m. It is more difficult to determine the distances at which sub-lethal effects (such as morphological, biochemical and physiological changes being indicators of some level of stress in an animal) could occur. Again, there are limited studies done specifically on the pearl oyster, and so conclusions must be drawn from studies done on similar bivalve species.

La Bella et al. (1996) examined biochemical indicators of stress in bivalves exposed to seismic noise and found that hydrocortisone, glucose and lactate levels between test and control animals were significantly different ($P > 0.05$) in the venerid clam *Paphia aurea*, showing evidence of stress caused by acoustic noise. This was at a minimum exposure range of 7.5 m.

<u>Extent and Duration of Exposure and Identified Potential Impact</u>

As detailed in *Section 5.6.1*, there are no current or future fisheries of *P. maxima* in or near the EMBA and they have a wide distribution throughout northern Australia and into Asia. There is no indication that the survey area includes any locations where molluscs would be in greater numbers than the surrounding areas.

Based on the research to date, mortality and mortal injury effects in molluscs that have been reported to occur in experiments relating to seismic surveys are only likely to occur at very close ranges to the source (< 10 m). Physiological impacts identified may affect individuals but are unlikely to have long term or population effects based on the small area of impact and that molluscs are likely to be widely distributed throughout the broader Joseph Bonaparte Gulf.

Summary

Consequence Level: If the activity results in physiological impacts to molluscs, there is potential for localised and medium term impacts - (III).

Likelihood Level: For this activity, localised and medium term impacts to molluscs is considered Unlikely (b).

Commercial Catch Rate

Receptor Sensitivity

Potential effects of seismic signals on catch rates and abundance have been tested on decapods with no significant differences detected in any of these studies between sites exposed to seismic operations and those not exposed (Carroll et al. 2017).

Parry and Gason (2006) detected no change in catch per unit effort in a Victorian Southern rock lobster (*Jasus edwardsii*) fishery before, during and after intensive seismic exploration projects. Steffe and Murphy (1992) observed a declining trend in catch rate in a king prawn (*Penaeus plebejus*) fishery in the period after a seismic survey, however, the authors could not attribute this trend directly to the survey. Andriguetto-Filho et al. (2005) examined bottom trawl yields of a non-selective Brazilian shrimp fishery before and after exposure to seismic sources (196 dB) and did not identify any statistically significant changes to the catch yield after exposure to seismic survey activity. It was stated that the limited dispersal capacities of shrimp (compared to migratory fish species) suggested any attempted movement out of the survey area was not detectable (DoF 2016). Christian et al. (2003) identified that post-seismic snow crab catches were higher than pre-seismic catches but this was likely due to physical, biological or behavioural factors unrelated to the seismic source. They concluded that there was no significant relationship between catch and distance from the seismic source (received levels 197-237 dB re 1 µPa PK-PK).

It should be noted that a number of researchers (Edmonds et al. 2016; Christian et al. 2003) have commented that current stock assessment methodologies do not have the resolution to show statistically significant changes in distribution or abundance from the seismic survey operations above that of natural variation.

In the past, commercial scallop fishermen expressed concerns about the potential impacts of seismic surveys on their catch levels. In a study off the Isle of Man, Brand and Wilson (1996) assessed the effect of seismic surveys in the field by comparing long-term catch-per-unit-effort (CPUE) of commercial scallops with CPUE following a seismic survey. They found no evidence that seismic surveys affected CPUE of scallops and instead attributed a decline (coincident with a 3D seismic survey) to two years of poor recruitment prior to the seismic survey.

Similarly in the Bass Strait, scallop fishermen expressed concern that seismic acquisition might kill scallops (*Pecten fumatus*), weaken their adductor muscles (indicator of sub-lethal effects) or increase the mortality of larval scallops. In a study conducted by the Victorian Marine and Freshwater Research Institute (MAFRI), the effects of seismic airgun noise were measured by comparing the mortality and adductor muscle strength of scallops deployed in an area exposed to passes of a survey vessel towing an operating 24-airgun array, with those in a control area 20 km away from the test area (Parry et al. 2002). This study found that mortality rate and adductor muscle strength of scallops suspended in the water column and exposed to the operating airgun array (at a minimum distance of 11.7 m) was not significantly different from the controls.

A recent critical review of the potential impacts of marine seismic surveys on fish and invertebrates (Carroll et al. 2017) concluded that"

> *"For marine invertebrates, the potential effects of seismic signals on catch rates or abundances have been tested on cephalopods, bivalves, gastropods, decapods, stomatopods, and ophiuroids with no significant differences detected in any of these studies between sites exposed to seismic operations and those not exposed".*

Extent and Duration of Exposure and Identified Potential Impact

Based on the research to date, that has not identified any changes to invertebrate catch rates from seismic surveys.

Based on NPF fishing intensity data from 2013 to 2016 (sourced from the ABARES Fishery Status Reports), the main area of fishing activity in the NPF in the southern JBG overlaps the Acquisition and Operational areas (*Figure 5.22*). However, based on catch and effort data presented in the NPF Data Summary 2016 (Laird 2017) the Bonaparte statistical area, within which the Acquisition and Operational areas are located, had the second lowest catch of banana prawns in 2016 (35 mt out of a total of 2,882 mt – 1.21%). Similarly, the Bonaparte area had the second lowest catch of tiger prawns in 2016 (0.1 mt out of a total of 2,136 mt – 0.005%). In 2015, the Bonaparte area had the lowest catch of banana prawns (26 mt out of a total of 3,916 mt – 0.66%), and there was no catch of tiger prawns recorded for this statistical area (Laird 2016).

In 2017, the Bonaparte statistical area recorded a catch of 383 mt of banana prawns and 9 mt of tiger prawns (Laird 2018), which represents 7.6% and 0.8% of total catches for banana and tiger prawns across the entire NPF, respectively.

Therefore, it is highly unlikely that catch rates and abundance of prawns will be significantly impacted in the area of the southern JBG where NPF fishing activity takes place. The NPF area covers 880,000 km^2 (NPFI 2017) and the area where the seismic source will be a full power is 975 km^2, which equates to an overlap of 0.1%. Any potential impacts would be localised (0.1% of the NPF area) and short term (for the period of the survey up to 30 days).

As described in *Section 5.7.2*, a seasonal closure for the NPF in the Joseph Bonaparte Gulf exists in the period 31 March – 15 June (AFMA 2017). Based on this seasonal closure area, banana prawns are not permitted to be caught at any time within the seasonal closure area, as the banana prawn season is between 1 April and 15 June. The seasonal closure is an exclusion zone in place for all licence holders within the NPF. The Beehive 3D MSS is mostly located within this exclusion zone (~ 11% of the Acquisition Area is outside of this exclusion zone).

<u>Summary</u>

Consequence Level: If the activity results in prawn catch rate impacts, there is potential for localised and short term impacts - (I).

Likelihood Level: For this activity, localised and short impacts to prawn catch is considered Remote (a).

7.1.5.3 *Fish*

<u>Receptor Sensitivity</u>

Fish have a range of sensory mechanisms that can detect sound and vibration, including free-standing neuromasts, lateral line systems, and otoliths. Neuromasts are sense organs that respond to water movement and are typically found in fish below the skin of their heads and in fluid filled canals (lateral lines) running along their sides. Neuromasts and lateral line systems detect particle motion.

Sound detection in fish is via ears consisting of hardened, calcareous otoliths overlying epithelia with sensory cilia. Some fish species also have swim bladders that are physically coupled to the ears, allowing them greater hearing sensitivity and frequency range. There are substantial differences in auditory capabilities from one fish species to another, hence the use of anatomy to distinguish fish groups, as done by Popper et al. (2014) (Table 7 4). Within these categories, two groups have an increased ability to hear. The first of those are fish with swim bladders close, but not intimately connected to the ear, can hear up to about 500 Hz, and are sensitive to both particle motion and sound pressure. Fish with swim bladders mechanically liked to the ear are primarily sensitive to pressure, although they can still detect particle motion. These fishes have the widest hearing range, extending to several kilohertz, are generally more sensitive to sound pressure than any of the other groups of fish (Hawkins and Popper 2016). The predominant frequency range of seismic survey sound emissions, which for the Beehive seismic source is below 650 Hz, is within the detectable hearing range of most fishes.

A review of research of seismic impacts on fish by the WA DoF (2016), detailed that observations from the literature indicate underwater noise produced by seismic air guns is generally not lethal to adult teleosts unless they are within a few metres of an air gun source, however sub lethal physical damage to structures such as the inner ear, lateral line or internal organs (e.g. swim bladder) may occur in fish up to 100 metres from a high energy sound source.

The Working Group on the Effects of Sound on Fish and Turtles undertook a review of experimental findings of sound on fishes. In their American National Standards Institute (ANSI) accredited report (Popper et al. 2014) they presented sound exposure criteria for different levels of effects for different groups of species, *Table 7.6*, for three types of immediate effects:

- Mortality, including injury leading to death.
- Recoverable injury, including injuries unlikely to result in mortality, such as hair cell damage and minor haematoma.
- Temporary threshold shift.

Masking and behavioural effects are assessed qualitatively, by assessing relative risk rather than by specific sound level thresholds. Because the presence or absence of a swim bladder has a role in hearing, fish's susceptibility to injury from noise exposure varies depending on the species and the presence and possible role of a swim bladder in hearing. Thus, different thresholds are proposed for fish without a swim bladder, fish with a swim bladder not used for hearing, and fish that use their swim bladders for hearing.

A recent study by Popper et al. (2016) found that the two fish species (pallid sturgeon and paddlefish), with body masses in the range 200–400 g, exposed to a single shot of a maximum received level of either 231 dB re 1 µPa (PK) or 205 dB re 1 $\mu Pa^2 \cdot s$ (SEL), remained alive for 7 days after exposure and that the probability of mortal injury did not differ between exposed and control fish. They also found no difference in injuries between fish exposed closest to the source compared with those exposed furthest.

Based on these studies and the sound exposure thresholds for fish proposed by Popper et al. (2014) (*Table 7.6*) the fish mortality, potential mortality injury and recoverable injury peak pressure level threshold of > 207 dB re 1 µPa (PK) is used for this assessment. Based on the modelling this threshold would be within 240 m (R_{max} distance) of the sound source (*Table 7.7*). It is possible that fish would move away from the sound source (Streever et al. 2016) and hence not be exposed to these levels.

Table 7.6 Sound exposure thresholds for fish

Receptor	Mortality and Potential Mortal Injury	Impairment			Behaviour
		Recoverable Injury	TTS	Maskin g	
Fish: No swim bladder (particle motion detection)	> 219 dB 24 h SEL or > 213 dB peak	> 216 dB 24 h SEL or > 213 dB peak	>> 186 dB 2 4 h SEL	N) Low (I) Low (F) Low	N) High (I) Moderate (F) Low
Fish: Swim bladder not involved in hearing (particle motion detection	210 dB 24 h SEL or > 207 dB peak	203 dB 24 h SEL or > 207 dB peak	>> 186 dB 2 4 h SEL	N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low
Fish: Swim bladder involved in hearing (primarily pressure detection)	207 dB 24 h SEL or > 207 dB peak	203 dB 24 h SEL or > 207 dB peak	186 dB 24 h SEL	(N) Low (I) Low (F) Moderate	(N) High (I) High (F) Moderate

Note: Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near (N), intermediate (I), and far (F).

Table 7.7 Fish mortality, potential mortal injury and recoverable injury peak pressure threshold

Receptor	Mortality and Potential Mortal Injury Recoverable Injury Peak pressure level threshold (dB re 1 µPa)	Distance R_{max} (m)
Fish – no swim bladder	213	58
Fish Swim bladder not involved in hearing Swim bladder involved in hearing	207	78

<u>Extent and Duration of Exposure and Identified Potential Impact</u>

No significant commercial fishing areas or spawning areas were identified to occur within or near the survey area or alternatively during the survey timing period. It is likely that a range of fish species including reef fish and syngnathids (pipefish, seahorse or pipehorse species) may be present in the EMBA, with more abundance of species expected to be associated with shallow bank feature located in the south-west portion of the Operational Area (*Figure 5.2*; *Figure 5.6*). At the closest point, this shallow bank feature, which forms part of the

Carbonate bank and terrace system of the Sahul Shelf KEF, is located ~ 10 km from the survey Acquisition Area.

Mortality, potential mortality injury and recoverable injury

Based on the noise modelling, the area where the sound source levels exceed the fish mortality, potential mortality injury and recoverable injury threshold is restricted to a distance of < 78 m from the seismic source at full power (Table 7 5). The area where the seismic source will be at full power is within the survey area (946 km^2) and one kilometre at each end of the survey area, as the source ramps up on entering and ramps down on leaving the survey area. To be conservative an additional 2 km, either end of the survey area, is applied to the survey area giving a total area of 975 km^2.

Thus, the area where the sound source levels are above the fish mortality, potential mortality injury and recoverable injury threshold would equate to 985 km^2 (975 km^2 plus buffer zone of 78 m).

However, this has to be viewed in the context of:

- The broader area in which the survey is being undertaken. For fish the Bonaparte Gulf Meso-scale Bioregion would be representative of the broader area in which the survey is being undertaken as it is representative of water depths, habitats and hydrodynamics within the survey area.
- Based on the area for the Bonaparte Gulf Meso-scale Bioregion (57,589 km^2; DoEE 2018), the area of potential impact of 985 km^2 represents 1.7% of this region.
- The area of impact does not include any locations where significant fish numbers occur. The shallow bank that has the potential for site attached or reef fish is located ~ 10 km from the Acquisition Area and therefore outside the area of impact. Thus, it is unlikely that large numbers of fish will be present in the area of impact during acquisition.
- Fish within the area of impact will not be evenly distributed and likely to moving within and in and out of the area.
- The area of potential impact assumes that the area will receive the same sound levels at the same time, which is not the case, sound levels will change as the seismic vessel moves through the area during the survey for up to 30 days;
- Potential fish mortality, potential mortality injury and recoverable injury to fish are unlikely with impacts more likely to be behavioural including avoiding or moving away from the area for the period of the survey.

Thus, based on this analysis, mortality, potential mortality injury and recoverable injury to fish is unlikely based on the localised area of impact (1.7% of the Bonaparte Gulf Meso-scale Bioregion) and short term that fish would be exposed to noise levels above threshold levels as the vessel moves through the survey area for the duration of the survey (up to 30 days).

Summary

Consequence Level: If the activity results in mortality, potential mortality injury and recoverable injury to fish, there is potential for localised and short term impacts - (I).

Likelihood Level: For this activity, localised and short term impacts to fish is considered Unlikely (b).

Temporary threshold shift

The following is sourced from Popper et al. (2014):

> *"Temporary threshold shift (TTS) is a temporary reduction in hearing sensitivity caused by exposure to intense sound. TTS has been demonstrated in some fishes, and its extent is of variable duration and magnitude. TTS results from temporary changes in sensory hair cells of the inner ear and/or damage to auditory nerves innervating the ear (Smith et al. 2006; Liberman 2015). However, sensory hair cells are constantly added in fishes (e.g., Corwin 1981, 1983; Popper and Hoxter 1984; Lombarte and Popper 1994) and also replaced when damaged (Lombarte et al. 1993; Smith et al. 2006; Schuck and Smith 2009), unlike in the auditory receptors of mammals. When sound-induced hair cell death occurs in fishes, its effects may be mitigated over time by the addition of new hair cells (Smith et al. 2006, 2011; Smith 2012, 2015).*

After termination of a sound that causes TTS, normal hearing ability returns over a period that is variable, depending on many factors, including the intensity and duration of sound exposure (e.g. Popper and Clarke 1976; Scholik and Yan 2001a, 2001b; Amoser and Ladich 2003; Smith et al. 2004 a, 2004b, 2006, 2011; Popper et al. 2005, 2007). While experiencing TTS, fishes may have a decrease in fitness in terms of communication, detecting predators or prey, and/or assessing their environment."

Popper et al. (2014) recommended a sound exposure criteria for TTS for fish with a swim bladder involved in hearing of >> 186 dB SEL_{cum} and 186 dB SEL_{cum} for fish with a swim bladder not involved in hearing (*Table 7.7*). For this survey the standard period of time applied to the SEL metric is 24 hours, as detailed in *Section 7.1.2*.

The results from the Santos commissioned study (in collaboration with the NT Fisheries Department) on goldband snapper (McCauley and Kent 2007), support the 186 dB re 1 $\mu Pa^2 \cdot s$ TTS threshold from Popper et al. (2014), despite the limited sample size. These results show an apparent increasing trend of damage above ~ 190 dB re 1 $\mu Pa^2 \cdot s$. However, this trend of damaged hair cells immediately after air gun exposure is limited to positive results derived from a limited number of samples and should be treated with caution, as stated in the report itself (McCauley and Kent 2007).

Another study by McCauley et al. (2003) demonstrated that exposure to repeated emissions of a single airgun (source level at 1 m of 222.6 dB re 1µPa peak-to-peak) from 5 to 15 m at the closest approach caused extensive damage to the sensory hair cells in the inner ear of caged pink snapper (*Pagrus auratus*). Although no mortality was observed, the damage was severe with no evidence of repair or replacement of damaged sensory cells up to 58 days post-exposure. The study did not look at if this damage has any effects on fish hearing. The study acknowledged that the fish were caged and therefore not able to swim away from sound source, and that the monitoring video suggested the fish would have fled the sound source if possible. The study also acknowledged that the impact of exposure on ultimate survival of the fish was not clear.

As part of Woodside's Maxima 3D MSS, an extensive field study was undertaken at Scott Reef. A component of this study investigated three potential impacts with regards to fish assemblages: 1) if resident fish species were physically damaged by the seismic signals; 2) if seismic signals damaged fish ears; and 3) how the behaviour of fish exposed to seismic signals changed. A summary of findings on potential impacts to fish hearing are as follows:

- There was statistically more ear damage on seismic exposed fish than on control fish but the damage was marginal, and—assuming a linear relationship between hair cell density and hearing capability—this implied that <1% of the fishes' hearing capability was impaired. Hearing damage was monitored through time on *Lutjanus kasmira* (bluestripe snapper) out to 60 days post seismic exposure and did not increase significantly through time, with almost zero damage detected by 60 days (McCauley 2008).
- A study of auditory brainstem response (ABR) in four species of tropical reef fishes following exposure to emissions from the 2,055 in^3 array showed that none of the four species, including the pinecone soldierfish (a hearing specialist) experienced any hearing sensitivity loss (i.e. TTS) following exposure to SEL_{cum} up to 190 dB re 1 µPa2.s (Hastings et al. 2008; Hastings and Miksis-Olds 2012).
- Fish exposed to the seismic passes were sampled for assessment of gross physiological damage by the NT Museum. Observations by researchers present during dissections were that no detectable gross physiological damage was found in individuals from any of the seven species (McCauley and Kent 2012).

The data collected from the ABR experiment at Scott Reef are consistent with the sound exposure guidelines proposed in Popper et al. (2014), which indicated that TTS may occur at SEL_{cum} levels >186 dB re 1µPa^2.s (*Table 7.7*), while other studies (Popper and Hastings 2009; Song et al. 2008) indicate that TTS may occur at levels as high as SPL 205-210 dB re 1µPa (PK).

Extent and Duration of Exposure and Identified Potential Impact

As shown in *Table 7.8*, the maximum range at which the TTS exposure criteria for fish with a swim bladder (>> 186 dB 24 h SEL) is predicted to occur is within 410 m (within the water column) or 380 m (at the seafloor) of the array, based on the predicted R_{max} radii. These radii represent the perpendicular distance from the closest survey line to the isopleth. Based on a predicted R_{max} radius of 410 m the associated region of TTS ensonification within the water column over 24 hours is 70.1 km^2 (for pelagic/demersal fish), and based on a predicted R_{max} radius of 380 m the associated region of TTS ensonification at the seafloor over 24 hours is 67.3 km^2 (for site attached fish).

Table 7.8 ***Distances to maximum-over-depth and seafloor SEL_{24h} based fish criteria for the 2,380 in^3 array, for the considered scenario within the Beehive Acquisition Area***

Marine animal group	Threshold for SEL_{24h} (dB re 1 $\mu Pa^2 \cdot s$)	Maximum-over-depth		Seafloor	
		R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)
Fish mortality and potential mortal injury					
I	219	0.07	11.00	-	-
II Fish eggs and larvae	210	0.07	11.00	-	-
III	207	0.07	11.00	-	-
Fish recoverable injury					
I	216	0.07	11.00	-	-
II, III	203	0.07	11.00	-	-
Fish TTS					
I, II, III	186	0.41	70.10	0.38	67.30

Fish I–No swim bladder; Fish II–Swim bladder not involved with hearing; Fish III–Swim bladder involved with hearing. A dash indicates the threshold is not reached.

This potential area of impact for fish TTS is assessed as being acceptable based on:

- Any hearing loss and subsequent decrease in fitness (if it were to occur in the first place) would be temporary and recovery would take place over a relatively short time frame after the seismic vessel has moved away from the exposed fish, and the sound levels are reduced. The period over which fish would regain normal hearing ability is dependent upon several factors including the intensity and duration of sound exposure. Popper et al. (2005) reported that for fish that showed TTS, recovery to normal hearing levels occurred within 18–24 hours.
- The only study carried out to date on exposure of tropical reef fishes to airgun noise found that no TTS occurred in either hearing specialists or generalists (Hastings et al. 2008; Hastings and Miksis-Olds 2012) at exposure levels 4 dB higher than the sound exposure threshold for TTS provided in Popper et al. (2014).
- The small size of the Beehive full power zone (975 km^2) and additional 410 m radius of each line where the TTS exposure criteria is potentially exceeded, within the broader area in which the survey is being undertaken. For fish the Bonaparte Gulf Meso-scale Bioregion would be representative of the broader

area in which the survey is being undertaken as it is representative of water depths, habitats and hydrodynamics within the survey area.

- Based on the area for the Bonaparte Gulf Meso-scale Bioregion (57,589 km^2; DoEE 2018), the area of the full power zone is 975 km^2, which represents ~ 1.7% of this region. An area of impact of 410 m would equate to 1,023 km^2, which represents 1.8% of this region.
- The area of potential impact assumes that the area will receive the same sound levels at the same time, which is not the case, sound levels will change as the seismic vessel moves through the area during the survey for up to 30 days.
- It is unlikely that listed fish species identified in the Protected Matters search are found within the survey area due to waters depths and habitat type. No significant commercial fishing areas were identified to occur within or near the survey area. A range of fish species, including reef fish, may be present within the potential area of TTS impact, with more abundance of species expected associated with the shallow bank, which is well outside the potential are of TTS impact (~ 10 km distance away).
- Impacts at a population level are unlikely as the survey is not being undertaken during any fish spawning seasons and the area is not identified as signification aggregation area.

Summary

Consequence Level: If the activity results in TTS, there is potential for localised and short term impacts - (I).

Likelihood Level: For this activity, localised and short term impacts to fish is considered Unlikely (b).

Fish behavioural changes

There are no recommended exposure criteria for fish behaviour or masking. Based on the risk criteria proposed by Popper et al. (2014) behavioural responses are more likely to occur near the seismic source (tens of metres) with diminishing responses further from the seismic source (source hundreds to thousands of metres). The subjective relative risk criteria from Popper et al. (2014) at intermediate to far ranges indicated that fish with no swim bladder or swim bladders not involved in hearing may experience a low to moderate behavioural impact, while fish that have swim bladders involved in hearing may experience a moderate to high behavioural impact. The risk criteria proposed by Popper et al. (2014) for masking is low at all distances from the seismic source for fish with no swim bladder or swim bladders not involved in hearing, while fish that have swim bladders involved in hearing may experience a low masking impacts at the close to the source increasing to moderate impact as they move away from the source and the noise becomes more or less continuous.

In terms of behavioural responses, there is the possibility that seismic survey noise could cause fish to move away from the survey area. Should this occur during spawning or other ecologically significant life history events, population level effects may occur.

To be considered a significant impact, any masking effects or behavioural changes would result in reduction of fish abundance due to health effects or increased aversion, which could reduce catchability by predators and thus affect other species of concern.

Potential behavioural and/or masking impacts to fish from the Beehive survey are assessed as being acceptable based on:

- Any behavioural and/or masking impacts to fish (if it were to occur in the first place) would be temporary and recovery would take place over a relatively short time frame after the seismic vessel has moved away from the exposed fish, and the sound levels are reduced.
- The small size of the Beehive full power zone (975 km^2), within the broader area in which the survey is being undertaken though noise levels. For fish the Bonaparte Gulf Meso-scale Bioregion would be representative of the broader area in which the survey is being undertaken as it is representative of water depths, habitats and hydrodynamics within the survey area.
- The area of potential impact assumes that the area will receive the same sound levels at the same time, which is not the case, sound levels will change as the seismic vessel moves through the area during the survey for up to 30 days.
- It is unlikely that listed fish species identified in the protected matters search are found within the survey area due to waters depths and habitat type. No commercial fishing areas were identified to occur within or near the survey area, a range of fish species including reef fish may be present within the potential area of impact with more abundance of species expected associated with the two pinnacles identified outside of the potential are of TTS impact.
- The shallow bank where higher abundance of fish species (including reef fish) may occur, is ~ 10 km from the survey area (where the seismic source is a full power). Based criteria of Popper et al. (2014) this feature (and any site attached fish associated with it) would be within the intermediate to far distances from the source. Potential behavioural impacts at these distances are likely to be:
  - Low for fish with no swim bladder or swim bladders not involved in hearing.
  - Moderate for fish with swim bladders involved in hearing.
- Potential masking impacts at these distances are likely to be:
  - Low for fish with no swim bladder or swim bladders not involved in hearing.

    - Low to moderate for fish with swim bladders involved in hearing.
- Impacts are short term based on the survey period of 30 days and therefore unlikely to result in reduction of fish abundance due to health effects or increased aversion.
- Impacts at a population level are unlikely as the survey is not being undertaken during any fish spawning seasons and the area is not identified as signification aggregation area.

Summary

Consequence Level: If the activity results in any behavioural and/or masking effects in fish, there is potential for localised and short term impacts - (I).

Likelihood Level: For this activity, localised and short term impacts to fish is considered Unlikely (b).

Commercial Catch Rate

Receptor Sensitivity

As noted by Kent et al. (2016) "*The issue of changes in commercial fisheries catch rates due to seismic surveys is almost always contentious in Australia*". They acknowledge that there has been some effort to relate fisheries catch data to seismic survey effort, but to date none of the Australian efforts to relate fin-fish catch rates with seismic surveys have yielded results of any meaning.

The potential effects of seismic surveys on fish distribution, local abundance or catch has been examined for some teleost species with varying results (Carroll et al. 2017). A range of responses has been observed when the behaviour of wild fishes has been studied in the presence of anthropogenic sounds. Studies suggest that fish will generally move away from a loud acoustic source in order to minimise their exposure, but this response might depend on the animal's motivational state. Anthropogenic sounds have been shown to cause changes in schooling patterns and distribution, including in relation to seismic operations (Engås et al. 1996; Engås and Løkkeborg 2002; Slotte et al. 2004; Løkkeborg et al. 2012a, 2012b; Popper et al. 2014; Streever et al. 2016).

The effects of seismic activity on long-line and trawl catch rates of cod were explored in Norway, and in areas exposed to seismic a 55-80% reduction in long-line catches and 80-85% reduction in trawl catches were observed immediately after the seismic survey. These observations likely reflected the physical movement of demersal fishes away from the sound source, however the study only explored effects shortly after the seismic passes with catches returning to pre-seismic levels within 24 hrs (Løkkeborg and Soldal, 1993).

In contrast, other studies have found positive, inconsistent or no effects from seismic surveys on catch rates or abundance.

The studies associated with Woodside's Maxima 3D survey at Scott Reef, that examined effects on site attached coral reef fish and mobile roaming demersal species, found no detectable effect on species richness or abundance (Woodside 2011bc; Miller and Cripps 2013).

Løkkeborg et al. (2012a) noted that reduced fish catches have been observed in commercial line and trawl fisheries during and after seismic surveys, but that catches also increased in some cases, with the increase attributed to a change in fish activity in response to the airgun sounds.

Sonar observations by Penä et al. (2013) looked at real time behaviour of herring schools exposed to a seismic survey and found no changes were observed in school size, swimming speed or direction.

The GMEM project provided no clear evidence of adverse effects on scallops, fish, or commercial catch rates due to the 2015 seismic survey (Przeslawski et al. 2016b):

> *"Catch rates in the six months following the seismic survey were different than predicted in nine out of the 15 species examined across both Danish Seine and Demersal Gillnet sectors. Across both fishing gear types, six species (tiger flathead, goatfish, elephantfish, boarfish, broadnose shark and school shark) indicated increases in catch subsequent to the seismic survey, and three species (gummy shark, red gurnard, sawshark) indicated decreases in catch. These results support previous work in which the effects of seismic surveys on catch seem transitory and vary among studies, species, and gear types."*

Research to date has identified effects and no effects from seismic surveys on catch rates and abundance. This is likely due to the importance of the context of exposure, as discussed above. In many instances, fish may move away from an area when a seismic survey is being undertaken. This could impact on the catchability and catch rates for the target species of any commercial fisheries occurring in the same area at the same time.

<u>Extent and Duration of Exposure and Identified Potential Impact</u>

As described in *Sections 5.7.3* and *5.7.4*, the Beehive Operational and Acquisition areas overlap three commercial fisheries that actively target finfish species within areas of the Joseph Bonaparte Gulf:

- Mackerel Managed Fishery (MMF – WA-managed);
- Northern Demersal Scalefish Managed Fishery (NDSMF – WA-managed); and
- Demersal Fishery (NT-managed).

Fish catch and effort data has been obtained from the WA DPIRD (Fisheries) for the MMF and NDSMF for the years 2012 to 2016. The data are summarised for coarse 60 nm x 60 nm Catch and Effort System (CAES) blocks, as presented in

Figure 7.2, with the Beehive Acquisition Area centred on the boundary between CAES blocks 1328 and 1428.

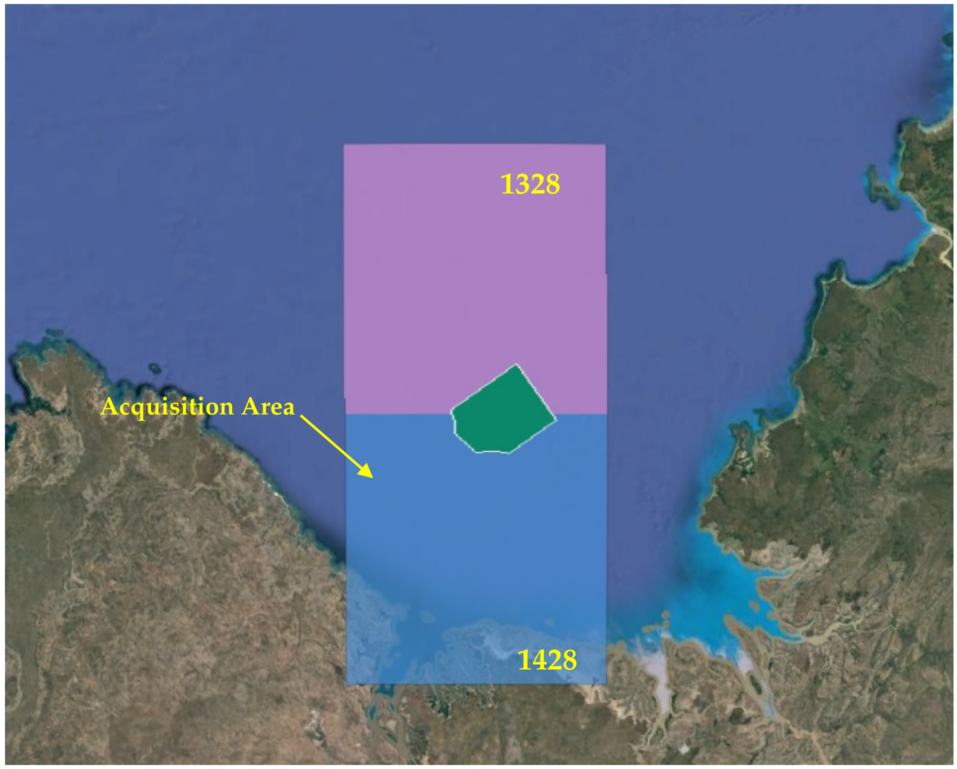

Figure 7.2 Location of the Beehive Acquisition Area in relation to CAES blocks 1328 and 1428

Review of the DPIRD (Fisheries) catch and effort data for 2012 to 2016 indicates that for the full five year period there was no recorded catch in CAES block 1428 for either the MMF or the NDSMF. For CAES block 1328 there was catch recorded in 2012 and 2013 for the MMF, and in 2012 and 2015 for the NDSMF. In other years, the level of catch and effort was below the levels at which DPIRD (Fisheries) are permitted to share data in accordance with the *Fisheries Resources Management Act 1994* (i.e. less than 3 vessels entering the block in total).

Similar data is not currently available from the NT DPIR (Fisheries) for the Demersal Fishery, but the area overlapped by the Beehive Operational and Acquisition areas is not expected to be a key area for the fishery. The Beehive Operational Area covers ~ 2,895 km^2 of the Demersal Fishery (0.84%) and the Acquisition Area covers ~ 300 km^2 of the Demersal Fishery (0.09%).

Therefore, the Beehive survey is not expected to significantly disrupt MMF, NDSMF or Demersal Fishery fishing activities, displace target species from significant fishing grounds or impact catch rates, although occasional vessels may be encountered during the survey.

Summary

Consequence Level: If the activity results in changes to commercial fish catch rates, there is potential for localised and medium term (< 1 year) impacts to a social value - (III).

Likelihood Level: For this activity, localised and medium term impacts to fish catch rates is considered - Possible (c).

7.1.5.4 *Sharks and Rays*

Receptor Sensitivity

Elasmobranchs sense sound via the inner ear end organs and as they lack a swim bladder it is thought that they are only capable of detecting the particle motion component of acoustic stimuli, unlike the more highly sensitive teleosts which can also detect sound pressure (Myrberg 2001).

Extent and Duration of Exposure and Identified Potential Impact

There are no migratory, feeding or aggregation areas within or near the EMBA for sharks, including whale sharks or rays.

To date there are no studies on seismic sound impacts on elasmobranchs. Popper et al. (2014) proposed that the sound exposure criteria for fish without a swim bladder are appropriate for sharks in the absence of other information.

The sound exposure thresholds proposed by Popper et al. (2014) (*Table 7.6*) for fish without a swim bladder mortality, potential mortality injury and recoverable injury peak pressure level threshold of > 213 dB re 1 µPa (PK) is used for this assessment. Based on the modelling this threshold would be within 58 m (R_{max} distance) of the sound source at full power (*Table 7.7*). The area where the seismic source will be at full power is within the survey area (946 km^2) and a kilometre at each end of the survey area, as the source ramps up on entering and ramps down on leaving the survey area. To be conservative an additional 2 km, either end of the survey area, is applied to the survey area giving a total area of 975 km^2.

Thus, the area where the sound source levels are above the mortality, potential mortality injury and recoverable injury threshold applicable to sharks and rays would equate to 982 km^2 (975 km^2 plus buffer zone of 58 m).

However, this has to be viewed in the context of:

- The broader area in which the survey is being undertaken. For shark and rays the Bonaparte Gulf Meso-scale Bioregion would be representative of the broader area in which the survey is being undertaken as it is representative of water depths, habitats and hydrodynamics within the survey area.

- Based on the area for the Bonaparte Gulf Meso-scale Bioregion (57,589 km^2; DoEE 2018), the area of potential impact of 982 km^2 represents 1.7% of this region.

- There is no indication that the area of potential impact includes any locations where significant shark or ray numbers occur, thus it is unlikely that large numbers of sharks or rays will be present in the survey area during acquisition.

- Sharks or rays will not be evenly distributed within the area of potential impact and likely to moving within and in and out of the area.

- The area of potential impact assumes that the area will receive the same sound levels at the same time, which is not the case, sound levels will change as the seismic vessel moves through the area during the survey for up to 30 days.

- Mortality, potential mortality injury and recoverable injury to sharks or rays are unlikely with impacts more likely to be behavioural including avoiding or moving away from the area for the period of the survey.

Thus, based on this analysis, mortality, potential mortality injury and recoverable injury to sharks or rays is unlikely based on the localised area of impact (1.7% of the Bonaparte Gulf Meso-scale Bioregion) and short term that sharks or rays would be exposed to noise levels above threshold levels as the vessel moves through the survey area for the duration of the survey (up to 30 days).

<u>Summary</u>

Consequence Level: If the activity results in mortality, potential mortality injury and recoverable injury to sharks and rays, there is potential for localised and short term impacts (I).

Likelihood Level: For this activity, localised and short term impacts to sharks and rays is considered Unlikely (b).

7.1.5.5 *Marine Reptiles*

7.1.5.5.1 *Turtles*

<u>Receptor Sensitivity</u>

There is limited information on sea turtle hearing. Morphological studies of green and loggerhead turtles (Ridgway et al. 1969; Wever 1978; Lenhardt et al. 1985) found that the sea turtle ear is similar to other reptile ears, but has some adaptations for underwater listening. A thick layer of fat may conduct sound to the ear in a similar manner as the fat in jawbones of odontocetes (Ketten et al. 1999), but sea turtles also retain an air cavity that presumably increases sensitivity to sound pressure. Sea turtles have lower underwater hearing thresholds than those in air, owing to resonance of the aforementioned middle ear cavity, and hence they hear best underwater (Willis 2016).

Electrophysiological and behavioural studies on green and loggerhead sea turtles found their hearing frequency range to be approximately 50–2000 Hz, with highest sensitivity to sounds between 200 and 400 Hz (Ridgway et al. 1969; Bartol et al. 1999; Ketten and Bartol 2005; Bartol and Ketten 2006; Yudhana et al. 2010; Piniak et al. 2011; Lavender et al. 2012; Lavender et al. 2014), although these studies were all conducted in air. Underwater audiograms are only available for three species. Two of these species, the red-eared slider (Christensen-Dalsgaard et al. 2012), the loggerhead turtle (Martin et al. 2012), both demonstrated higher sensitivity at around 500 Hz (Willis 2016). Recent work on green turtles has refined their maximum underwater sensitivity to be between 200 and 400 Hz (Piniak et al. 2016). Yudhana et al. (2010) measured auditory brainstem responses from two hawksbill turtles in Malaysia and found that peak frequency sensitivity occurred at 457 Hz in one turtle and at 508 Hz in the other.

Nelms et al. (2016) conducted a review of seismic surveys and turtles which considers the studies detailed below. A common theme is the complex nature of the studies, from the interpretation of behavioural responses, determining responses due to airguns or vessel noise/presence, through to difficulties in visually detecting animals. Most studies looking at the effect of seismic noise on marine turtles have focused on behavioural responses as physiological impacts are more difficult to observe in living animals.

Sea turtles have been shown to avoid low-frequency sounds (Lenhardt 1994) and sounds from an airgun (O'Hara and Wilcox 1990), but these reports did not note received sound levels. Moein et al. (1994) found that penned loggerhead sea turtles initially reacted to a single airgun but then showed low or no response to the sound (habituated to it). Caged green (*Chelonia mydas*) and loggerhead (*Caretta caretta*) turtles increased their swimming activity in response to an approaching airgun when the received SPL was above 166 dB re 1 μPa and they behaved erratically when the received SPL was approximately 175 dB re 1 μPa (McCauley et al. 2000). This study was conducted in cold water, and might not represent typical responses.

Sound levels defined by Popper et al. (2014) show that animals are very likely to exhibit a behavioural response when they are near an airgun (tens of metres), a moderate response if they encounter the source at intermediate ranges (hundreds of metres), and a low response if they are far (thousands of meters) from the airgun.

Weir (2007) carried out observations from on-board a seismic survey vessel during a 10-month 3D survey offshore from West Africa, concluding that:

> *"..There was indication that turtles occurred closer to the source during guns-off than full-array, with double the sighting rate during guns-off in all distance bands within 1000 m of the array."*

The reduction in number of turtles observed within 1,000 m during operation of a full airgun array (Weir 2007) is therefore reasonably consistent with the observations of McCauley et al. (2003), which indicated an avoidance response threshold of approximately 175 dB re 1 µPa (SPL_{rms}).

In the absence of definitive data which could be used to determine the sound levels that could injure a turtle, temporary threshold shift (TTS) or permanent threshold shift (PTS) onset were considered possible at an SPL of 180 dB re 1 µPa (NSF 2011). Since this time, Popper et al. (2014) suggested mortality and potential mortal injury to turtles could occur for sound exposures above 207 dB re 1 µPa (PK) or above 210 dB re 1 $\mu Pa^2 \cdot s$ (SEL_{24h}). The Popper et al. (2014) > 207 dB re 1 µPa (PK) threshold is used in this assessment as it is based on the latest information to date. Based on the modelling this threshold would be within 78 m (R_{max} distance) of the sound source where it is expected that turtles would move away from the sound source and hence not be exposed to these levels.

Based on the limited data in regards to noise levels that illicit a behavioural response in turtles, the lower level of 166 dB re 1 µPa level drawn from NSF (2011) is typically applied, both in Australia and by NMFS, as the threshold level at which behavioural disturbance could occur. Based on the modelling this threshold would be within 1.1 km (R_{max} distance) of the sound source. The R_{max} distance is used for this receptor based on the fact that the Acquisition and Operational areas overlap foraging BIAs for a number of turtle species, and are adjacent to the area of 'habitat critical to the survival of a species' for flatback turtles in the southern JBG (see *Section 5.6.7*).

Extent and Duration of Exposure and Identified Potential Impact

Flatback, loggerhead, green and olive ridley turtles may be encountered during the survey based on based on the fact that the Acquisition and Operational areas overlap, or are adjacent to, foraging BIAs for these species. Additionally, the Operational Area abuts the boundary of the 'habitat critical to the survival of a species' for flatback turtles in the southern JBG.

No information is available on the timing or peak seasons for foraging activity of green and olive ridley turtles within the foraging BIA that is overlapped by the Acquisition and Operational areas. Flatback turtles nest at Cape Domett throughout the year. Whiting et al. (2008) identified peak nesting as occurring during August and September. The Recovery Plan for Marine Turtles in Australia 2017 -2017 (DoEE 2017s) details the peak nesting period at Cape Domett as July to September (in Section 3.3 of the Recovery Plan) and as August to September (in Section 5.3). Thus, acquisition of the Beehive survey could overlap part of the peak nesting period for this population. As the survey will not be acquired during Exercise KAKADU (31 August – 15 September 2018, see *Section 5.7.8*) acquisition will not occur over a significant proportion of the peak nesting period if the survey takes place in 2018.

Research findings indicate that impacts on marine turtles from seismic survey noise are likely to be restricted to:

- short ranges and high sound intensities (perhaps less than few hundred metres range from source) on individuals;
- surveys that take place over protracted periods close to areas that constitute narrow, restricted migratory paths; or
- surveys that take place over protracted periods close to areas important for feeding, breeding and nesting.

Marine turtles may possibly be exposed to noise levels sufficient to cause physical damage if airgun arrays start suddenly with turtles nearby. In circumstances where arrays are already operating, (i.e. as a vessel moves along an acquisition line) individuals would be expected to implement avoidance measures before entering ranges at which physical damage might take place. With soft start procedures, it is extremely unlikely that an individual will be exposed to levels that may result in physical damage.

The Beehive 3D Acquisition and Operational areas do not overlap any identified narrow or restricted migratory paths, and so impacts on an individual or at a population level are not anticipated.

A study of turtle bycatch of the NPF, which included the waters of the southern JBG overlapped by the EMBA, recorded five species: flatback, 59% of the total, loggerhead (10%), olive ridley (12%), green (8%) and hawksbill (5%). They identified that turtle catches varied with water depth: the highest catch rates were from trawls in water between 20 and 30 m deep, relatively few turtles (10%) were captured in water deeper than 40 m (Poiner and Harris 1996). Thus, it is unlikely that the Acquisition Area (mean water depth of ~43 m) and Operational Area (water depth range of ~ 28 to 63 m) represent predominant foraging areas for turtles.

<u>Mortality, potential mortality injury and recoverable injury</u>

Based on the noise modelling, the area where the sound source levels exceed the turtle mortality or mortal injury threshold (207 dB re 1 µPa PK) is restricted to a distance of < 78 m (R_{max} distance) from the seismic source at full power. The area where the seismic source will be at full power is within the survey area (946 km^2) and a kilometre at each end of the survey area, as the source ramps up on entering and ramps down on leaving the survey area. To be conservative an additional 2 km, either end of the survey area, is applied to the survey area giving a total area of 975 km^2.

Thus, the area where the sound source levels are above the turtle mortality or mortal injury threshold would equate to 985 km^2 (inclusive of an additional 78 m buffer).

For this risk assessment process, an acceptable level of impact has been set at no mortality or injury of marine turtles due to underwater noise from the seismic source.

However, this has to be viewed in the context of:

- The area of potential impacts is small in context of the turtle foraging areas within which turtles likely to be present in the survey area would be likely to occur within.
- Based on the green and olive ridley turtle foraging BIAs the area of potential impact is ~ 2.3% (*Table 7.9*).
- The Acquisition Area is located > 10 km from the boundary of the flatback turtle 'habitat critical to the survival of a species' area. Therefore, there will be no mortality, potential mortality injury or recoverable injury effects to flatback turtles within the 'habitat critical to the survival of a species' area.
- Turtles within the area of potential impact will not be evenly distributed and likely to moving within and in and out of the area.
- The area of potential impact assumes that the area will receive the same sound levels at the same time, which is not the case, sound levels will change as the seismic vessel moves through the area during the survey for up to 30 days.
- Potential mortality or mortal injury to turtles are unlikely with impacts more likely to be behavioural including avoiding or moving away from the area for the period of the survey.

Thus, based on this analysis, mortality or mortal injury to turtles is unlikely based on the localised area of impact, with up to 2.3% of the available foraging area impacted, and short term that turtles would be exposed to noise levels above threshold levels as the vessel moves through the survey area for the duration of the survey (up to 30 days).

Table 7.9 Area of overlap for turtle foraging areas and full power area with 78 m mortality, potential mortal injury and recoverable injury threshold area

Turtle	Foraging Area (km²)	Area Intersecting Full Power Area incl. 78 m threshold (km²)	Area Intersecting Full Power Area incl. 78 m threshold (%)
Green	42,391	985	2.3
Olive ridley	42,619	985	2.3

<u>Summary</u>

Consequence Level: If the activity results in mortality, potential mortality injury and recoverable injury to turtles there is potential for localised and short term impacts to fauna of environmental value - (II).

Likelihood Level: For this activity, localised and short term impacts to turtles is considered Unlikely (b).

Behavioural disturbance

Based on the noise modelling, the area where the sound source levels exceed the turtle behavioural disturbance threshold (SPL 166 dB re 1 µPa) is restricted to a distance of 1.1 km (R_{max} distance) of the sound source at full power. The area where the seismic source will be at full power is within the survey area (946 km^2) and a kilometre at each end of the survey area, as the source ramps up on entering and ramps down on leaving the survey area. To be conservative an additional 2 km, either end of the survey area, is applied to the survey area giving a total area of 975 km^2.

Thus, the area where the sound source levels are above the turtle behavioural disturbance threshold would equate to 1,114 km^2 (inclusive of an additional 1.1 km buffer)

For this risk assessment process, an acceptable level of impact has been set at 10%—i.e. <10% of green and olive ridley turtles present in the foraging BIA are exposed to behavioural disturbance in due to underwater noise from the seismic source.

However, this has to be viewed in the context of:

- The Acquisition Area is located >10 km from the boundary of the 'habitat critical to the survival of a species' for flatback turtles in the southern JBG. At this distance received sound levels are estimated to be ~120-130 dB per-pulse SEL (maximum-over-depth – MOD) and ~130-140 dB SPL (MOD), based on the results of the JASCO acoustic modelling study for the Beehive survey (Appendix 3 to this EP). Therefore, received sound levels present within the 'habitat critical to the survival of a species' are not predicted to exceed the marine turtle behavioural threshold of 166 dB re 1 µPa (SPL). As such, acoustic impacts to flatback turtles within the 'habitat critical to the survival of a species' are reduced to ALARP, as distances >1.1 km will provide adequate separation and protection from behavioural disturbance caused by the seismic acquisition. Furthermore, control measures (see Table 7.13) are consistent with the requirements of the Recovery Plan for Marine Turtles in Australia 2017 – 2027.
- The area of potential impacts is small in context of the turtle foraging areas within which turtles likely to be present in the survey area would be likely to occur within.
- Based on the green and olive ridley turtle foraging BIA the area of potential impact is 2.6% (Table 7.10), which is within the defined acceptable level of impact for behavioural disturbance (see above).
- Turtles within the area of potential impact will not be evenly distributed and likely to moving within and in and out of the area.
- The area of potential impact assumes that the area will receive the same sound levels at the same time, which is not the case, sound levels will change

as the seismic vessel moves through the area during the survey for up to 30 days.

- There is no peak season identified for turtles to be present in significant numbers within the foraging areas.

Based on this assessment it is possible that foraging turtles may receive noise levels above the behavioural disturbance threshold criteria and this could lead to them moving from the area. Thus, it is possible that turtles could be disturbed and move away from a localised area (~ 2.6%) of their foraging areas for the duration of the survey (30 days – short term).

Table 7.10 Area of overlap for turtle foraging areas and full power area with 1.1 km behavioural threshold area

Turtle	Foraging Area (km^2)	Area Intersecting Full Power Area incl. 1.1 km threshold (km^2)	Area Intersecting Full Power Area incl. 1.1 km threshold (%)
Green	42,391	1,114	2.6
Olive ridley	42,619	1,114	2.6

Summary

Consequence Level: If the activity results in behavioural disturbance to turtles there is potential for localised and short term impacts to fauna of environmental value - (II).

Likelihood Level: For this activity, localised and short term impacts to turtles is considered Possible (c).

7.1.5.5.2 Sea Snakes

Little information is available about the effects of seismic surveys on sea snakes. In the absence of observations of sea snake exposed to air gun noise, either of captive animals or in the field, it is assumed that they will respond in a similar way to turtles, such as exhibiting behavioural change to an approaching sound source.

Three characteristics suggest that sea snakes could be vulnerable to seismic impacts:

- Sealed nostrils and an air-filled lung extending the length of the body, plus slower swimming speeds than other marine vertebrates, might mean they are unable to avoid tissue damage at close range.

- Scale sensillae that allow sea snakes to detect the vibrations of their prey show peak sensitivity to low frequencies that overlap those produced by seismic sources, this may disrupt feeding (via acoustic masking) and provoke avoidance behaviour.

- Translocation (a common response to seismic sources) is associated with high mortality in sea snakes; habitat displacement might have long term consequences for highly isolated populations.

The key outcomes of a research project – "Investigating the impact of seismic surveys on threatened sea snakes in Australia's North West Shelf" (undertaken at the School of Earth and Environmental Sciences, University of Adelaide) have recently been made available on the project's website: http://www.apscience.org.au/projects/APSF_12_5/apsf_12_5.html

1. Behaviour

Field experiments were trialled over 10 days in the Ningaloo Marine Park, Western Australia, August 2013. The team trialled an alternative method to BRUVS that involved actively searching for snakes and using a baited monopod with a GoPro attached at a fixed distance from the underwater speaker. The aim was to test for correlation between the time for change in underwater sound and time for change in snake behaviour. They were able to perform this experiment on six olive sea snakes (*Aipysurus laevis*). None of the snakes showed an observable change in behaviour at the initiation of (or during) the sound treatment. The experiment used a powerful underwater speaker (Clark Synthesis AQ339) to expose snakes to a peak sound pressure of 66.3 db~µPA at 1 metre with dominant frequencies between 20 and 100 Hz. However, although startle responses were seen in nearby fishes, the sound generated did not reach the received levels considered harmful for other marine vertebrates (above 100 db re µPA).

2. Morphology

Scanning electron microscopy and comparative phylogenetic analyses were used to provide evidence that the scale sensilla (touch receptors) of terrestrial elapid snakes may function as hydrodynamic receptors in sea snakes. Scale sensilla were more protruding (dome-shaped) in sea snakes than in their terrestrial counterparts, and exceptionally high overall coverage of sensilla was found only in the sea snakes. High sensilla coverage appears to have evolved multiple times within sea snakes, so that the impacts of anthropogenic noise on sea snakes will likely vary among species. These findings are now published (Crowe-Riddell et al. 2016) and were used to inform taxon selection in the electrophysiology study (below).

3. Electrophysiology

Auditory evoked potentials (AEP) of wild caught sea snakes were measured in 2015 and 2016, providing the first experimental data on the hearing abilities of sea snakes underwater. The audiogram of *Hydrophis stokesii* (based on two individuals) shows a limited frequency range of about 40 Hz to about 1000 Hz, peaking at low frequencies (60 Hz). This sensitivity is similar to species of fish only receptive to particle motion (e.g. fish without a swim bladder, elasmobranchs), which could suggest that sea snakes are not sensitive to sound pressure. By overlapping the signature of a typical airgun on the audiogram of *H. stokesii*, the research team predict that these snakes are able to detect an airgun sound up to 100 m from the source.

One of the findings of the research and monitoring studies conducted at Scott Reef to study the effects of Woodside's Maxima 3D survey was that the seismic survey did not cause any observed physiological effects or mortality in marine fauna, including sea snakes (Woodside 2008).

Most sea snakes have shallow benthic feeding patterns and live in shallow, coastal tropical waters; rarely found in water depths exceeding 30 m (Cogger 1975; Guinea 2013). Based on the analysis of bathymetric data conducted for the JASCO acoustic modelling study, water depths within the Acquisition Area range from ~32 – 51 m, with a mean depth of ~43 m. Therefore, it is unlikely that a high abundance of sea snakes will be present in the Acquisition Area. Sea snakes are not sedentary and, like turtles, can swim away from an approaching sound source.

Using turtles as a surrogate, sea snakes could experience mortality, potential mortal injury and recoverable injury within a distance of < 78 m (R_{max} distance) from the seismic source at full power. Similarly, sea snakes could be exposed to sound levels that cause behavioural effects at a distance of 1.1 km (R_{max} distance) of the sound source at full power.

However, this has to be viewed in the context of:

- The low likelihood that a high abundance of sea snakes will be present in the area exposed to the seismic source at full power. Normal habitat for sea snakes is shallow waters < 30 m depth, and the mean water depth within the Acquisition Area is ~43 m.

- The Beehive Acquisition and Operational areas do not overlap any important habitats for sea snakes, or any locations with sea snake populations with a high diversity and abundance (e.g. shallow banks and shoals, coral reefs).

- The area of potential impact assumes that the area will receive the same sound levels at the same time, which is not the case, sound levels will change as the seismic vessel moves through the area during the survey for up to 30 days.

- Potential mortality or mortal injury effects to sea snakes are unlikely, with impacts more likely to be behavioural including avoiding or moving away from the area for the period of the survey.

Summary

Consequence Level: If the activity results in mortality, potential mortality injury and recoverable injury to sea snakes there is potential for localised and short term impacts to fauna of environmental value - (II).

Likelihood Level: For this activity, localised and short term impacts to sea snakes is considered Unlikely (b).

Consequence Level: If the activity results in behavioural disturbance to sea snakes there is potential for localised and short term impacts to fauna of environmental value - (II).

Likelihood Level: For this activity, localised and short term impacts to sea snakes is considered Possible (c).

7.1.5.6 *Marine Mammals*

Marine mammal species evolved from terrestrial mammals and share basic hearing anatomy and physiology with their terrestrial ancestors. Marine mammals, however, have broader hearing frequency ranges due to the much higher sound speed underwater compared to in air. The functional hearing of cetaceans is characterised by a shift of the area of best hearing to higher frequencies for odontocetes (toothed whales and dolphins) and lower frequencies for mysticetes (baleen whales) (Wartzok and Ketten 1999; Mooney et al. 2012). Mysticetes and potentially odontocetes increased their ability to receive sound through the skull and both modified their middle ear structures to increase the amplitude of low-frequency sounds in particular (Ketten 1993; Cranford and Krysl 2015).

Because sounds can propagate well underwater and over large distances, many marine species use underwater acoustic signals as their principal mode of information transmission and situation awareness. Listening to the environment or active signalling requires well-developed hearing abilities. Cetaceans, in particular, depend heavily on hearing and sound to communicate, avoid predators, and forage.

The type and scale of the effect on cetaceans to seismic sounds will depend on a number of factors including the level of exposure, the physical environment, the location of the animal in relation to the sound source, how long the animal is exposed to the sound, the exposure history, how often the sound repeats (repetition period) and the ambient sound level. The context of the exposure plays a critical and complex role in the way an animal might respond (Gomez et al. 2016; NMFS 2016).

High levels of anthropogenic underwater noise can have potential effects on cetaceans ranging from changes in their acoustic communication, behavioural disturbances and in more severe cases physical injury or mortality (Richardson et al. 1995).

Permanent and Temporary Hearing Loss

Receptor Sensitivity

Physiological impacts such as physical damage to the auditory apparatus, e.g., loss of hair cells or permanently fatigued hair cell receptors, can occur in marine mammals when they are exposed to intense or moderately intense sound levels and could cause permanent or temporary loss of hearing sensitivity. While the loss of hearing sensitivity is usually strongest in the frequency range of the emitted noise, it is not limited to the frequency bands where the noise occurs but can affect a broader hearing range. This is because animals perceive sound structured by a set of auditory bandwidth filters that proportionately increase in width with frequency.

A temporary threshold shift (TTS) is hearing loss from which an animal recovers, usually within a day at most, whereas permanent threshold shift (PTS) is hearing loss from which an animal does not recover (permanent hair cell or receptor damage). The severity of TTS is expressed as the duration of hearing impairment and the magnitude of the shift in hearing sensitivity relative to pre-exposure sensitivity, in dB. TTS occurs at lower exposure levels than PTS. The cumulative effects of repeated TTS, especially if the animal receives another sound exposure near or above the TTS threshold before recovering from the previous sensitivity shift, could cause PTS. If the sound is intense enough, an animal could succumb to PTS without first experiencing TTS (Weilgart 2007). Though the relationship between the onset of TTS and the onset of PTS is not fully understood, a specific amount of TTS can be used to predict sound levels that are likely to result in PTS. For example, in establishing PTS thresholds, Southall et al. (2007) assume that PTS occurs with 40 decibels of TTS. While there are results from TTS and PTS studies on odontocetes exposed to impulsive sounds (Finneran 2016), there is no data for mysticetes.

For seismic surveys in Australian waters, the EPBC Act Policy Statement 2.1 determines suitable exclusion zones with an unweighted per-pulse SEL threshold of 160 dB re 1 $\mu Pa^2 \cdot s$ (DEWHA 2008). This threshold minimises the likelihood of TTS in mysticetes and large odontocetes according to the background paper. Policy Statement 2.1 does not apply to smaller dolphins and porpoises, as DEWHA assessed these cetaceans as having peak hearing sensitivities occurring at higher frequency ranges than those that seismic arrays typically produce.

Extent and Duration of Exposure and Identified Potential Impact

As the Beehive EMBA is not within or near any BIAs or migratory routes for cetaceans, there is a low likelihood of encountering cetaceans and those in the area would be transiting.

Based on the noise modelling, the area where the sound source levels exceeds the cetacean TTS threshold (SEL 160 dB re 1 $\mu Pa^2 \cdot s$) is within 0.9 km (R_{max} distance) from the seismic source at full power. The area where the seismic source will be at full power is within the survey area (946 km^2) and a kilometre at each end of the survey area, as the source ramps up on entering and ramps down on leaving the survey area. To be conservative an additional 2 km, either end of the survey area, is applied to the survey area giving a total area of 975 km^2.

Thus, the area in which cetaceans could experience noise levels above threshold levels would equate to 1,088 km^2.

However, this has to be viewed in the context of:

- The broader area in which the survey is being undertaken. For cetaceans the Bonaparte Gulf Meso-scale Bioregion would be representative of the broader area in which the survey is being undertaken as it is representative of water depths, habitats and hydrodynamics within the survey area.
- Based on the area for the Bonaparte Gulf Meso-scale Bioregion (57,589 km^2; DoEE 2018), the area of potential impact of 1,088 km^2 represents 1.9% of this region.
- There is no indication that the area of potential impact includes any biologically important areas or migratory paths, thus it is unlikely that large numbers of cetaceans will be present in the survey area during acquisition.
- Cetaceans within the area of potential impact will not be evenly distributed and likely to moving within and in and out of the area.
- The area of potential impact assumes that the area will receive the same sound levels at the same time, which is not the case, sound levels will change as the seismic vessel moves through the area during the survey for up to 30 days.
- TTS and PTS to cetaceans is unlikely as they are likely to move away from the survey area when noise levels are above behavioural thresholds.

Thus, based on this analysis, TTS and PTS to cetaceans is unlikely based on the implementation of a low power and shut down zones, with potential impact to be within a localised area (1.9% of the Bonaparte Gulf Meso-scale Bioregion) and short term in that cetaceans would be exposed to noise levels above threshold levels as the vessel moves through the survey area for the duration of the survey (up to 30 days).

<u>Summary</u>

Consequence Level: If the activity results in TTS or PTS there is potential for a localised and short term impacts to animals of environmental value– (II).

Likelihood Level: For this activity cetacean TTS or PTS resulting in a localised and short term impact to animals of environmental values is considered Unlikely (b).

Behavioural Disturbance

Receptor Sensitivity

Behavioural responses to underwater sound are difficult to determine because animals vary widely in their response type and strength, and the same species exposed to the same sound may react differently (Nowacek et al. 2004; Gomez et al. 2016; Southall et al. 2016). An individual's response to a stimulus is influenced by the context in which the animal receives the stimulus and how relevant the individual perceives the stimulus to be. A number of biological and environmental factors can affect an animal's response—behavioural state (e.g. foraging, travelling or socialising), reproductive state (e.g., female with or without calf, or single male), age (juvenile, sub-adult, adult), and motivational state (e.g., hunger, fear of predation, courtship) at the time of exposure as well as perceived proximity, motion, and biological meaning of the sound and nature of the sound source.

Animals might temporarily avoid anthropogenic sounds, but could display other behaviours such as approaching novel sound sources, increasing vigilance, hiding and/or retreating, that might decrease their foraging time (Purser and Radford 2011). Some cetaceans might also respond acoustically to seismic survey noise in a range of ways, including by increasing the amplitude of their calls (Lombard effect), changing their spectral (frequency content) or temporal vocalisation properties, and in some cases, cease vocalising (McDonald et al. 1995, 2007; Parks et al. 2007; Di Iorio and Clark 2010; Castellote et al. 2012; Hotchkin and Parks 2013 Blackwell et al. 2015).

The BRAHSS (Behavioural Response of Australian Humpback whales to Seismic Surveys) project conducted studies at Peregian Beach, QLD, and Dongara, WA, to better understand the behavioural responses of humpback whales to noise from the operation of seismic air gun arrays (Cato et al. 2013). Results from the first sets of experiments have recently been published (Dunlop et al. 2015, 2016; Godwin et al. 2016), together with concurrent studies of the effects of vessel noise on humpback whale communications (Dunlop 2016). In most exposure scenarios a distance increase from the sound source was observed and interpreted as potential avoidance. The study, however, found no difference in the 'avoidance' response to either 'ramp-up' or the constant source producing sounds at a higher level than early ramp-up stages. In fact, a small number of groups showed inspection behaviour of the source during both treatment scenarios. 'Control' groups also responded, which suggested that the presence of the source vessel alone had some effect on the behaviour of the whales. Despite this, the majority of groups appeared to avoid the source vessel at distances greater than the radius of most injury based mitigation zones.

Small odontocetes responded to airgun sounds by moving laterally away from the sound, showing the strongest lateral spatial avoidance, compared to mysticetes and killer whales which showed more localised spatial avoidance. Other larger odontocetes studied included long-finned pilot whales

(*Globicephala melas*) which only changed their orientation in response to sound exposure, while sperm whales did not significantly avoid the sound (Stone and Tasker 2006).

Southall et al. (2007) extensively reviewed marine mammal behavioural responses to sounds as documented in the literature. Their review found that most marine mammals exhibit varying responses between an SPL of 140 and 180 dB re 1 µPa, but a lack of convergence in the data from multiple studies prevented them from suggesting explicit criteria. The causes for variation between studies included lack of control groups, imprecise measurements, inconsistent metrics, and context dependency of responses including the animal's activity state.

The National Marine Fisheries Service (NMFS) in the U.S use a threshold SPL 160 dB re 1 µPa for potential behavioural disturbance to marine mammals (NMFS 2013). From the modelling for the survey this noise threshold level could be expected to occur within 1.3 km ($R_{95\%}$) and 1.4 km (R_{max}) of the seismic source. Avoidance, however, is not directly related to sound level thresholds but also influenced by the state of the animals (e.g. their reproductive, health, and foraging condition) and the context of exposure.

Extent and Duration of Exposure and Identified Potential Impact

As the Beehive EMBA is not within or near any BIAs or migratory routes for cetaceans, there is a low likelihood of encountering cetaceans and those in the area would be transiting.

Based on the noise modelling, the area where the sound source levels exceeds the behavioural disturbance to marine mammals threshold (SPL 160 dB re 1 µPa) is within 1.4 km (R_{max} distance) from the seismic source at full power. The area where the seismic source will be at full power is within the survey area (946 km^2) and a kilometre at each end of the survey area, as the source ramps up on entering and ramps down on leaving the survey area. To be conservative an additional 2 km, either end of the survey area, is applied to the survey area giving a total area of 975 km^2.

Thus, the area in which cetaceans could experience noise levels above threshold levels would equate to 1,153 km^2.

However, this has to be viewed in the context of:

- The broader area in which the survey is being undertaken. For cetaceans the Bonaparte Gulf Meso-scale Bioregion would be representative of the broader area in which the survey is being undertaken as it is representative of water depths, habitats and hydrodynamics within the survey area.
- Based on the area for the Bonaparte Gulf Meso-scale Bioregion (57,589 km^2; DoEE 2018), the area of potential impact of 1,153 km^2 represents 2.0% of this

region. This is a conservative assessment as marine mammals identified to be within the survey area would be transiting through a much greater area.

- There is no indication that the area of potential impact includes any biologically important areas or migratory paths, thus it is unlikely that large numbers of cetaceans will be present in the survey area during acquisition.
- Cetaceans within the area of potential impact will not be evenly distributed and likely to moving within and in and out of the area.
- The area of potential impact assumes that the area will receive the same sound levels at the same time, which is not the case, sound levels will change as the seismic vessel moves through the area during the survey for up to 30 days.

Thus, based on this analysis, behavioural disturbance to cetaceans could occur within a localised area (2.0% of the Bonaparte Gulf Meso-scale Bioregion) and be short term in that cetaceans would be exposed to noise levels above threshold levels as the vessel moves through the survey area for the duration of the survey (up to 30 days).

Any behavioural responses in cetaceans would be likely to consist of avoiding the area of the survey.

<u>Summary</u>

Consequence Level: If the activity results in behavioural disturbance to cetaceans there is potential for localised and short term impacts to animals of environmental value– (II).

Likelihood Level: For this activity behavioural disturbance to cetaceans resulting in a localised and short term impact to animals of environmental values is considered Possible (c).

Acoustic Masking

<u>Receptor Sensitivity</u>

Acoustic masking occurs when sounds interfere with an animal's ability to perceive biologically relevant sounds. It can be defined as a reduction in communication and listening space (active acoustic space) that an individual experiences due to an increase in background noise (natural and anthropogenic) in the frequency bands relevant for communicating and listening. Acoustic masking can decrease the range over which an animal might communicate with its peers or detect predators or prey (Clark et al. 2009). Masking can occur naturally from wind, precipitation (Au et al. 2004), wave action, seismic activity (Nowacek et al. 2015), other natural phenomena and biological sounds (Zelick et al. 1999; Erbe et al. 2015).

Marine wildlife almost certainly has adapted to naturally occurring signal masking, yet the reduced active acoustic space under noisy natural conditions is a physical constraint that cannot be overcome completely. Anthropogenic sounds contribute to the ambient soundscape, and can mask biologically important sounds, potentially reducing the active (perception) space to levels that can't support active foraging and socialising. The amount of masking an animal experiences is determined by the amplitude, timing, and frequency content of the interfering sounds, as well as how sounds are spatially distributed.

Studies in regards to acoustic masking in the ocean have traditionally focused on mysticetes and shipping sounds (Clark et al. 2009). Mysticetes communicate using calls with energy primarily in low-frequency bands that overlap completely with the bands carrying the main energy of shipping sounds (Arveson and Vendittis 2000; Allen et al. 2012; Bassett et al. 2012). Sound output from ships can also extend to relatively high frequencies (e.g. up to 30 kHz: Arveson and Vendittis 2000, and up to 44.8 kHz: Aguilar Soto et al. 2006) and can affect odontocetes (toothed whales) especially at shorter ranges.

Sound from seismic surveys contribute to ocean-wide acoustic masking (Hildebrand 2009), and are considered to have the potential to displace some species and populations from their habitats (Erbe et al. 2015; Nowacek et al. 2015). Little is known, however, about the masking effects of seismic sounds other than aggregate noise from multiple seismic surveys and shipping can lead to higher sound levels, resulting in increased masking (Nowacek et al. 2015).

In order to estimate impact of masking through considering the reduction in active acoustic space quantitatively, it is necessary to take into account parameters such as call source levels and their adaptive compensation (Lombard response), detection thresholds based on the receiver perception capabilities, signal directivity, band specific (spectral) noise levels, and noise and signal duration. Instead, a qualitative assessment of masking has been undertaken for this risk assessment, and only mysticetes and killer whales have been considered due to the overlap between the frequency content of the seismic pulses and their hearing capabilities. Comparisons to ambient measurements made in deeper water to the north-east can be made (McPherson et al. 2016a, 2016c), as this is the closest available monitoring location for which results are available, although it is deeper and likely quieter. The length of time a seismic pulse will have an SPL higher than the ambient maximum from the monitoring program (146 dB re 1 µPa) is no longer than approximately one second. However, even distant seismic impulses can take 2 seconds to fall below average ambient levels in the Timor Sea (McPherson et al. 2016b), when considering 0.125 s windowed data. A worst case assessment could assume that in the area ensonified above 140 dB re 1 µPa, masking or reduction of active acoustic space is significant for the duration of a seismic pulse, and could occur for up to four seconds. Depending upon the propagation environment, inter-pulse noise levels can be higher than average ambient noise levels for the entire period between seismic impulses (Guan et al. 2015; McPherson et al. 2016b).

Masking effects on killer whales would only occur close to the seismic source, due to the limited transmission range of biologically relevant frequencies. The seismic vessel itself will likely contribute equally to the masking experienced by killer whales as the seismic source, and the ranges that this masking could occur at would be small given the propagation environment.

Calls from mysticetes, which might transit through the EMBA, are typically longer than the period of time the sound levels are above the upper ambient levels, and thus a portion of calls may experience masking beyond what could naturally occur. However, the negative effect on communication efficiency of prolonged periods of time during which seismic pulses compete with calls may be more pronounced than this argument for a single pulse would indicate and cannot be readily estimated.

Extent and Duration of Exposure and Identified Potential Impact

As the Beehive EMBA is not within or near any BIAs or migratory routes for cetaceans, there is a low likelihood of encountering cetaceans and those in the area would be transiting. so though masking may occur it could range from localised to within an extensive area (maximum of ~ 120 km) and would be for a short duration (4 seconds per pulse until the cetacean move away from the survey area and hence unlikely to have a significant impact).

Summary

Consequence Level: If the activity results in cetacean masking there is potential for extensive and short term impacts to animals of environmental value– (III).

Likelihood Level: For this activity cetacean masking resulting in an extensive and short term impact to animals of environmental values is considered Unlikely (b).

7.1.5.7 *Disturbance to Conservation Values*

The Beehive EMBA does not overlap any World Heritage Properties, National Heritage Properties, Ramsar wetlands, State or Territory Marine Parks, or Indigenous Heritage Sites (*Sections 5.8, 5.10, 5.11, 5.12 and 5.13*). As described in *Section 5.2*, a search of the DoEE Protected Matters Database identified that the Beehive EMBA overlaps part of the Joseph Bonaparte Gulf (JBG) Marine Park Multiple Use Zone (VI - 6,345 km^2) and the Special Purpose Zone (VI - 2,251 km^2) (*Figure 5.28*). The Operational Area and Acquisition Area do not overlap either zone of the JBG Marine Park (JBGMP).

The conservation values of the JBGMP are described in *Section 5.12*, and the potential impacts of underwater sound to those values is assessed in this section.

Extent and Duration of Exposure and Identified Potential Impact

Table 7.11 identifies the major conservation values and KEF of the JBGMP and summarises potential impacts and risks from the discharge of the 2,380 in^3 array.

Values of the Joseph Bonaparte Gulf Marine Park

1. **Habitat critical to the survival of a species – flatback turtle internesting area**

See evaluation of environmental impacts and risks for marine turtles in *Section 7.1.5.5*.

The boundary of the 'habitat critical to the survival of a species' (flatback turtle internesting area) is located ~28 km from the Acquisition Area (*Figure 5.15*). Predicted noise levels within the 'habitat critical to the survival of a species' are predicted to be 120-130 dB re 1 µPa (SPL) (*Table 7.11*). Therefore, received sound levels present within the 'habitat critical to the survival of a species' within the JBGMP are not predicted to exceed the marine turtle behavioural threshold of 166 dB re 1 µPa (SPL) (*Table 7.11*). As such, acoustic impacts to flatback turtles within the 'habitat critical to the survival of a species' within the JBGMP are reduced to ALARP, as distances >1.1 km will provide adequate separation and protection from behavioural disturbance caused by the seismic acquisition. Furthermore, control measures (see *Table 7.13*) are consistent with the requirements of the Recovery Plan for Marine Turtles in Australia 2017 – 2027.

Table 7.11 Potential acoustic impacts from the Beehive survey to the major conservation values of the Joseph Bonaparte Gulf Marine Park

Major Conservation Value of JBG Marine Park	Biological Communities Identified	EP Section	Distance from MP Value to Acquisition Area	Estimated Received Sound Levels at Value	Horizontal Distance to Modelled MOD or Seafloor Received Levels	Exposure Criteria for Assessing Potential Impacts	Predicted Received Level Below Exposure Criteria?	Consequence Level (see Table 6.3)	Likelihood Level (see Table 6.4)	Residual Risk Ranking Level 1 (Acceptable)	Acceptability
Habitat critical to the survival of a species (flatback turtle internesting area)	NA[1]	*7.1.5.5*	~28 km	110-120 dB per-pulse SEL (MOD[2]) 120-130 dB SPL (MOD)	78 m	Mortality/ PMI[3] 210 dB SEL_{24h} or >207 dB PK	Yes	II	a	Very Low (1)	Predicted received levels are below the relevant exposure criteria. A Level 1 residual risk is considered acceptable and ALARP. Control measures are consistent with the requirements of the Recovery Plan for Marine Turtles in Australia 2017 – 2027. Therefore, impacts to turtles within the flatback turtle 'habitat critical to the survival of a species' within the JBGMP are considered Acceptable.
					1.1 km	Behavioural disturbance >166 dB SPL	Yes	II	b	Very Low (1)	
Important foraging area for green and olive ridley turtles	NA	*7.1.5.5*	~10 km	120-130 dB per-pulse SEL (MOD) 130-140 dB SPL (MOD)	78 m	Mortality/ PMI 210 dB SEL_{24h} or >207 dB PK	Yes	II	a	Very Low (1)	Predicted received levels are below the relevant exposure criteria. A Level 1 residual risk is considered acceptable and ALARP. Control measures are consistent with the requirements of the Recovery Plan for Marine Turtles in Australia 2017 – 2027.
					1.1 km	Behavioural disturbance >166 dB SPL	Yes	II	b	Very Low (1)	

Major Conservation Value of JBG Marine Park	Biological Communities Identified	EP Section	Distance from MP Value to Acquisition Area	Estimated Received Sound Levels at Value	Horizontal Distance to Modelled MOD or Seafloor Received Levels	Exposure Criteria for Assessing Potential Impacts	Predicted Received Level Below Exposure Criteria?	Consequence Level (see Table 6.3)	Likelihood Level (see Table 6.4)	Residual Risk Ranking Level 1 (Acceptable)	Acceptability
											Therefore, impacts to turtles within the green and olive ridley turtle foraging BIA within the JBGMP are considered Acceptable.
Important breeding area for snubfin dolphins	NA	*7.1.5.6*	~56 km	110-115 dB per-pulse SEL (MOD) 115-120 dB SPL (MOD)	0.9 km	>160 dB per-pulse SEL	Yes	II	b	Very Low (1)	Predicted received levels are below the relevant exposure criteria. A Level 1 residual risk is considered acceptable and ALARP. Therefore, impacts to snubfin dolphins within the breeding BIA within the JBGMP are considered Acceptable.
					1.4 km	Behavioural disturbance >160 dB SPL	Yes	II	b	Very Low (1)	
Examples of shallow water ecosystems & communities of Northwest Shelf Transition	Plankton	*7.1.5.1*	~10 km	120-130 dB per-pulse SEL (MOD) 130-140 dB SPL (MOD)	78 m	Mortality/ PMI 210 dB SEL_{24h} or >207 dB PK	Yes	I	b	Very Low (1)	A Level 1 residual risk is considered acceptable and ALARP. Therefore, impacts to plankton within the JBGMP are considered Acceptable.
					1.95 km	Max. received level 178 dB PK-PK					
					NA	Behaviour (N) Moderate (I) Low	Yes	I	b		

Major Conservation Value of JBG Marine Park	Biological Communities Identified	EP Section	Distance from MP Value to Acquisition Area	Estimated Received Sound Levels at Value	Horizontal Distance to Modelled MOD or Seafloor Received Levels	Exposure Criteria for Assessing Potential Impacts	Predicted Received Level Below Exposure Criteria?	Consequence Level (see Table 6.3)	Likelihood Level (see Table 6.4)	Residual Risk Ranking Level 1 (Acceptable)	Acceptability
						(F) Low					
	Sponges/corals	-	~72 km (Emu Reef)	<100 dB PK	NA	260 dB PK-PK	Yes	I	a	Very Low (1)	Predicted received levels are below the relevant exposure criteria. A Level 1 residual risk is considered acceptable and ALARP. Therefore, impacts to sponges and corals within the JBGMP (Emu Reef) are considered Acceptable.
	Prawns	*7.1.5.2*	~10 km	<180 dB PK-PK	265 m	Mortality/ PMI >202 dB PK-PK	Yes	II	b	Very Low (1)	Predicted received levels are below the relevant exposure criteria. Therefore, impacts to prawns within the JBGMP are considered Acceptable.
	Molluscs	*7.1.5.2*	~10 km	<180 dB PK-PK	63-123 m	213 dB PK-PK	Yes	II	b	Very Low (1)	Predicted received levels are below the relevant exposure criteria. Therefore, impacts to molluscs within the JBGMP are considered Acceptable.
	Demersal & pelagic fishes	*7.1.5.3*	~10 km	120-130 dB per-	78 m	Mortality/ PMI	Yes	I	a	Very Low (1)	Predicted received levels are below the relevant exposure criteria.

Major Conservation Value of JBG Marine Park	Biological Communities Identified	EP Section	Distance from MP Value to Acquisition Area	Estimated Received Sound Levels at Value	Horizontal Distance to Modelled MOD or Seafloor Received Levels	Exposure Criteria for Assessing Potential Impacts	Predicted Received Level Below Exposure Criteria?	Consequence Level (see Table 6.3)	Likelihood Level (see Table 6.4)	Residual Risk Ranking Level 1 (Acceptable)	Acceptability
				pulse SEL (MOD) 130-140 dB SPL (MOD)		207 dB SEL_{24h} or >207 dB PK					A Level 1 residual risk is considered acceptable and ALARP. Therefore, impacts to demersal and pelagic fishes within the JBGMP are considered Acceptable.
					58 m	Mortality/ PMI >219 dB SEL_{24h} or >213 dB PK	Yes	I	a	Very Low (1)	
					410 m	TTS >186 dB SEL_{24h}	Yes	I	a	Very Low (1)	
					NA	Behaviour (N) High (I) High (F) Moderate	Yes	I	b	Very Low (1)	
	Sharks & rays	*7.1.5.4*	~10 km	120-130 dB per-pulse SEL (MOD) 130-140 dB SPL (MOD)	58 m	Mortality/ PMI >219 dB SEL_{24h} or >213 dB PK	Yes	I	a	Very Low (1)	Predicted received levels are below the relevant exposure criteria. A Level 1 residual risk is considered acceptable and ALARP. Therefore, impacts to sharks and rays within the JBGMP are considered Acceptable.
					410	TTS >186 dB SEL_{24h}	Yes	I	a		
					NA	Behaviour (N) High (I) High (F) Moderate	Yes	I	b		

Major Conservation Value of JBG Marine Park	Biological Communities Identified	EP Section	Distance from MP Value to Acquisition Area	Estimated Received Sound Levels at Value	Horizontal Distance to Modelled MOD or Seafloor Received Levels	Exposure Criteria for Assessing Potential Impacts	Predicted Received Level Below Exposure Criteria?	Consequence Level (see Table 6.3)	Likelihood Level (see Table 6.4)	Residual Risk Ranking Level 1 (Acceptable)	Acceptability
	Marine turtles	*7.1.5.5*	~10 km	120-130 dB per-pulse SEL (MOD) 130-140 dB SPL (MOD)	78 m	Mortality/ PMI 210 dB SEL_{24h} or >207 dB PK	Yes	II	b	Very Low (1)	Predicted received levels are below the relevant exposure criteria. A Level 1 residual risk is considered acceptable and ALARP. Control measures are consistent with the requirements of the Recovery Plan for Marine Turtles in Australia 2017 – 2027. Therefore, impacts to turtles within the JBGMP are considered Acceptable.
					1.1 km	Behavioural disturbance >166 dB SPL	Yes	II	b	Very Low (1)	
	Marine mammals	*7.1.5.6*	~10 km	120-130 dB per-pulse SEL (MOD) 130-140 dB SPL (MOD)	0.9 km	>160 dB per-pulse SEL	Yes	II	b	Very Low (1)	Predicted received levels are below the relevant exposure criteria. A Level 1 residual risk is considered acceptable and ALARP. Therefore, impacts to marine mammals within the JBGMP are considered Acceptable.
					1.4 km	Behavioural disturbance >160 dB SPL	Yes	II	b	Very Low (1)	
Carbonate bank and terrace system of the Sahul Shelf KEF	Sponges/corals	-	~46 km	<100 dB PK	NA	260 dB PK-PK	Yes	I	a	Very Low (1)	Predicted received levels are below the relevant exposure criteria. A Level 1 residual risk is considered acceptable and ALARP.

Major Conservation Value of JBG Marine Park	Biological Communities Identified	EP Section	Distance from MP Value to Acquisition Area	Estimated Received Sound Levels at Value	Horizontal Distance to Modelled MOD or Seafloor Received Levels	Exposure Criteria for Assessing Potential Impacts	Predicted Received Level Below Exposure Criteria?	Consequence Level (see Table 6.3)	Likelihood Level (see Table 6.4)	Residual Risk Ranking Level 1 (Acceptable)	Acceptability
											Therefore, impacts to sponges and corals associated with this KEF within the JBGMP are considered Acceptable.
	Prawns	*7.1.5.2*	~46 km	<100 dB PK-PK	265 m	Mortality/ PMI >202 dB PK-PK	Yes	II	a	Very Low (1)	Predicted received levels are below the relevant exposure criteria. A Level 1 residual risk is considered acceptable and ALARP. Therefore, impacts to prawns associated with this KEF within the JBGMP are considered Acceptable.
	Molluscs	*7.1.5.2*	~46 km	<100 dB PK-PK	63-123 m	213 dB PK-PK	Yes	II	a	Very Low (1)	Predicted received levels are below the relevant exposure criteria. A Level 1 residual risk is considered acceptable and ALARP. Therefore, impacts to molluscs associated with this KEF within the JBGMP are considered Acceptable.
	Demersal & pelagic fishes	*7.1.5.3*	~46 km	110-120 dB per-	78 m	Mortality/ PMI	Yes	I	a	Very Low (1)	

Major Conservation Value of JBG Marine Park	Biological Communities Identified	EP Section	Distance from MP Value to Acquisition Area	Estimated Received Sound Levels at Value	Horizontal Distance to Modelled MOD or Seafloor Received Levels	Exposure Criteria for Assessing Potential Impacts	Predicted Received Level Below Exposure Criteria?	Consequence Level (see Table 6.3)	Likelihood Level (see Table 6.4)	Residual Risk Ranking Level 1 (Acceptable)	Acceptability
				pulse SEL (MOD) 120-125 dB SPL (MOD)		207 dB SEL_{24h} or >207 dB PK					
					58 m	Mortality/ PMI >219 dB SEL_{24h} or >213 dB PK	Yes	I	a	Very Low (1)	Predicted received levels are below the relevant exposure criteria. A Level 1 residual risk is considered acceptable and ALARP. Therefore, impacts to demersal and pelagic fishes associated with this KEF within the JBGMP are considered Acceptable.
					410 m	TTS >186 dB SEL_{24h}	Yes	I	a	Very Low (1)	
					NA	Behaviour (N) High (I) High (F) Moderate	Yes	I	a	Very Low (1)	
	Sharks & rays	*7.1.5.4*	~46 km	110-120 dB per-pulse SEL (MOD) 120-125 dB SPL (MOD)	58 m	Mortality/ PMI >219 dB SEL_{24h} or >213 dB PK	Yes	I	a	Very Low (1)	Predicted received levels are below the relevant exposure criteria. A Level 1 residual risk is considered acceptable and ALARP. Therefore, impacts to sharks and rays associated with this KEF within the JBGMP are considered Acceptable.
					410 m	TTS >186 dB SEL_{24h}	Yes	I	a		
					NA	Behaviour (N) High (I) High (F) Moderate	Yes	I	b		

Major Conservation Value of JBG Marine Park	Biological Communities Identified	EP Section	Distance from MP Value to Acquisition Area	Estimated Received Sound Levels at Value	Horizontal Distance to Modelled MOD or Seafloor Received Levels	Exposure Criteria for Assessing Potential Impacts	Predicted Received Level Below Exposure Criteria?	Consequence Level (see Table 6.3)	Likelihood Level (see Table 6.4)	Residual Risk Ranking Level 1 (Acceptable)	Acceptability
	Marine turtles	*7.1.5.5*	~46 km	110-120 dB per-pulse SEL (MOD) 120-125 dB SPL (MOD)	78 m	Mortality/ PMI 210 dB SEL_{24h} or >207 dB PK	Yes	II	a	Very Low (1)	Predicted received levels are below the relevant exposure criteria. A Level 1 residual risk is considered acceptable and ALARP. Control measures are consistent with the requirements of the Recovery Plan for Marine Turtles in Australia 2017 – 2027. Therefore, impacts to turtles associated with this KEF within the JBGMP are considered Acceptable.
					1.1 km	Behavioural disturbance >166 dB SPL	Yes	II	a	Very Low (1)	
	Sea snakes	-	~46 km	110-120 dB per-pulse SEL (MOD) 120-125 dB SPL (MOD)	78 m	Mortality/ PMI 210 dB SEL_{24h} or >207 dB PK	Yes	II	a	Very Low (1)	Predicted received levels are below the relevant exposure criteria. A Level 1 residual risk is considered acceptable and ALARP. Therefore, impacts to sea snakes associated with this KEF within the JBGMP are considered Acceptable.
					1.1 km	Behavioural disturbance >166 dB SPL	Yes	II	a		

1 Not Applicable
2 Maximum-over-depth (i.e. in the water column)
3 Potential mortal injury

2. Important foraging area for green and olive ridley turtles

See evaluation of environmental impacts and risks for marine turtles in *Section 7.1.5.5*.

The Acquisition and Operational areas, and the JBGMP overlap the foraging area BIA for green and olive ridley turtles in the JBG. However, the boundary of the Acquisition Area is ~10 km from the JBGMP boundary. Predicted received sound levels within the area of the foraging BIA overlapped by the JBGMP are predicted to be 130-140 dB re 1 µPa (SPL) (*Table 7.11*). Therefore, received sound levels present within the JBGMP are not predicted to exceed the marine turtle behavioural threshold of 166 dB re 1 µPa (SPL) (*Table 7.11*). As such, acoustic impacts to green and olive ridley turtles within the JBGMP are reduced to ALARP, as distances >1.1 km will provide adequate separation and protection from behavioural disturbance caused by the seismic acquisition. Furthermore, control measures (see *Table 7.13*) are consistent with the requirements of the Recovery Plan for Marine Turtles in Australia 2017 – 2027.

3. Important breeding area for snubfin dolphins

See evaluation of environmental impacts and risks for marine mammals in *Section 7.1.5.6.*

The boundary of the breeding BIA for snubfin dolphins within the JBGMP is located ~56 km from the Acquisition Area (*Figure 5.18*). Predicted received sound levels within the breeding BIA for snubfin dolphins are predicted to be 115-120 dB re 1 µPa (SPL) (*Table 7.11*). Therefore, received sound levels present within the snubfin dolphin breeding BIA within the JBGMP are not predicted to exceed the cetacean behavioural threshold of 160 dB re 1 µPa (SPL) (*Table 7.11*). As such, acoustic impacts to snubfin dolphins within the breeding BIA within the JBGMP are reduced to ALARP, as distances >1.4 km will provide adequate separation and protection from behavioural disturbance caused by the seismic acquisition.

4. Examples of shallow water ecosystems & communities of Northwest Shelf Transition

The Acquisition and Operational areas are located within the Northwest Shelf Transition provincial bioregion, however the Acquisition Area only overlaps 0.3% of this bioregion. Biological communities identified within the Northwest Shelf Transition, and therefore potentially occurring within the JBGMP, are plankton, invertebrates (sessile filter feeders, e.g. sponges and corals – present at Emu Reef, ~72 km east of the Acquisition Area), crustaceans (e.g. prawns), molluscs, fish (demersal and pelagic), sharks and rays, marine turtles and marine mammals (DEWHA 2008a, 2008b). The evaluation of environmental impacts and risks for these communities and faunal groups has been undertaken in:

- Plankton - *Section 7.1.5.1.*

- Prawns and molluscs - *Section 7.1.5.2.*
- Fish (demersal and pelagic) - *Section 7.1.5.3.*
- Sharks and rays - *Section 7.1.5.4.*
- Marine turtles - *Section 7.1.5.5.*
- Marine mammals - *Section 7.1.5.6.*

Table 7.11 identifies the major conservation values of the Northwest Shelf Transition bioregion potentially occurring within the JBGMP and summarises potential impacts and risks from the discharge of the 2,380 in^3 array.

As such, acoustic impacts to the major conservation values of the Northwest Shelf Transition bioregion potentially occurring within the JBGMP are reduced to ALARP, as distances >10 km (for plankton, prawns, molluscs, fishes, sharks and rays, and turtles) and >72 km (sponges and corals at Emu Reef) provides adequate separation and protection from acoustic impacts caused by the seismic activities. At these distances, received sound levels from the seismic activities will not cause acoustic impacts nor exceed known acoustic threshold criteria for marine fauna, and thus will not impact adversely the corresponding IUCN management principles for the multiple use and special purpose zones of the JBGMP (see *Table 5.19*), which define the acceptable levels of impact for values of the Northwest Shelf Transition bioregion within the JBGMP.

5. Carbonate bank and terrace system of the Sahul Shelf KEF

The JBGMP overlaps a portion of one shallow bank/shoal that is part of the Carbonate bank and terrace system of the Sahul Shelf KEF (see *Figure 5.2*). The bank that is located ~10 km to the west of the Acquisition Area is not within the JBGMP. At the closest point, the bank that is part of this KEF that is within the JBGMP (at the mouth of the Cambridge Gulf) is located ~46 km from the boundary of the Acquisition Area (*Figure 5.2*). Biological communities that may potentially be associated with this bank within the JBGMP, are sponges and corals, prawns, molluscs, fish (demersal and pelagic), sharks and rays, marine turtles and sea snakes (DEWHA 2008a, 2008b). The evaluation of environmental impacts and risks for these communities and faunal groups has been undertaken in:

- Prawns and molluscs - *Section 7.1.5.2*.
- Fish (demersal and pelagic) - *Section 7.1.5.3*.
- Sharks and rays - *Section 7.1.5.4*.
- Marine turtles - *Section 7.1.5.5.1*.
- Sea snakes - *Section 7.1.5.5.2*.

Table 7.11 identifies the major conservation values of the Carbonate bank and terrace system of the Sahul Shelf KEF potentially occurring within the JBGMP and summarises potential impacts and risks from the discharge of the 2,380 in^3 array.

As such, acoustic impacts to the major conservation values of the KEF potentially occurring within the JBGMP are reduced to ALARP, as a distance of >46 km provides adequate separation and protection from acoustic impacts caused by the seismic activities. At this distance, received sound levels from the seismic activities will not cause acoustic impacts nor exceed known acoustic threshold criteria for marine fauna, and thus will not impact adversely the corresponding IUCN management principles for the multiple use and special purpose zones of the JBGMP (see *Table 5.19*), which define the acceptable levels of impact for values of the KEF within the JBGMP.

<u>Summary</u>

Consequence Level: If the activity results in effects to the major conservation values of the JBGMP, there is potential for Localised and short term impacts - (II).

Likelihood Level: For this activity, effects to the major conservation values of the JBGMP resulting in localised and short term impacts is considered unlikely (b).

7.1.5.8 *Cumulative Impacts*

Cumulative impacts can occur from multiple surveys occurring at the same time leading to an increase in predicted noise levels on receptors. It can also occur from repeated surveys within the same area over time. A review of the NOPSEMA website and via stakeholder consultation the surveys detailed in *Table 7.12* have identified as completed or planned in the area of Beehive survey.

This section assesses the potential for cumulative impacts associated with:

- The Beehive survey being undertaken within an area where previous seismic surveys have occurred.
- The Beehive survey being undertaken at the same time as another seismic survey within the area.

This section does not assess cumulative impacts from seismic surveys within the area that occur after the Beehive survey as that should be the responsibility of that titleholder as part of their cumulative impact assessment.

Table 7.12 Completed or planned surveys within or near the Beehive survey area

Year	Company	Permit	Name	Comment
2012	Santos	WA-459-P	Fishburn 2D Seismic Survey	Within the WA-459-P permit, ~ 108 km NW of Beehive Acquisition Area
2012	MEO Australia	WA-454-P	Floyd 3D Seismic Survey	Within the WA-454-P permit, ~ 35 km NW of Beehive Acquisition Area
2013	GX Technology Australia Pty Ltd		Westralia 2D SPAN Marine Seismic Survey	One line (AUI-5700) crossing Beehive Operational and Acquisition areas.
2017	Origin	NT/P84	Gulpener 2D Seismic Survey	Acquired June – July 2017.

Year	Company	Permit	Name	Comment
				Located ~ 47 km east of Beehive Acquisition Area.
2018	Polarcus	WA-522-P	Zénaïde 3D MSS	Within the WA-522-P permit, ~ 135 km NW of Beehive Acquisition Area. Acquisition planned for March-April 2018.

Previous Seismic Surveys

Cumulative impacts can occur when the timing between surveys is less than the recovery rate of any potential impacts to receptors.

A review of the receptors within and adjacent to the Beehive survey area (*Section 5*, summarised in *Table 5.1*) identified the following:

- With the exception of BIAs for foraging green and olive ridley turtles, and 'habitat critical to survival of a species' for flatback turtles, no biological important habitats were identified for other species.
- No sensitive benthic habitats were identified that are not likely to be widespread within the Joseph Bonaparte Gulf.
- No protected or commercial species habitats were identified to occur in the area.
- Commercial fishing activities in the survey area are limited. The Operational and Acquisition areas overlap areas fished in the NPF, NDSMF, MMF and Demersal Fishery.
- Most of the Acquisition Area is located within the banana prawn seasonal closure area within the southern JBG.
- Part of one shallow bank that forms part of the Carbonate bank and terrace system of the Sahul Shelf KEF is within the Operational Area.
- The Pinnacles of the Bonaparte Basin KEF is located outside the Operational Area.

Based on the seismic noise impact assessment undertaken for the Beehive survey, impacts were identified to be short term (days/weeks) within the period of the seismic survey (30 days) with the exception of physiological impacts to invertebrates, which was assessed as medium term (6 months).

As the last seismic acquisition undertaken within the Beehive survey area was in 2013 (Westralia 2D SPAN; *Table 7.12*) cumulative impacts to receptors from the Beehive survey are not likely.

Seismic Surveys within Same Time Period

Based on information available on NOPSEMA's website, the only seismic acquisition that could potentially occur concurrently with the Beehive survey in the southern JBG area is activities conducted as part of PGS's proposed Rollo Multi-client Marine Seismic and CSEM Surveys program. However, at this point in time the Rollo EP has not been accepted and no further information is available concerning surveys that could be conducted in the Joseph Bonaparte Gulf region under this EP. Consultation with PGS for the Beehive survey (see *Section 4*) indicated that they do have plans for acquisition in the general area in 2018 and/or 2019, although final line locations and timing are yet to be determined.

On this basis, there is no information available to inform a cumulative impact assessment for the Beehive survey.

The Polarcus Zénaïde survey is due to be acquired in March – April 2018 (*Table 7.12*), and will therefore be completed prior to the commencement of the Beehive survey.

Table 7.13 Seismic underwater noise risk assessment

ALARP Decision Context			
Decision Context	**Justification**		
B	3D seismic surveys are commonly undertaken in both Australian and international waters. There have been numerous studies on the effects of seismic sound on receptors with a range of effects to no effects identified. Seismic surveys in Australia are well regulated and significant guidance is available for managing potential impacts to sound sensitive marine fauna. Sound sensitive marine fauna have been identified as having the potential to transit through the area, and the Acquisition Area is, at the closest point, > 10 km from the boundary of the 'habitat critical to survival of a species' for flatback turtles in the southern Joseph Bonaparte Gulf. The Operational and Acquisition areas also overlap foraging BIA for green and olive ridley turtles. During consultation WA DPIRD raised concerns in regards to the impacts of seismic surveys on commercial fish and invertebrate species. These concerns were addressed and controls recommended by parties implemented. Consequently, Santos believes that decision context B be applied to this hazard.		
Control Measure Identification			
Good Practice Control Measure	**Cost**	**Benefit**	**Applied?**
EPBC Act Policy Statement 2.1 - Interaction between Offshore seismic exploration: Part A applied to whales	The implementation of Part A of the EPBC policy statement for whales considered to be a good practice control measure thus costs have not been evaluated further.	The implementation of Part A of the EPBC Policy Statement 2.1 minimises impacts to whales that may be transiting through the area and includes: • 30-minute pre start-up-visual observations (3+ km observation zone); • 30-minute soft-start procedures;	**Yes**

		• Start-up delay procedures;
		• Low-power zone (2 km) and shut-down zone (500 m), and low-power/shut-down procedures;
		• Night-time and low visibility procedures, whereby start-up and operations may commence during night-time/low-visibility conditions provided:
		  ○ there have not been 3 or more shut-downs / power downs for whales in preceding 24-hour period; or
		  ○ if operations were not previously underway during the preceding 24 hours, the vessel has been in the vicinity (~10 km) of the proposed start up position for at least 2 hours (under good visibility conditions) within the preceding 24 hour period, and no whales have been sighted.	

EPBC Act Policy Statement 2.1 - Interaction between Offshore seismic exploration: Part A applied to turtles	The implementation of Part A of the EPBC policy statement to turtles has an increased cost as may lead to increased shut downs.	The environmental benefit of applying EPBC Act Policy Statement 2.1 Part A controls to turtles, in addition to whales, is considered marginal given the current information regarding the sensitivity of turtles to sound. However, given that the area overlaps a turtle foraging BIA, and is adjacent to designated 'habitat critical for the survival of a species' for flatback turtles, the benefit is considered to outweigh the cost.	**Yes**

		The proposed controls therefore include:
		• 30-minute pre start-up-visual observations (3+ km observation zone);
		• 30-minute soft-start procedures;
		• Start-up delay procedures;
		• Low-power zone (2 km) and shut-down zone (500 m), and low-power/shut-down procedures;
		• Night-time and low visibility procedures, whereby start-up and operations may commence during night-time/low-visibility conditions provided:
		  ○ there have not been 3 or more shut-downs / power downs for turtles in preceding 24-hour period; or
		  ○ if operations were not previously underway during the preceding 24 hours, the vessel has been in the vicinity (~10 km) of the proposed start up position for at least 2 hours (under good visibility conditions) within the preceding 24 hour period, and no turtles have been sighted.	

DoF Guidance Statement on Undertaking Seismic Surveys in WA Waters	The implementation of mitigation strategies within the DoF guidance statement is considered to be a good practice control measure thus has not been evaluated further.	Minimise impacts to commercial fish and invertebrate species.	**Yes**
Recovery Plan for Marine Turtles in Australia 2017 – 2027 identifies that soft start provisions may afford protection to marine turtles	This control measure is covered under the implementation of EPBC Act Policy Statement 2.1 - Interaction between Offshore seismic exploration: Part A and thus is not discussed further.	The environmental benefit of applying EPBC Act Policy Statement 2.1 Part A controls to turtles is considered marginal given the current information regarding the sensitivity of turtles to sound. However given that the area overlaps a turtle foraging BIA, the benefit is considered to outweigh the cost.	**Yes**
EPBC Act Policy Statement 2.1 - Interaction between Offshore seismic exploration: Part B. B.1. Marine Fauna Observers	Employment of experienced MMOs are not considered to result in a significant cost to the project.	The benefit of having two trained MMOs ensures controls are implemented and they are better equipped to identify whales and other fauna.	**Yes**
Schedule survey to avoid receptors seasonal timings – turtle foraging and internesting	A commitment to avoid the seasonal peak for flatback turtle nesting could potentially result in an increased level of impacts and risks to other sensitive receptors (e.g. NPF trawling activity, seasonal closure to protect juvenile prawns).	Avoidance of receptors reducing potential impacts. Turtle foraging in JBG does not have a seasonal period. Flatback turtles nest year-round at Cape Domett, with a peak in Jul-Sep.	**No**
Schedule survey to avoid receptors seasonal timings – Northern Prawn Fishery	There are restrictions of the timing of acquisition (e.g. completion of the Bethany survey, no overlap with Exercise KAKADU) that limit the ability to avoid the seasonal timing of events of important to NPF in the southern JBG.	Avoidance of receptors reducing potential impacts. Improved relationship with stakeholders. The first prawn season extends from 1 Apr - 15 Jun, and the second prawn season extends from 1 Aug – 30 Nov. Acquisition of the Beehive survey will not commence prior to 15 June. Hence, the survey period will not overlap the first fishing season or the main migration of juvenile prawns in the JBG, with the migration of the main	**Partial**

		cohort occurring between November and March, with a possible second cohort migrating from April to June.	
Schedule survey to avoid receptors seasonal timings – zooplankton	Reducing the survey timing window can lead to increased costs due to stand by time or full acquisition of data not being achieved. This can have a significant cost (> $1 million).	Avoidance of receptors reducing potential impacts. There is generally less seasonality in zooplankton biomass in tropical regions and thus the time of the year that a survey is conducted is less important (from a zooplankton perspective: Richardson et al. 2017).	**No**
Undertake the survey during the day when potentially less zooplankton is near the surface	Only conducting the survey during the day would double the survey time and cost this can have a significant cost (> $1 million).	No significant spawning or fauna reliant on plankton are identified in the area. It is also unclear how effective this control would be considering the increased costs and time of the survey as such the costs outweigh the environmental benefits.	**No**
Conduct survey into or across the prevailing currents to reduce likelihood of plankton being impacted multiple times by the seismic source	The predominant current directions in the survey area are northwest or southeast, which 90° to the survey line direction.	No significant spawning or fauna reliant on plankton are identified in the area and potential impacts are low. The survey will be acquired across the direction of the prevailing currents in the area.	**Yes**
EPBC Act Policy Statement 2.1 - Interaction between Offshore seismic exploration: Part B. B.2. Additional night-time/poor visibility procedures	Increased restrictions for poor visibility / night time conditions (e.g. cessation of night-time / low-visibility operations) may potentially double the time to undertake the survey and significantly increase costs. Increasing the overall duration of the survey will also result in a longer overall period of sound exposure and increased impacts to other receptors and stakeholders in the JBG.	Fauna numbers are expected to be low as most fauna identified in the area are transitory, with the exception of foraging turtles. Due the small area where acquisition will be undertaken (~ 2.5%) compared to the turtle foraging area it is unlikely that significant turtles will be encountered. In addition, turtles are expected to exhibit a temporary behavioural avoidance response to the active seismic source. EPBC Act Policy Statement 2.1 Part A: night time and low visibility procedures will already be applied to both	**No**

		whales and turtles, as outlined above. As such the significant costs and delays associated with additional night-time / poor visibility procedures are disproportionate to the relatively limited additional environmental benefit that these will provide.	
EPBC Act Policy Statement 2.1 - Interaction between Offshore seismic exploration: Part B. B.3.Spotter Vessel(s) and Aircraft	There are significant costs to the project associated with the contracting and operation of additional vessels (or a spotter plane)	Fauna numbers are expected to be low as most fauna identified in the area are transitory, with the exception of foraging turtles. Due the small area where acquisition will be undertaken (~ 2.5%) compared to the turtle foraging area it is unlikely that significant turtles will be encountered. As such the costs outweigh the environmental benefits	**No**
EPBC Act Policy Statement 2.1 - Interaction between Offshore seismic exploration: Part B. B.4 Increased Precaution zones and Buffer Zones	The application of existing low power zones has been applied to turtle presence. As such there is the potential that the application of Low power zones when turtles are observed will result in increased non-productive time at a cost to the project	The environmental benefit of including observations for turtles within low power zones is considered marginal given the current information regarding the sensitivity of turtles to sound. However, given that the area overlaps turtle foraging BIA, the benefit is considered to outweigh the cost. Further increased precaution zones and buffer zones have also been considered in relation to adaptive management measures (see below).	**Yes**
EPBC Act Policy Statement 2.1 - Interaction between Offshore seismic exploration: Part B. B.5. Passive acoustic Monitoring	The cost to implement PAM is considerable as it requires additional personnel and equipment that needs to be run for the duration of the program.	PAM only applies for cetaceans and as there are no BIAs associated with cetaceans in or near the survey area large numbers are not expected to be encountered. As such the costs outweigh the environmental benefits.	**No**

EPBC Act Policy Statement 2.1 - Interaction between Offshore seismic exploration: Part B. B.6. Adaptive Management	Applying additional restrictions to the survey through adaptive management could potentially result in increased survey time with additional costs.	Fauna numbers are expected to be low as most fauna identified in the area are transitory, with the exception of foraging turtles. There are no BIAs associated with cetaceans in or near the survey areas and so large numbers are not expected to be encountered. The area where acquisition will be undertaken is relatively small (~ 2.5%) compared to the turtle foraging area it is unlikely that significant turtles will be encountered. Thus the implementation of an adaptive management plan is not considered to provide significant additional environmental benefit. As such, the potential costs or implementing adaptive management for cetaceans outweigh the environmental benefits. However, given the proximity of turtle foraging BIAs and adjacent 'habitat critical for the survival of a species' for flatback turtles, it is considered reasonably practicable to apply adaptive management if the numbers of observed turtles are higher than expected. Adaptive management will take the form of increased precaution zones and buffer zones for turtles, as outlined in the environmental performance standards below.	**No (cetaceans)** **Yes (turtles)**

Relocation of the survey vessel to alternative survey lines if the numbers of observed turtles are higher than expected	Relocation of the survey vessel to alternative survey lines if the numbers of observed turtles are higher than expected may result in a number of unexpected survey delays due to the time taken to relocate and recommence acquisition. The Beehive Acquisition Area is only ~ 975 km^2 in area, comprising a limited number of 35 km long (8-hour duration) pre-determined sail lines aligned in a south-west to north-east direction. The Acquisition Area is approximately 28 km across (north-west to south-east). Therefore, the seismic survey vessel and towed array is already constrained to a small survey area, whereby the vessel will cross from one end of the Acquisition Area to the other 2-3 times in a 24-hour period. Therefore, there is limited space available within the Acquisition Area to accommodate any meaningful relocation to alternative lines. Relocating to alternative survey lines may therefore not be possible and is instead likely to result in increased shut-down periods and delays.	Relocating to alternative lines is not expected to provide any material additional environmental benefit, for the following reasons: • the Acquisition Area is relatively small and is entirely within a turtle foraging BIA. Therefore, relocating to alternative lines does not provide any additional assurance that turtles will be present in lower numbers in any other part of the Acquisition Area; • sail lines are orientated in a south-west to north-east direction. Therefore, relocating to lines further to the north-west or the south-east does not result in any difference in proximity to the 'habitat critical for the survival of a species' for flatback turtles and does not provide any additional assurance that turtles will be present in lower numbers in any other part of the Acquisition Area. Given the small Acquisition Area, the potential costs, delays and limitations of implementing relocation controls, the already limited risk of behavioural impacts to turtles with the other proposed control measures in place for turtles, and the limited/no additional environmental benefit that this control will provide, it is not considered practicable.	**No**

Avoiding infill activities / overlapping sail lines during infill activities	Methods for reducing the requirement for infill activities are: • Steerable streamers to help maintain consistent cable shape which leads to less areas requiring infill. • Using a technique where towed streamers are wider at tail than front. This has proven to significantly reduce infill requirements without affecting technical objectives. The aim is to minimise the amount of infill required as this increases the survey time and costs. Reducing the amount of infill also means a reduction in overlapping lines.	Reducing the requirement for infill activities reduces survey duration and overlapping survey lines. These both reduce noise exposure to fauna as well as costs.	**Yes**
Reducing the number of lines or shot points	The survey design has been developed to obtain the acquisition information in the most effective manner. The shot point spacing, which impacts the number of shots, has been optimised to be able to adequately image the data. If the shot point spacing is increased (reduction in shots) it becomes less effective to be able to differentiate between the primary signal and unwanted noise. The survey lines have been designed to be the least number and shortest survey duration while still meeting the acquisition objectives. The survey lines have been design to be the least and shortest while still meeting the acquisition objectives. The shortest and least numbers of lines reduces the time and therefore the cost of the survey.	Reducing the number of shots and lines would reduce noise associated impacts to fauna. The number of shots and lines have been reduced to the minimum required to achieve the acquisition objectives most efficiently and cost effectively. Further reductions would compromise the acquisition of data.	**No**

Increase minimum number of streamers for the survey to 16	Whilst increasing the number of streamers would reduce the number of vessel passes for the survey, and result in a shorter survey duration, there are several issues that would result. Geophysically, due to the shallow water depths, an increased tow width means a lesser percentage of the survey area will adequately image the seabed, which in turn will significantly affect Santos's ability to remove the multiple energy within processing utilising 3D SRME algorithms, thus potentially compromising the geophysical objectives of the survey. Operationally, an increased number of streamers will result in increased depth of the lead-ins at the front end of the array, thus limiting the water depth the survey vessel can operate within. This has already been identified as a problem for a significant percentage of the survey area Commercially, there is a lack of survey vessels capable of towing 16 x 6/8 km spreads at 100 m+ separation, which means that the competitive tender becomes more of an issue, Furthermore, this raises issues related to availability of vessels. Whilst the Santos acknowledges that the larger in-sea towing configurations will reduce the number of vessel passes, the above factors also need to be taken into account. Santos considers operational constraints, geophysical objectives, environmental concerns and commercial viability when determining the	Increasing the minimum number of streamers would increase line spacing, thereby reducing the number of lines and the area affected by peak received noise levels, and also reducing survey duration.	**No**

	optimum towing configuration. In this case, the primary factor is that of operational water depths, which precludes the usage of large streamer spreads.		
Sound source verification	Verification of equivalent source levels prior to commencement of the survey would add considerable additional costs to the survey, as it requires in-field deployment of hydrophones and a single line pass of at least 6 km in length.	A sound source verification (SSV) process would enable the seismic contractor that the proposed airgun array has equivalent source levels that match the specifications used in the acoustic modelling study. The equivalent source levels predicted in the acoustic modelling study for the Beehive survey will already have been validated by an SSV process conducted prior to survey commencement.	**No**

Residual Risk Ranking			
Potential Impact	**Consequence**	**Likelihood (of Consequence)**	**Residual Risk**
Physical, such as mortality or mortal injury – plankton	I	Possible (c)	Very Low (1)
Physiological impacts – invertebrates	III	Unlikely (b)	Low (2)
Impacts to commercial catch rates – prawns	I	Remote (a)	Very Low (1)
Physical, such as mortality or mortal injury - fish	I	Unlikely (b)	Very Low (1)
Physical, such as injury including temporary hearing loss - fish	I	Unlikely (b)	Very Low (1)
Behavioural, such as disturbance or displacement or impairment/mask the ability to navigate, find food or communicate - fish	III	Possible (c)	Low (2)
Impacts to commercial catch rates – fish	III	Possible (c)	Low (2)
Physical, such as mortality or mortal injury – sharks and rays	I	Unlikely (b)	Very Low (1)
Physical, such as mortality or mortal injury – turtles and sea snakes	II	Unlikely (b)	Very Low (1)
Behavioural, such as disturbance or displacement or impairment/mask the	II	Possible (c)	Low (2)

ability to navigate, find food or communicate – turtles and sea snakes			
Physical, such as injury including permanent or temporary hearing loss – marine mammals	II	Unlikely (b)	Very Low (1)
Behavioural, such as disturbance or displacement or impairment/mask the ability to navigate, find food or communicate – marine mammals	II	Possible (c)	Low (2)
Acoustic masking – marine mammals	III	Unlikely (b)	Low (2)
Impacts to the conservation values of the JBG Marine Park	II	Unlikely (b)	Very Low (1)

Environmental Performance Outcomes, Standards & Measurement Criteria

EPO	Control Measures & EPS	MC
Undertake seismic acquisition in a manner that prevents injury and PTS impacts to cetaceans and turtles resulting from seismic sound emissions, consistent with EPBC Policy Statement 2.1	*Survey Timing* Survey undertaken within time period 15 June – 31 October 2018 or 2019.	Daily reports
	EPBC Act Policy Statement EPBC Act Policy Statement Part A will be implemented for the survey with the following precaution zones for whales and turtles: • Observation zone: 3+ km horizontal radius from the acoustic source. • Low power zone: 2 km horizontal radius from the acoustic source. • Shut-down zone: 500 m horizontal radius from the acoustic source. The pre start-up visual observation conducted by the MFOs will extend for a timeframe of at least 40 min.	MFO records
	EPBC Act Policy Statement Part B1: MMO • Two trained MFOs will undertake observations for fauna during daylight hours, for the duration of the survey. • Given the location of the survey area, preference will be given to employing	MFO records MFO has previous experience as an MFO

	MFOs with previous experience with marine turtle observations and interactions.	
	Adaptive Management Procedure If the observed numbers of turtles are higher than expected, as determined by there being 3 or more shut-downs / power downs for turtles in 24 hours, the following adaptive management procedure will be implemented: • Increased Precaution zones and Buffer Zones: ➢ Observation zone: 4+ km horizontal radius from the acoustic source (where conditions permit). ➢ Low power zone: 3 km horizontal radius from the acoustic source. ➢ Shut-down zone: 1 km horizontal radius from the acoustic source.	MFO records
Seismic survey conducted in compliance with DoF Guidance Statement on Undertaking Seismic Surveys in WA Waters	*DoF Guidance Statement on Undertaking Seismic Surveys* The following will be implemented: • 'Soft Starts" for every event.	MFO records
Undertake seismic acquisition in a manner that reduces the likelihood of plankton being impacted multiple times by the seismic source	*Survey Design* • The survey will be acquired across the direction of the prevailing currents in the area. • The predominant current directions in the survey area are northwest or southeast, which are 90° to the survey line direction.	Survey line plan Daily reports
Undertake seismic acquisition in a manner that prevents long term or population impacts to invertebrates, fish and turtles	*Array Volume* A seismic source of ≤2,380 in^3 will be used to meet the geophysical objectives of the survey.	Contractor records of airgun array configuration Confirmation of maximum total array capacity from Santos Offshore Representative and MFO
	Source Operation • The source will not be operated at full power outside the Acquisition Area.	Daily reports MFO records

	• There will be no discharge of the source in waters outside the Operational Area. • Soft start procedures will be conducted in accordance with Part A of EPBC Policy Statement 2.1.	
	Survey Duration • The survey will have a maximum duration of 30 days.	Daily reports
	Survey Timing • Acquisition of the Beehive survey will not commence prior to 15 June.	Daily reports
	EPBC Act Policy Statement 2.1 • EPBC Act Policy Statement 2.1 Part A will be implemented for the survey for turtles. • The pre start-up visual observation conducted by the MFOs will extend for a timeframe of at least 40 min. • EPBC Act Policy Statement 2.1 Part B1: Two trained MFOs will undertake observations for fauna during daylight hours, for the duration of the survey. Given the location of the survey area, preference will be given to employing MFOs with previous experience with marine turtle observations and interactions.	Daily reports MFO records
	Adaptive Management Procedure (see above)	MFO records
Undertake seismic acquisition in a manner that ensures that noise levels above turtle mortality or mortal injury thresholds, or the turtle behavioural disturbance threshold, are not received at the 'habitat critical for the survival of a species' for flatback turtles, consistent with the requirements of the	*Array Volume* • A seismic source of ≤2,380 in^3 will be used to meet the geophysical objectives of the survey.	Record of airgun array configuration
	Source Operation • The source will not be operated at full power outside the Acquisition Area. • There will be no discharge of the source in waters	Daily reports MFO records

Recovery Plan for Marine Turtles in Australia 2017 – 2027	outside the Operational Area. • Soft start procedures will be conducted in accordance with Part A of EPBC Policy Statement 2.1.	
	Survey Duration • The survey will have a maximum duration of 30 days.	Daily reports
	EPBC Act Policy Statement 2.1 • EPBC Act Policy Statement 2.1 Part A will be implemented for the survey for turtles. • The pre start-up visual observation conducted by the MFOs will extend for a timeframe of at least 40 min. • EPBC Act Policy Statement 2.1 Part B1: Two trained MFOs will undertake observations for fauna during daylight hours, for the duration of the survey. Given the location of the survey area, preference will be given to employing MFOs with previous experience with marine turtle observations and interactions.	Daily reports MFO records
	Adaptive Management Procedure (see above)	MFO records
Undertake seismic acquisition in a manner that prevents injury to green and olive ridley turtles within foraging BIA, and also prevents exclusion of turtles from these foraging BIA	*Array Volume* • A seismic source of ≤2,380 in^3 will be used to meet the geophysical objectives of the survey.	Record of airgun array configuration
	Source Operation • The source will not be operated at full power outside the Acquisition Area. • There will be no discharge of the source in waters outside the Operational Area. • Soft start procedures will be conducted in accordance with Part A of EPBC Policy Statement 2.1.	Daily reports MFO records

	Survey Duration • The survey will have a maximum duration of 30 days.	Daily reports
	EPBC Act Policy Statement 2.1 • EPBC Act Policy Statement 2.1 Part A will be implemented for the survey for turtles. • The pre start-up visual observation conducted by the MFOs will extend for a timeframe of at least 40 min. • EPBC Act Policy Statement 2.1 Part B1: Two trained MFOs will undertake observations for fauna during daylight hours, for the duration of the survey. Given the location of the survey area, preference will be given to employing MFOs with previous experience with marine turtle observations and interactions.	Daily reports MFO records
	Adaptive Management Procedure (see above)	MFO records
Undertake seismic acquisition in a manner that ensures that potential impacts from the survey on conservation values of the JBG Marine Park will be consistent with the relevant Australian IUCN Reserve Management Principles and management plan objectives	*Array Volume* A seismic source of ≤2,380 in^3 will be used to meet the geophysical objectives of the survey.	Record of airgun configuration
	Source Operation • The source will not be operated at full power outside the Acquisition Area. • There will be no discharge of the source in waters outside the Operational Area. • Soft start procedures will be conducted in accordance with Part A of EPBC Policy Statement 2.1.	Daily reports MFO records
	Survey Duration The survey will have a maximum duration of 30 days.	Daily reports
	EPBC Act Policy Statement 2.1 • EPBC Act Policy Statement 2.1 Part A will be	Daily reports MFO records

	implemented for the survey for turtles. • The pre start-up visual observation conducted by the MFOs will extend for a timeframe of at least 40 min. • EPBC Act Policy Statement 2.1 Part B1: Two trained MFOs will undertake observations for fauna during daylight hours, for the duration of the survey. Given the location of the survey area, preference will be given to employing MFOs with previous experience with marine turtle observations and interactions.	
Limitation on amount of infill acquired during the survey	*Infill Component* • Infill lines will comprise < 20% of the survey area	Records of % infill lines

	Streamer Configuration
	• The streamer configuration will consist of:
	  ○ steerable streamers
	  ○ fan-mode technique
		Record of streamer configuration

Demonstration of Acceptability		
Is residual risk determined to be 1 and the ALARP Decision Framework A applied? If No ALARP must be demonstrated and the following must be met.	No – there is the potential of behavioural disturbances to fauna and physiological impacts to prawns. The assessment in Section 7.1.5.1 Plankton takes into account new research in regards to seismic noise impacts to plankton by McCauley et al. (2017) and modelling of this new data by CSIRO (Richardson et al. 2017). No change in the level of consequence was identified and impacts are still assessed as acceptable.	
Principles of ecologically sustainable development met?	Yes Decision making processes integrated long and short term economic, environmental, social and equitable considerations by selecting a restricted survey time that avoids the NPF season. The assessment of seismic noise impact to plankton was updated to include new research in regards to seismic noise impacts to plankton and further controls assessed to ensure impacts remained ALARP. No threats of serious of irreversible environmental damage were identified from the risk assessment. The principal of inter-generational equity are not compromised as potential disturbance impacts were identified to be localised and short term. Conservation of biological diversity and ecological integrity have been considered in decision making as activity seen as	

	acceptable as potential disturbance impacts were identified to be localised and short term. Cost benefit analysis has been used to determine applicable controls based on localised and short term impacts.
Legal and other requirements met?	Yes EPBC Act Policy Statement 2.1 Part A And B1 and the mitigation strategies from the DoF Guidance Statement on Undertaking Seismic Surveys in WA Waters will be implemented. Two trained and experienced MFOs will be used for the duration of the survey. Policies, guidelines, plans of management, recovery plans, threat abatement plans and other relevant advice issued by government agencies relevant to noise sensitive receptors have been taken into account in assessing potential risks and impacts. The Recovery Plan for Marine Turtles in Australia 2017 – 2027 identifies seismic noise as a threat to turtles. The plan identifies that soft start provisions may afford protection to marine turtles. As the surveys occurs within foraging BIA for green and olive ridley turtles, and adjacent to 'habitat critical to survival of a species' for flatback turtles, this control will be implemented. The Blue, Finn and Sei Whale Recovery Plan and the Humpback Whale Recovery Plan (though no longer in force) identified acoustic pollution including seismic survey activity as a threat. Recommended action that all seismic surveys must be undertaken consistently with the EPBC Act Policy Statement 2.1 – Interaction between offshore seismic exploration and whales, will be implemented.
Santos policy and standards met?	Yes As per the EHS Policy Santos understands and has controls in place to ensure potential disturbance impacts are managed and monitored.
Stakeholder expectations met?	Yes. No overlap between Acquisition and Operational areas with JBG Marine Park. MNES – implementation of EPBC Act Policy Statement 2.1 for whales and turtles.

7.2 VESSEL AND HELICOPTER NOISE

7.2.1 *Hazard*

Noise emission subsea will occur from:

- Vessel engines and thrusters.
- Helicopter rotors.

7.2.2 *Environment that May Be Affected by the Hazard*

All vessels emit underwater noise via machinery on the vessels transmitting sound through the hull and from propeller cavitation which is the loudest source. Kent et al. (2016) details that propeller cavitation noise is broadband due to the range of bubble sizes involved, from a few Hz to tens of kHz. Survey vessels in the absence of an operating acoustic source have been measure to have a broadband source level (SL_{bb}) of 180–191 dB re 1 µPa @ 1 m (Hannay et al. 2004; Wyatt 2008 in Kent et al. 2016). This is on par with fishing vessels that have been measured to have a broadband source level (SL_{bb}) of 174–195 dB re 1 µPa @ 1 m (Kent et. al. 2016).

Studies of the radiating underwater sound generated from the thrusters and propellers of support vessels when holding position indicate highest measured levels of up to 182 dB re 1Pa with levels of 120 dB re 1 µPa SPL RMS measured at 3–4 km (McCauley 1998).

Sound pressure in the water directly below a helicopter is greatest at the surface and diminishes with increasing receiver depth. Richardson et al. (1995) reports figures for a Bell 214 helicopter (stated to be one of the noisiest) being audible in air for four minutes before it passed over underwater hydrophones but detectable underwater for only 38 seconds at 3 m depth and 11 seconds at 18 m depth. Thus, noise from helicopter activities would be localised.

7.2.3 *Sensitive Environmental Receptors with the Potential to occur within the EMBA*

Based upon the receptors identified in *Table 5.2*, those known to be sensitive to vessel and/or helicopter underwater sound include:

- Fish.
- Sharks and rays.
- Turtles.
- Marine mammals - whales and dolphins (cetaceans).

7.2.4 *Known and Potential Environmental Impacts*

Given the levels of noise predicted potential impacts to fauna would be limited to non-physiological effects such as

- Behavioural changes.
- Localised avoidance.

7.2.5 *Evaluation of Environmental Impacts*

Receptor Sensitivity

Activities that generate underwater noise can affect marine fauna by interfering with aural communication, eliciting changes in behaviour or, in extreme cases, by causing physiological damage to auditory organs. The potential for noise from anthropogenic sources to impact fauna depends on a range of factors, including the intensity and frequencies of the noise, prevailing ambient noise levels and the proximity of noise sensitive species.

Hearing damage in marine mammals from shipping noise has not been widely reported (OSPAR 2009) and there is no direct evidence of mortality or potential mortal injury to fish or sea turtles from ship noise (Popper et al. 2014).

There are no noise thresholds for continuous noise sources, such as vessels, for fauna - such as fish without a swim bladder (sharks, rays), fish with a swim bladder (but not used in hearing), or turtles (Popper et al. 2014). Popper et al. (2014) includes proposed thresholds for recoverable injury and TTS based on exposure of goldfish to white noise. Popper et al. (2014) identified that responses from fauna to vessel noise are likely to be low for mortality, mortal injury and recoverable injury, moderate for TTS near the vessel (tens of metres), and low at intermediate (hundreds of metres) to far distances (thousands of metres), respectively. Masking and behavioural changes are more likely near the vessel (tens of metres) and at intermediate distances (hundreds of metres).

Sound traveling from a source in the air such as a helicopter, to a receiver underwater is affected by both in-air and underwater propagation processes, which are further complicated by processes occurring at the air-seawater surface interface. The received level underwater depends in a complex way on source altitude and lateral distance, receiver depth, water depth, and other variables.

Extent and Duration of Exposure and Identified Potential Impact

For the majority of the time that the seismic vessel is in the area the seismic source will be the dominate noise source.

Underwater noise generated by the presence of the survey vessels may result in changes in behaviour of marine fauna such as disturbance, avoidance or attraction. Underwater noise from the survey vessels is transient and is typical of other underwater noise emitted by commercial shipping or fishing vessels.

There are no breeding, feeding or resting areas for cetaceans, sharks or rays in or near the Acquisition Area, hence, impacts would be to transiting cetaceans, sharks or rays and would be limited to local avoidance of the area. There are also habitats within the Operational Area likely to support reef or site attached fish. A shallow bank, which forms part of the Carbonate bank and terrace system of the Sahul Shelf KEF, is located within the EMBA and may potentially support reef or site attached fish.

The Acquisition Area overlaps foraging BIAs for green and olive ridley turtles and the EMBA overlaps 'habitat critical to survival of a species' for the flatback turtle and therefore, turtles may move away from areas where the vessels are operating.

Based on the noise levels likely from the support vessels and that they will be moving throughout the Operational Area, it is possible impacts would be localised, based on a smaller area than from the seismic source noise levels, and short term (survey duration of up to 30 days) to fauna of environmental value.

Based on the extremely short duration that helicopter noise is likely to be heard underwater (seconds to minutes) and the low frequency of helicopter flights to the seismic vessel during the survey (once a fortnight for crew change) it is unlikely that fauna in the area will be impacted by localised and short term noise from a helicopter.

<u>Summary</u>

Consequence Level: If the activity results in a disturbance to marine fauna from vessel or helicopter noise, there is potential for localised and short term impacts to animals of environmental value – (II).

Likelihood Level (Vessel): For this activity, localised and short term impacts to animals of environmental value resulting from vessel noise is considered Possible (c).

Likelihood Level (Helicopter): For this activity, localised and short term impacts to animals of environmental value resulting from helicopter noise is considered Unlikely (b).

Table 7.14 Vessel and helicopter noise risk assessment

ALARP Decision Context	
Decision Context	**Justification**
A	The use of vessel and helicopters offshore is well practiced and potential impacts from vessel underwater sound is well studied and understood. Sound levels associated with vessels and helicopters are not large enough to result in significant impacts. Though the area of potential impact overlaps turtle foraging BIA, in the worst case it could exclude turtles from the Operational Area for up to 30 days. No objections or concerns were raised by relevant stakeholders regarding the generation of underwater noise from vessel or helicopters. Consequently, Santos believes that decision context A be applied to this hazard.
Control Measure Identification	
Good Practice Control Measure	**Control Measure Source**

EPBC Regulations 2000 – Part 9 Division 8.1 Interacting with cetaceans	The Australian National Guidelines for Whale and Dolphin Watching (DEWHA 2005) was developed jointly by the Australian and all state and territory governments through the Natural Resource Management Ministerial Council and describes strategies to ensure cetaceans are not harmed during interactions with vessels and aircraft. These guidelines will be applied to turtles. By implementing this procedure, exposure of noise emissions from vessels and helicopter operation will be minimised.

Residual Risk Ranking			
Potential Impact	**Consequence**	**Likelihood (of Consequence)**	**Residual Risk**
Disturbance to marine fauna from vessel noise	II	Possible (c)	Low (2)
Disturbance to marine fauna from helicopter noise	II	Unlikely (b)	Very Low (1)

Environmental Performance Outcomes, Standards & Measurement Criteria		
EPO	**Control Measures & EPS**	**MC**
Vessels and helicopters meet the requirements of the EPBC Regulation Part 8	EPBC Regulations Part 8 Vessels will meet the requirements of Part 8 of the EPBC Regulations specifically: • Travel at less than 6 knots within the cautionary zone of a cetacean (150 m radius for dolphins, 300 m for whales and turtles). • Do not approach closer than the caution zones for whales, turtles and dolphins. • If cetacean or turtle shows signs of disturbance move away at a constant speed less than 6 knots.	MFO Records
	EPBC Regulations Part 8 Helicopters will meet the requirements of Part 8 of the EPBC Regulations specifically: • Must not operate at a height lower than 1,650 feet or within a horizontal radius of 500 m of a cetacean or turtle.	MFO records.

Demonstration of Acceptability	
Is residual risk determined to be 1 and the ALARP Decision Framework A applied?	No – there is the potential of behavioural disturbance to fauna.

If No ALARP must be demonstrated and the following must be met.	
Principles of ecologically sustainable development met?	Yes - Decision making processes integrated long and short term economic environmental, social and equitable considerations ensuring that the area of disturbance is localised. No seasonal component to foraging within the BIA was identified. No threats of serious or irreversible environmental damage were identified from the risk assessment. The principles of inter-generational equity are not compromised as potential disturbance impacts were identified to be localised and short term. Conservation of biological diversity and ecological hierarchy have been considered in decision making as activity seen as acceptable as potential disturbance impacts were identified to be localised and short term.
Legal and other requirements met?	Yes – EPBC Regulation Part 8 will be implemented to cover both cetaceans and turtles. Policies and guidelines, plans of management, recovery plans, threat abatement plans and other relevant advice issued by government agencies relevant to noise sensitive receptors have been taken into account in accessing potential risks and impacts. The Recovery Plan for Marine Turtles in Australia 2017 – 2027 identifies vessel noise as a threat to turtles, thus separation distances as per the EPBC Regulation Part 8 will be implemented for vessels. The Conservation Management Plan for Blue Whales identified shipping as a threat. Actions from this plan were only relevant to Blue whales BIAs which are not in or near the Acquisition Area. Blue, Fin and Sei Whale Recovery Pan, though no longer in force, did identify vessel noise as a threat. Recommended action of assess and manage physical disturbance and development activities, has been implemented via the impact assessment.
Santos policy and standards met?	Yes – As per the EHS Policy Santos understands and has controls in place to ensure potential disturbance impacts are managed and monitored.
Stakeholder expectations met?	Yes – EPBC Regulation Part 8 will be implemented for cetaceans and turtles. The Beehive 3D MSS will be undertaken largely within a seasonal closure area for banana prawn fishing in the southern JBG. MNES – Implementation of EPBC Act Policy Statement 2.1 for whales and turtles.

7.3 Light Emissions

7.3.1 *Hazard*

The seismic and support vessels will operate during day and night. The vessels are required to be lit for safety and navigational purposes and for safe deck operations whilst working at night.

7.3.2 *Environment that May Be Affected by the Hazard*

Lighting from the seismic and support vessels will be localised to a small radius of light glow around the vessels and temporary in nature as the vessel transits.

7.3.3 *Sensitive Environmental Receptors with the Potential to occur within the EMBA*

Based upon the receptors identified in, those known to be sensitive to light emissions include:

- Turtles.
- Marine Birds.

There is no evidence to suggest that artificial light sources adversely affect the migratory, feeding or breeding behaviours of cetaceans. Cetaceans predominantly utilise acoustic senses to monitor their environment rather than visual sources (Simmonds et al. 2004).

7.3.4 *Known and Potential Environmental Impacts*

Given the temporary nature of vessel lighting, the predicted potential impacts to fauna would be limited to:

- Localised attraction.

7.3.5 *Evaluation of Environmental Impacts*

7.3.5.1 *Turtles*

The Acquisition and Operational areas are located within a foraging BIA for green and olive ridley turtles. The Operational Area abuts the 'habitat critical to survival of a species' for flatback turtles in the southern JBG. Lighting from moving vessels has not been identified as a risk to foraging turtles in the EPA Environmental Assessment Guideline No. 5 Protecting Marine Turtles from Light Impacts (EPA 2010), the DoEE Species Profile and Threats Database or the Recovery Plan for Marine Turtles in Australia 2017 – 2027 (DoEE 2017s).

<u>Extent and duration of exposure and identified potential impact</u>

Lighting from seismic and support vessels will be localised to a small radius of light glow around the vessels and temporary in nature as the vessel transits through the Acquisition and Operational areas over the short duration of the survey (maximum 30 days). The Acquisition Area is located > 10 km from the 'habitat critical to survival of a species' for flatback turtles adjacent to Cape Domett, however, the southwest boundary of the Operational Area is contiguous with the outer boundary of this habitat. The Acquisition Area does overlap with the foraging BIA for green and olive ridley turtles, and the EMBA overlaps with a portion of the 'habitat critical to survival of a species' for flatback turtles (*Figure 5.15*; *Figure 5.16*).

Lighting from moving vessels has not been identified as a risk to foraging turtles and consequently, as light emissions would be localised, within metres of the vessel, and short term as the vessel moves through the area and for a duration of up to 30 days, impacts to fauna of an environmental value are remote.

7.3.5.1 Marine Birds

Seabirds may be attracted to vessels at night due to the light glow. Bright lighting can disorientate birds, thereby increasing the likelihood of seabird injury or mortality through collision with infrastructure, or mortality from starvation due to disrupted foraging at sea (Wiese et al. 2001 in DSEWPaC 2012e). Nesting birds may be disorientated where lighting is adjacent to rookeries, however, this is not identified as a potential impact as the nearest rookeries are on land, a minimum of 50 km from the EMBA.

<u>Extent and duration of exposure and identified potential impact</u>

Lighting from the seismic and support vessels will be localised to a small radius of light glow around the vessels and temporary in nature as the vessel transits through the Acquisition and Operational areas over the short duration of the survey (maximum 30 days). No biologically important areas or specific aggregation areas have been identified as potentially occurring within the EMBA. A breeding BIA for the lesser crested tern is located adjacent to the EMBA, in the southern JBG. As such, it is only expected that transient individuals will be exposed to changes in ambient light levels. Consequently, as light emissions would be localised, within metres of the vessel, and short term as the vessel moves through the area and for a duration of up to 30 days, impacts to fauna are remote.

<u>Summary</u>

Consequence Level: If the activity results in a localised attraction of fauna to vessel lighting, there is the potential for localised and short-term environmental impacts to animals of environmental value – (II).

Likelihood Level: For this activity the localised attraction of fauna to vessel lighting resulting in a localised and short-term environmental impact is considered Remote– (a).

Table 7.15 Lighting Risk Assessment

<table>
<tr><th colspan="4">ALARP Decision Context</th></tr>
<tr><th>Decision Context</th><th colspan="3">Justification</th></tr>
<tr><td>A</td><td colspan="3">The use of vessels offshore and lighting at night is normal operations. Impacts of light to sensitive receptors are well understood. Though light sensitive marine fauna were identified as having the potential to be present in the area, there is a high level of certainty that impacts would be localised and temporary due to the size of the vessels, transitory nature of the vessels and short duration of the survey. There is little uncertainty associated with this aspect. No objections or concerns were raised by relevant stakeholders regarding light emissions from vessels. Consequently, Santos believes that decision context A be applied to this hazard.</td></tr>
<tr><th colspan="4">Control Measure Identification</th></tr>
<tr><th colspan="2">Good Practice Control Measure</th><th colspan="2">Control Measure Source</th></tr>
<tr><td colspan="2">Vessel lighting limited to that required for safe navigation under:
• Marine Order Part 30 (Prevention of Collisions) 2016
• Marine Order 59 (Offshore Support Vessel Operations) 2011</td><td colspan="2">Lighting is required on vessels to ensure safe operations:
• Marine Order Part 30 (Prevention of Collisions) 2016
• Marine Order 59 (Offshore Support Vessel Operations) 2011
Lighting not required to meet navigational and safe operational requirements will be prevented.</td></tr>
<tr><th colspan="4">Residual Risk Ranking</th></tr>
<tr><th>Potential Impact</th><th>Consequence</th><th>Likelihood (of Consequence)</th><th>Residual Risk</th></tr>
<tr><td>Localised attraction of fauna to vessel lighting</td><td>II</td><td>Remote (a)</td><td>Very Low (1)</td></tr>
<tr><th colspan="4">Environmental Performance Outcomes, Standards & Measurement Criteria</th></tr>
<tr><th>EPO</th><th colspan="2">Control Measures & EPS</th><th>MC</th></tr>
<tr><td>Lighting reduced to that required for navigational and safe operations to limit localised attraction of marine fauna</td><td colspan="2">Vessel lighting requirements
External lights will be directed onto deck, except where required for navigational purposes or safe operations.</td><td>Lighting inspection</td></tr>
<tr><th colspan="4">Demonstration of Acceptability</th></tr>
<tr><td colspan="2">Is residual risk determined to be 1 and the ALARP Decision Framework A applied?
If No ALARP must be demonstrated and the following must be met.</td><td colspan="2">Yes</td></tr>
<tr><td colspan="2">Principles of ecologically sustainable development met?</td><td colspan="2">Evaluation not required</td></tr>
</table>

Legal and other requirements met?	Evaluation not required
Santos policy and standards met?	Evaluation not required
Stakeholder expectations met?	Evaluation not required

7.4 *ATMOSPHERIC EMISSIONS*

7.4.1 *Hazard*

The following vessel activities will generate atmospheric emissions:

- Combustion of marine diesel from vessel engines and deck equipment.
- Incineration of wastes.

7.4.2 *Environment that May Be Affected by the Hazard*

Air emissions will disperse rapidly in prevailing winds and, given the volumes involved, are expected to result in a temporary and highly localised effect on ambient air quality.

7.4.3 *Sensitive Environmental Receptors with the Potential to occur within the EMBA*

No receptors identified in *Table 5.1* are expected to be exposed to atmospheric emissions.

7.4.4 *Known and Potential Environmental Impacts*

The known and potential environmental impacts of atmospheric emissions are:

- Localised and temporary decrease in air quality.
- Contribution to global greenhouse gas effect.

7.4.5 *Evaluation of Environmental Impacts*

The combustion of diesel in vessels may result in a localised reduction in air quality. Greenhouse gases will be produced via the combustion of diesel in vessel engines, generators and deck equipment. Infrequent, incineration of a small volume of solid waste may also occur.

Due to the short duration of the survey (maximum 30 days) and proximity to settlements (130 km from the EMBA), air emissions are not expected to result in a detectable impact to sensitive receptors. In addition to this, total air emissions generated from the activity would represent an insignificant contribution to overall greenhouse gas emissions. Consequently, air emissions would be localised and short term. Therefore potential impacts are unlikely.

Summary

Consequence Level: It is expected that a localised and temporary decrease in air quality and contribution to global greenhouse gas emissions has the potential to result in localised and short term environmental impacts – (I).

Likelihood Level: For this activity, a localised and short term decrease in air quality or contribution to global greenhouse gas emissions resulting in localised and short term impacts to sensitive environmental receptors is Remote – (a).

Table 7.16 Atmospheric emissions risk assessment

ALARP Decision Context	
Decision Context	**Justification**
A	The use of vessels offshore and generation of atmospheric emissions is normal operations. The management of vessel air emissions is well practiced and understood. Given the remote offshore location of the Beehive 3D MSS, no sensitive environmental receptors were identified. There is little uncertainty associated with this aspect. The management of vessel air emissions is well regulated. No objections or concerns were raised by relevant stakeholders regarding atmospheric emissions from vessels. Consequently, Santos believes that decision context A be applied to this hazard.

Control Measure Identification	
Good Practice Control Measure	**Control Measure Source**
Maritime Legislation Amendment (Prevention of Air Pollution from Ships) Act 2007 gives rise to MARPOL 73/78 Annex VI	Specifically, Annex VI requires: • Sulphur content of fuel oil not to exceed 3.5% thus reducing quantities of sulphur oxides produced. • Vessels with gross tonnage > 400 t have International Air Pollution Certificate (IAPP).
IMO MARPOL Annex VI, Chapter III Regulation 16 and Appendix IV	Specifically, Appendix IV - Requirements for Control of Emissions from Ships – Shipboard Incineration requires that: • The incinerator has IMO certificate. • Personnel responsible for operation of the incinerator are trained.
Contractor Vessel Planned Maintenance System	Ensure that generators and engines are maintained in accordance with the Planned Maintenance System.

Residual Risk Ranking			
Potential Impact	**Consequence**	**Likelihood (of Consequence)**	**Residual Risk**
Localised and temporary decrease in air quality	I	Remote (a)	Very Low (1)
Contribution to global greenhouse gas (GHG) effect	I	Remote (a)	Very Low (1)

Environmental Performance Outcomes, Standards & Measurement Criteria		
EPO	**Control Measures & EPS**	**MC**
Atmospheric emissions are limited to those necessary for operation to minimise contribution to GHG effect	*Marine diesel quality* Low-sulphur marine diesel (where sulphur content of fuel oil does not exceed 3.5%) will be used as the primary fuel source.	Bunker receipts confirm the use of low-sulphur marine grade diesel.
	Equipment maintenance Vessel engines will be maintained in accordance with Planned Maintenance System.	Maintenance records confirm engines are maintained to schedule.
	Air Pollution Certificate Vessels with gross tonnage > 400 t will have International Air Pollution Certificate (IAPP).	IAPP certificate.
	MARPOL Annex VI; Control of Emissions from Ships – Shipboard Incineration If incineration is undertaken, incinerator has IMO certificate.	IMO incinerator certificate.
	Training Personnel responsible for operation of the incinerator are trained.	Training records.

Demonstration of Acceptability	
Is residual risk determined to be 1 and the ALARP Decision Framework A applied? If No ALARP must be demonstrated and the following must be met.	Yes
Principles of ecologically sustainable development met?	Evaluation not required
Legal and other requirements met?	Evaluation not required
Santos policy and standards met?	Evaluation not required
Stakeholder expectations met?	Evaluation not required

7.5 *WASTE WATER DISCHARGES*

7.5.1 *Hazard*

The following waste water discharges will be generated from the survey vessels:

- Sewage and grey water.
- Deck drainage.
- Bilge water.
- Cooling water.

- Brine.

7.5.2 *Environment that May Be Affected by the Hazard*

Monitoring of waste water discharges (sewage, cooling water and produced water) from a floating production, storage and offloading (FPSO) facility did not detect elevated contaminants within ~250 m down-current of the vessel (the first sample site) (GHD 2014). The volume of discharges from a FPSO would be significantly higher than from the seismic or support vessels so it is conservatively assumed that the environment that may be affected by waste water discharges would be < 250 m from a vessel.

7.5.3 *Sensitive Environmental Receptors with the Potential to occur within the EMBA*

Based upon the receptors identified in *Table 5.1*, the following could be exposed to planned waste water discharges:

- Plankton including commercially important fish larvae/eggs.
- Invertebrates including commercial species.
- Fish.
- Sharks and rays.
- Turtles.
- Marine mammals – whales and dolphins (cetaceans).

7.5.4 *Known and Potential Environmental Impacts*

The known and potential environmental impact of waste water discharges is:

- Localised impact on water quality from increased temperature, salinity, nutrients and hydrocarbons.

7.5.5 *Evaluation of Environmental Impacts*

7.5.5.1 *Sewage and Greywater*

Sewage and greywater discharges can cause temporary and localised turbidity and nutrient enrichment. Sewage is treated in a sewage treatment plant prior to discharge reducing solid levels and hence turbidity and nutrient content. Grey waters include shower, hand basin and sink discharges and are not treated prior to discharge.

<u>Extent and duration of exposure and identified potential impact</u>

No sensitive receptors to turbidity and nutrient enrichment such as seagrass and coral reefs where identified within the EMBA.

As the vessels will be moving whilst discharging sewage and greywater, any changes to water quality will be limited to surface waters with these wastes rapidly diluted in the surface layers of the water column and dispersed by currents.

Given the high dilution and dispersal, low volumes and short discharge period, discharge of these wastes is expected to result in localised changes to water quality periodically around the vessels over the short duration of discharge for the short duration of the survey (maximum 30 days). Consequently, sewage and greywater discharges will be localised, within metres of the vessel, and short term as the vessel moves through the area for a duration of up 30 days, impacts to fauna including fauna of an environmental value are unlikely.

7.5.5.2 *Deck Drainage*

Decks are maintained clean and free from oil and grease, with all hazardous materials stored in bunded areas and drip trays under any potential leakage points. Uncontaminated deck drainage from rain, sea splash and wash down water is channelled via scuppers directly into the sea. Impacts from desk drainage can only occur from minor spills that are not appropriately responded to and clean-up. These spills can potentially be discharged into the marine environment via deck drainage.

<u>Extent and duration of exposure and identified potential impact</u>

Given the small volumes of deck drainage and the low concentration of chemicals or hydrocarbons that it could contain, any release to the sea would be expected to result in a change to water quality that is highly localised and temporary in nature.

Given the high dilution and dispersal, low volumes and short discharge period, discharge of contaminated deck drainage is expected to result in localised changes to water quality periodically around the vessels over the short duration of the survey (maximum 30 days). Consequently, deck drainage discharges will be localised, within metres of the vessel, and short term as the vessel moves through the area for a duration of up to 30 days, therefore, impacts to fauna including fauna of an environmental value are unlikely.

7.5.5.3 *Bilge Water*

Bilge water is the mixture of water, oily fluids, lubricants, cleaning fluids, and other similar wastes that accumulate in the lowest part of a vessel typically from engines and machinery. It is managed by either being retained in a holding tank and discharged to a facility on-shore, or treated on-board with an oily water separator (OWS) after which the treated bilge water can be discharged overboard if the oil-in-water concentration is below 15 ppm. Discharge can only be undertaken while the vessel is moving.

Extent and duration of exposure and identified potential impact

As the vessels will be moving whilst discharging bilge waters that are treated to reduce hydrocarbon content to below 15 ppm, any changes to water quality will be limited to surface waters with these discharges rapidly diluted in the surface layers of the water column and dispersed by currents. Given the high dilution and dispersal, low volumes and short discharge period, discharge of these wastes is expected to result in localised changes to water quality periodically around the vessels over the short duration of the survey (maximum 30 days). Consequently, deck drainage discharges will be localised, within metres of the vessel, and short term as the vessel moves through the area for a duration of up to 30 days, therefore, impacts to fauna including fauna of an environmental value are unlikely.

7.5.5.4 *Cooling Water*

Vessels will either use seawater as a heat exchange medium for cooling engines or have box coolers that have no discharge. Were seawater is used as a cooling medium discharge temperatures are typically 5 to 10 °C higher then inlet temperature.

Extent and duration of exposure and identified potential impact

As the vessels will be moving whilst discharging cooling waters any increases in water temperature will be limited to surface waters with these discharges rapidly diluted in the surface layers of the water column and dispersed by currents. Given the high dilution and dispersal, low volumes and short discharge period, discharge of the cooling water is expected to result in localised changes to water quality periodically around the vessels over the short duration of the survey (maximum 30 days). Consequently, cooling water discharges will be localised, within metres of the vessel, and short term as the vessel moves through the area for a duration of up to 30 days, therefore, impacts to fauna including fauna of an environmental value are unlikely.

7.5.5.5 *Brine*

Vessels will have fresh water generators to make freshwater for drinking, showers and cooking. Fresh water generators use either reverse osmosis or distillation. Both processes result in the discharge of seawater with a slightly elevated salinity (~ 10% higher).

Extent and duration of exposure and identified potential impact

As the vessels will be moving whilst discharging brine, any increases in salinity will be limited to surface waters with these discharges rapidly diluted in the surface layers of the water column and dispersed by currents. Given the high dilution and dispersal, low volumes and short discharge period, discharge of brine is expected to result in localised changes to water quality periodically around the vessels over the short duration of the survey (30 days).

Consequently, brine discharges will be localised, within metres of the vessel, and short term as the vessel moves through the area for a duration of up to 30 days, therefore, impacts to fauna including fauna of an environmental value are unlikely.

Summary

Consequence Level: It is expected that there is potential for localised and short term impact on water quality from increased temperature, salinity, nutrients and hydrocarbons – (I).

Likelihood Level: For this activity, impacts on water quality resulting in localised and short term impacts to sensitive environmental receptors is Possible – (c).

Table 7.17 Waste water discharge risk assessment

ALARP Decision Context	
Decision Context	**Justification**
A	The use of vessels offshore and the discharge of waste waters is normal operations. Impacts are well understood. The management of vessel waste waters is well practiced and understood. There is little uncertainty associated with this aspect. The offshore management of waste waters is well regulated, and as no objections or concerns were raised by relevant stakeholders regarding waste water management, consequently Santos believes that decision context A be applied to this aspect.
Control Measure Identification	
Good Practice Control Measure	**Control Measure Source**
MARPOL Annex IV (enacted by AMSA Marine Orders Part 96, Sewage)	MARPOL Annex IV, specifically • Sewage discharges treated via a MARPOL approved STP.
Regulations 12 & 14 of MARPOL Annex I	Specifically Regulations 12 & 14 of MARPOL Annex I requires: • Bilge water to be treated through an Oil Water Separator to prevent the discharge of water with a >15 ppm oil in water content • Discharge of bilge while on route.
Santos Offshore Chemical Assessment Process	Santos' offshore chemical assessment process ensures that chemicals are evaluated and approved if there is the potential for release to the environment.
MARPOL Annex III (enacted by AMSA Marine Order Part 96, Marine pollution prevention — packaged harmful substances	Packaged harmful substances to be properly packed, marked, labelled, stowed and secured.

<table>
<tr><td colspan="2">MARPOL Annex I (enacted by AMSA Marine Order Part 91, Marine pollution prevention – oil)</td><td colspan="2">Under Marine Order 91 – a Shipboard Oil Pollution Emergency Plan is required to be in place and approved.</td></tr>
<tr><th colspan="4">Residual Risk Ranking</th></tr>
<tr><th>Potential Impact</th><th>Consequence</th><th>Likelihood (of Consequence)</th><th>Residual Risk</th></tr>
<tr><td>Localised and temporary impact on water quality</td><td>I</td><td>Possible (c)</td><td>Very Low (1)</td></tr>
<tr><th colspan="4">Environmental Performance Outcomes, Standards & Measurement Criteria</th></tr>
<tr><th>EPO</th><th colspan="2">Control Measures & EPS</th><th>MC</th></tr>
<tr><td rowspan="6">No unplanned waste water discharges to the marine environment</td><td colspan="2">Sewage treatment plant
Sewage will be treated prior to discharge via a MARPOL approved sewage system.</td><td>Valid International Sewage Pollution Prevention certificate.</td></tr>
<tr><td colspan="2">Preventative Maintenance System
The MARPOL approved sewage system will be maintained in accordance with the PMS</td><td>Maintenance records confirm sewage system maintained in accordance with the PMS.</td></tr>
<tr><td colspan="2">Oil-water separator
Bilge water will pass through a MARPOL approved oil-water separator to reduce OIW content to 15ppm prior to discharge.
Treated bilge will only be discharged while en-route.</td><td>Oil Pollution Prevention certificate.
Oil record book shows bilge water only discharged when <15 ppm OIW content and en-route.</td></tr>
<tr><td colspan="2">Preventative Maintenance System
The MARPOL approved oil-water separator will be calibrated and maintained in accordance with the PMS</td><td>Maintenance records confirm OWS calibrated and maintained in accordance with the PMS.</td></tr>
<tr><td colspan="2">Operating Parameters
Cooling water systems and fresh water generators operated within operating parameters.</td><td>Vessel inspection</td></tr>
<tr><td colspan="2">Chemical Assessment
Santos Offshore Chemical Assessment Process used to assess and approve fluids with potential to be discharged to marine environment.</td><td>Completed and approved chemical assessment.</td></tr>
<tr><td rowspan="2">No spills to marine environment</td><td colspan="2">Containment
Equipment, chemicals and hydrocarbons with the potential for spillage will be contained in appropriately bunded areas.</td><td>Inspection records confirm equipment, chemicals and hydrocarbons with potential for spills are contained within appropriately bunded areas.</td></tr>
<tr><td colspan="2">Vessel SOPEP
Vessel SOPEP implemented.
Vessel SOPEP kits available and stocked.</td><td>Records from oil spill response incident.</td></tr>
</table>

		Inspection records confirm SOPEP kits available and stocked.

Demonstration of Acceptability	
Is residual risk determined to be 1 and the ALARP Decision Framework A applied? If No ALARP must be demonstrated and the following must be met.	Yes
Principles of ecologically sustainable development met?	Evaluation not required.
Legal and other requirements met?	Evaluation not required.
Santos policy and standards met?	Evaluation not required.
Stakeholder expectations met?	Evaluation not required.

7.6 *WASTE*

7.6.1 *Hazard*

Both non-hazardous and hazardous wastes will be generated on the vessels during the activity. With the exception of food scraps and wastes that can be incinerated all wastes will be sent to shore for recycling or disposal.

7.6.2 *Environment that May Be Affected by the Hazard*

Macerated food scraps will be the only wastes discharged from the vessels and it is conservatively assumed that the area that might be affected would be < 250 m from a vessel given that it is expected to be much less than that of planned wastewater discharges documented in *Section 7.5*.

7.6.3 *Sensitive Environmental Receptors with the Potential to occur within the EMBA*

Based upon the receptors identified in *Table 5.1*, those known to be sensitive to food scrap discharges are:

- Fish.

Those that maybe impacted by windblown waste are:

- Fish.
- Rays and sharks.
- Turtles.
- Cetaceans.

7.6.4 *Known and Potential Environmental Impacts*

Potential impacts from the discharge of food scraps and waste accidentally going overboard are:

- Marine and onshore litter.
- Injury to marine fauna and seabirds.
- Changes to fauna behaviour.
- Localised and temporary increase in nutrient matter.

Atmospheric emissions from incineration of waste on-board vessels are covered in *Section 7.4*.

7.6.5 *Evaluation of Environmental Impacts*

7.6.5.1 *Putrescible Waste*

Under the *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* (Section 26F), food/galley wastes of < 25 mm size are permitted to be discharged overboard when a vessel is en-route, and is located greater than 3 nm from land.

Extent and duration of exposure and identified potential impact

Periodic discharge of macerated food scraps to the marine environment will result in a temporary increase in nutrients in the water column that is expected to be localised to waters surrounding the vessel over the short duration of the survey (up to 30 days). As the vessel is not stationary, it is expected that any impacts to fauna associated with an increased food source would be temporary and not lead to changes of behaviour due to the short periods of time the vessels would be in one area. Consequently, given the high dilution and dispersal, low volumes and short discharge period, discharge of macerated food scraps will be localised, within metres of the vessel, and short term as the vessel moves through the area for a duration of up to 30 days, therefore, impacts to fauna including fauna of an environmental value are unlikely.

Summary

Consequence It is expected that there is potential for localised and short term impact on water quality from increased nutrients – (I).

Likelihood Level: For this activity, impacts on water quality resulting in changes to fauna behaviour or other impacts to sensitive environmental receptors is Unlikely – (b).

7.6.5.2 *Windblown Waste*

Windblown wastes not recovered from the marine environment may impact fauna if it is eaten or via entanglement.

Extent and duration of exposure and identified potential impact

Ingestion or entanglement of windblown waste has the potential to result in fauna mortality. Windblown wastes would be rare as wastes with the potential to be windblown will be stored in closed containers and in the event of waste being blown overboard attempts would be made to recover it.

Consequently, potential impacts to marine fauna as a result of windblown waste is unlikely and would be limited to individual occurrences not expected to affect populations, thus are considered as localised and short term.

Summary

Consequence Level: If the activity results in the marine or onshore litter, there is the potential for localised and short term impacts to the environment– (I).

Likelihood Level: For this activity, it is expected that the generation of marine and onshore litter resulting in a localised and short term impact to the environment is Unlikely – (b).

Table 7.18 Waste risk assessment

ALARP Decision Context	
Decision Context	**Justification**
A	The use of vessels offshore and discharges of macerate food scraps is normal operations. The management of vessel waste is well practiced and understood. There is little uncertainty associated with this aspect. The management of vessel waste is well regulated. No objections or concerns were raised by relevant stakeholders regarding waste management. Consequently, Santos believes that decision context A be applied to this hazard.

Control Measure Identification	
Good Practice Control Measure	**Control Measure Source**
Protection of the Sea (Prevention of Pollution from Ships) Act 1983 (Section 26F)	Food waste is macerated to ≤25 mm in size prior to overboard discharge.
Regulation 9 of Annex V of MARPOL (enacted by AMSA Marine Order Part 94, Packaged harmful substance and Marine Orders Part 95, Garbage)	MARPOL Annex V, specifically: • Garbage / waste management plan and garbage record book is required to be in place and implemented.

Residual Risk Ranking			
Potential Impact	**Consequence**	**Likelihood (of Consequence)**	**Residual Risk**
Marine and onshore litter	I	Unlikely (b)	Very Low (1)

Localised and temporary decrease in water quality	I	Unlikely (b)	Very Low (1)

Environmental Performance Outcomes, Standards & Measurement Criteria		
EPO	**Control Measures & EPS**	**MC**
No unplanned discharge of waste to the marine environment	*Waste Management Plan* Waste will be handled according to the vessel waste management	Vessel waste management plan. Garbage Record Book details waste sent to shore and incinerated.
	Waste Management Plan Waste with potential to be windblown will be stored in covered containers.	Inspection records confirm waste with potential to be windblown is stored in covered containers.
	Waste Management Plan Waste blown overboard will be recovered if possible.	Incident report.
	MARPOL Annex V Food scraps will be macerated to ≤25 mm size, and are only discharged overboard when vessel is greater than 3 nm from land.	Garbage Record Book details food macerated.

Demonstration of Acceptability	
Is residual risk determined to be 1 and the ALARP Decision Framework A applied? If No ALARP must be demonstrated and the following must be met.	Yes
Principles of ecologically sustainable development met?	Evaluation not required
Legal and other requirements met?	Evaluation not required
Santos policy and standards met?	Evaluation not required
Stakeholder expectations met?	Evaluation not required

7.7 *SEABED DISTURBANCE*

7.7.1 *Hazard*

The following may result in seabed disturbance from the survey activities:

- Anchoring in the event of an emergency.
- Streamer loss.
- Dropped objects.

Vessel grounding was not identified as feasible risks due to there being no emergent features within the Acquisition area.

7.7.2 *Environment that May Be Affected by the Hazard*

The area that may be affected by this hazard is limited to the Operational Area.

7.7.3 *Sensitive Environmental Receptors with the Potential to occur within the EMBA*

Based upon the receptors identified in *Table 5.1*, those known to be sensitive to seabed disturbance include:

- Key Ecological Features (KEF) – Carbonate bank and terrace system of the Sahul Shelf.
- Commercial fisheries - Northern Prawn Fishery (Commonwealth), Mackerel Managed Fishery (WA), Northern Demersal Scalefish Managed Fishery (WA) and Demersal Fishery (NT).

7.7.4 *Known and Potential Environmental Impacts*

Predicted potential impacts of seabed disturbance are:

- Disturbance to and/or loss of benthic habitat.
- Damage to commercial trawling or fishing equipment.

7.7.5 *Evaluation of Environmental Impacts*

7.7.5.1 *Disturbance to Benthic Habitat*

Although the Operational Area overlaps part of a shallow bank that forms part of the Carbonate bank and terrace system of the Sahul Shelf KEF (as detailed in *Section 5.3*), no sensitive benthic habitats were identified within the Acquisition Area.

<u>Extent and duration of exposure and identified potential impact</u>

Seabed disturbance is not planned to occur during this survey as per:

- Anchoring will only occur in an emergency situation.
- Streamer drag is not expected given water depths in the Operational Area (~ 30 – 50 m) and the streamers are fitted with pressure activated, self-inflating buoys that are designed to bring the equipment to surface if accidently lost.
- All lifting over water will be undertaken within the safe work load. Any dropped objects will be recovered if possible.

In the unlikely event that one of the events detailed occurred, and the object was not recoverable, impacts to benthic habitats would be localised due to the size of the object interacting with the seabed. In addition, any impacts would be expected to recover and thus are considered short term.

Summary

Consequence Level: If the activity results in seabed disturbance / loss of benthic habitat there is potential for localised and short term environmental impacts – (I).

Likelihood Level: For this activity, it is expected that disturbance to and/or loss of benthic habitat resulting in localised and short term environmental impacts is Unlikely – (b).

7.7.5.2 *Damage to Commercial Trawling or Fishing Equipment*

There is limited commercial trawling or fishing in the Beehive 3D MSS Acquisition Area. Four commercial fisheries have been identified as being relevant to the Beehive 3D MSS. The Northern Prawn Fishery is the only active fishery within the Acquisition Area of the Beehive 3D MSS. The catch levels for the NPF have been relatively low since 2013 in the JBG. A seasonal closure for the NPF in the Joseph Bonaparte Gulf exists in the period 31 March – 15 June (~11% of the Beehive Acquisition Area is located outside of this exclusion zone). Therefore, it is not anticipated that there will be any interaction with commercial fishers.

Extent and duration of exposure and identified potential impact

Damage to commercial trawling or fishing equipment can potentially occur if an object is not recoverable from the sea floor. In these circumstances the location of the object will be recorded and communicated to fisheries stakeholders, including the WA DPIRD (Fisheries) and the NT DPIR (Fisheries).

In the unlikely event that a dropped object occurred, and the object was not recoverable, commercial fishers would be required to avoid a highly localised area. Interaction with the dropped object would potentially result in damage to equipment that is readily treated / repaired.

Summary

Consequence Level: If the activity results in unrecoverable objects, there is potential for damage to commercial trawling or fishing equipment – (II).

Likelihood Level: For this activity, it is expected that the likelihood of damaging commercial trawling or fishing equipment due to objects on the seabed that are unrecoverable is Remote – (a).

Table 7.19 Seabed disturbance risk assessment

ALARP Decision Context	
Decision Context	**Justification**
A	Seabed disturbance is not a planned aspect of this activity. As such there is an inherently low risk that seabed disturbance would occur. As the events that could create seabed disturbance are known and well understood there is a high level of certainty in regards to the impacts. Although a part of a KEF is present within the Beehive 3D MSS Operational Area, no sensitive benthic habitats were identified; hence any unplanned disturbance would be of a low consequence. No objections or concerns were raised by relevant stakeholders regarding seabed disturbance. Consequently, Santos believes that decision context A be applied to this hazard.

Control Measure Identification	
Good Practice Control Measure	**Control Measure Source**
Marine Order 32, Cargo handling equipment	Marine Order 32, Cargo handling equipment, specifically: • Loading and unloading, and testing, examination and inspection of material handling equipment.
IAGC Environment Manual for Worldwide Geophysical Operations 2013	IAGC Environment Manual for Worldwide Geophysical Operations, specifically: • Local traffic and the appropriate regulatory agencies should be notified when equipment is lost. • Lost equipment must be retrieved as soon as possible after a sighting is reported.
*S*treamers fitted with pressure activated, self-inflating buoys	*S*treamers fitted with pressure activated, self-inflating buoys is standard practice in the industry.
Vessel anchoring in emergency situations only	Vessel anchoring in emergency situations only is standard practice in the industry.

Residual Risk Ranking			
Potential Impact	**Consequence**	**Likelihood (of Consequence)**	**Residual Risk**
Disturbance to and/or loss of benthic habitat	I	Unlikely (b)	Very Low (1)
Damage to commercial trawling or fishing equipment	II	Remote (a)	Very Low (1)

Environmental Performance Outcomes, Standards & Measurement Criteria		
EPO	**Control Measure & EPS**	**MC**
No impact to benthic habitat from	*Lifting procedures* Lifts across water will be undertaken within safe work loads.	Lifting checklists identify safe work loads.

anchoring or dropped objects	*Vessel anchoring requirements* Vessel anchoring will only occur in emergency situations.	Vessel log of any anchoring.
	Streamer equipment Streamers will be fitted with pressure activated, self-inflating buoys.	Pre-start audit.
No damage to commercial trawling or fishing equipment from dropped objects	*Dropped object management* Dropped objects will be recovered where feasible.	Log of dropped object recovery. Documented assessment if dropped object recovery not feasible.
	Dropped object reporting If recovery of a dropped object is not feasible its location will be recorded and communicated to fishing groups and the WA Department of Primary Industries and Regional Development (DPIRD).	Notification to fishing groups and WA DPIRD.

Demonstration of Acceptability	
Is residual risk determined to be 1 and the ALARP Decision Framework A applied? If No ALARP must be demonstrated and the following must be met.	Yes
Principles of ecologically sustainable development met?	Evaluation not required.
Legal and other requirements met?	Evaluation not required.
Santos policy and standards met?	Evaluation not required.
Stakeholder expectations met?	Evaluation not required.

7.8 FAUNA INTERACTIONS

7.8.1 Hazard

Vessels undertaking the seismic survey have the potential to interact with fauna.

7.8.2 Environment that May Be Affected by the Hazard

The area that may be affected by this hazard is limited to the survey Operational Area.

7.8.3 Sensitive Environmental Receptors with the Potential to occur within the EMBA

Based upon the receptors identified in *Table 5.1*, those known to be sensitive to fauna interaction include:

- Turtles.
- Sharks and rays.
- Cetaceans.

7.8.4 *Known and Potential Environmental Impacts*

The known and potential environmental impacts from vessels interactions with fauna are:

- Injury and/or death from vessel strike.

7.8.5 *Evaluation of Environmental Impacts*

7.8.5.1 *Receptor Sensitivity Fauna Strike*

Marine fauna such as cetaceans, sharks, rays and turtles that are likely to be in surface waters are potentially at risk from being struck by a vessel.

Cetaceans are naturally inquisitive marine mammals that are often attracted to vessels with dolphins commonly seen 'bow riding'. The reaction of cetaceans to the approach of a ship is quite variable. Some species remain motionless when in the vicinity of a ship while others are known to be curious and often approach ships that have stopped or are slow moving, although they generally do not approach, and sometimes avoid, faster moving ships (Richardson et al. 1995).

Collisions between vessels and cetaceans have been reported to occur more frequently where high vessel traffic and cetacean habitats overlap (WDCS 2006). A recent review of vessel whale strike data identified up to 109 potential strikes in Australian waters from 1840 to 2015 (Peel et al. 2016a). Typically, more strikes occur in areas where there are higher vessel and fauna numbers such as off the east coast of Australia (*Figure 7.3*).

There is limited data on other potential fauna such as turtles, sharks and rays potentially due to lack of collisions being noticed and lack of reporting, however, there is evidence of strikes occurring via marks observed on animals (Peel et al. 2016b).

7.8.5.2 *Receptor Sensitivity - Fauna Entanglement*

Potential impacts to fauna can occur from entanglement in streamers. Turtles are seen as being potentially at risk as they can entangled in the streamers and drown. Nelms et al. (2016) undertook a literature review of impacts of seismic surveys on turtles and commented that no peer-reviewed literature documented any turtle entrapments in tail buoys, but the authors had received anecdotal reports (unpublished) of turtle entrapments in tail buoys.

No data or anecdotal evidence could be found in regards to entanglement of other fauna in seismic streamers.

<u>Extent and Duration of Exposure and Identified Potential Impact</u>

The risk of vessel strike and entanglement is limited to the footprint of the vessels, which is temporary in nature as the vessel transits through the Acquisition and Operational areas over the short duration of the survey (maximum 30 days). Within these areas, it is expected that numbers of cetaceans, sharks or rays present will be low as there are no identified feeding, breeding, and aggregation or migration areas present. The Acquisition Area, however, does overlap with foraging BIA for green and olive ridley turtles, and the EMBA overlaps with a portion of the 'habitat critical to survival of a species' for flatback turtles in the southern JBG. Therefore, there is the potential for a larger number of individuals to be present in the area.

The potential to be struck or become entangled in equipment may be present in the area, however events are unlikely and impacts are assessed as localised and short-term to fauna as:

- Vessels will be slow moving (4.5 – 5 knots).
- A Marine Fauna Observer (MFO) will be engaged on the seismic vessel.
- Fauna with the potential to be struck or become entangled are expected to move away from vessels based on the predicted noise levels.
- Streamers will have turtle excluders to minimise potential for entanglement.

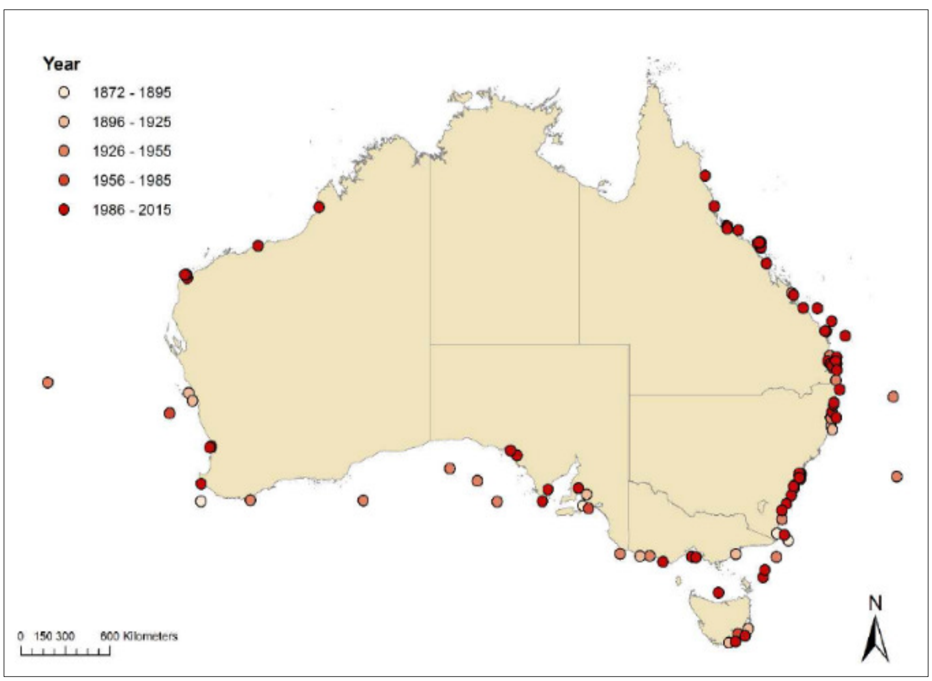

Figure 7.3 Approximate locations of fauna vessel strikes causing death (Peel et al. 2016a)

Summary

Consequence Level: If the activity results in a vessel strike or entanglement there is potential for a localised and short term impacts to animals of environmental value– (II).

Likelihood Level: For this activity fauna injury or death resulting in a localised and short term impact to animals of environmental values is considered Unlikely (b).

Table 7.20 Fauna interaction risk assessment

ALARP Decision Context	
Decision Context	**Justification**
A	Vessel interaction with marine fauna is not a planned activity. As such there is an inherently low risk that it would occur. The potential for vessel interaction with marine fauna is well understood. It is expected that the numbers of cetaceans, sharks or rays present will be low as there are no identified feeding, breeding, and aggregation or migration areas present The Beehive 3D MSS Acquisition Area does overlap with the foraging BIA for green and olive ridley turtles, and the EMBA overlaps part of the 'habitat critical to survival of a species' area for flatback turtles in the southern JBG. Vessels will be slow moving and as such potential interactions were considered to be unlikely. The offshore management of fauna interactions is well regulated in Australia. No objections or concerns were raised by relevant stakeholders regarding fauna strike / interaction. Consequently, Santos believes that decision context A be applied to this hazard.
Control Measure Identification	
Good Practice Control Measure	**Control Measure Source**
EPBC Regulations 2000 - Part 8 Division 8.1 interacting with cetaceans	The Australian National Guidelines for Whale and Dolphin Watching (DEWHA 2005) was developed jointly by the Australian and State and Territory governments through the Natural Resource Management Ministerial Council and describes strategies to ensure cetaceans are not harmed or disturbed from vessel and aircraft interactions.
EPBC Act Policy Statement 2.1. Part A	EPBC Act Policy Statement 2.1 has been developed under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) with the purpose of providing practical standards to minimise the risk of acoustic injury to whales in the vicinity of seismic survey operations. By implementing Part A: Standard Management Procedures, the risk of physical interaction with fauna will be reduced.
Turtle guards	The use of tail buoy turtle guards on towed streamers to avoid trapping turtles in the equipment is a typical control utilised in the industry.

Draft National Strategy for Mitigating Vessel Strike of Marine Mega-fauna	Draft National Strategy for Mitigating Vessel Strike of Marine Mega-fauna, specifically use of the national Vessel Strike Database.

Residual Risk Ranking

Potential Impact	Consequence	Likelihood (of Consequence)	Residual Risk
Injury and/or death from vessel strike or entanglement	II	Unlikely (b)	Very Low (1)

Environmental Performance Outcomes, Standards & Measurement Criteria

<table>
<tr><th>EPO</th><th>Control Measures & EPS</th><th>MC</th></tr>
<tr><td rowspan="4">No injury and/or death to marine fauna caused by vessel strike or entanglement in streamers</td><td>EPBC Regulations Part 8
Vessels will meet the requirements of Part 8 of the EPBC Regulations specifically:
• Travel at less than 6 knots within the caution zone of a cetacean (150 m radius for dolphins, 300 m for whales and turtles).
• Do not approach closer than the caution zones for whales, turtles and dolphins.
• If cetacean or turtle shows signs of disturbance move away at a constant speed less than 6 knots.</td><td>MFO records.</td></tr>
<tr><td>EPBC Act Policy Statement Part B1: MMO
A trained MFO will undertake observations for fauna.</td><td>MFO records.
MFO has previous experience as an MFO.</td></tr>
<tr><td>Vessel/Fauna Requirements – streamers deployed
Turtle guards fitted to tail and head buoys.</td><td>MFO records.</td></tr>
<tr><td>Fauna Strike Reporting Requirements
Collisions with fauna will be reported via the online National Ship Strike Database.</td><td>National Ship Strike Database records.</td></tr>
</table>

Demonstration of Acceptability

Is residual risk determined to be 1 and the ALARP Decision Framework A applied? If No ALARP must be demonstrated and the following must be met.	Yes.
Principles of ecologically sustainable development met?	Evaluation not required.
Legal and other requirements met?	Evaluation not required.
Santos policy and standards met?	Evaluation not required.
Stakeholder expectations met?	Evaluation not required.

7.9 *MARINE USERS INTERACTIONS*

7.9.1 *Hazard*

The seismic and support vessels have the potential to interact with other marine users in the area.

7.9.2 *Environment that May Be Affected by the Hazard*

The area that may be affected by this hazard is limited to the Operational Area.

7.9.3 *Sensitive Environmental Receptors with the Potential to occur within the EMBA*

Based upon the receptors identified in *Table 5.1*, the relevant marine users identified are:

- Commercial fisheries - Northern Prawn Fishery, Mackerel Managed Fishery, Northern Demersal Scalefish Managed Fishery and Demersal Fishery.
- Commercial shipping.
- Defence activities (Exercise KAKADU).
- Other petroleum activities

7.9.4 *Known and Potential Environmental Impacts*

The known and potential environmental impacts of interactions with potential receptors are:

- Vessel collision.
- Interference with movements of surface vessels, submarines and aircraft (Exercise KAKADU).

Note: Vessel collisions resulting in a diesel spill are addressed in *Section 7.12*.

7.9.5 *Evaluation of Environmental Impacts*

Interactions with other marine users are limited to the footprint of the seismic and support vessels within the Operational Area. Any interactions will be temporary in nature as the vessel transits through the Acquisition and Operational areas over the short duration of the survey (30 days). A review of receptors within the Operational Area did not identify any recreational fishing activity and limited shipping activity. However, the EMBA does overlap the areas fished in the Northern Prawn Fishery (NPF), Northern Demersal Scalefish Managed Fishery (NDSMF), Mackerel Managed Fishery (MMF), and Demersal Fishery. The NDSMF, MMF and Demersal Fishery all have the potential to fish within the area of the Beehive 3D MSS.

Defence Activities – Exercise Kakadu

The Acquisition and Operational areas overlap the NAXA, which is the primary location of the KAKADU training exercise that operates biannually, with the 2018 exercise scheduled for 31 August – 15 September 2018. This overlaps with the proposed timing of acquisition for the Beehive survey (1 May to 31 October 2018 or 2019).

<u>Extent and Duration of Exposure and Identified Potential Impact</u>

If the acquisition of the Beehive survey were to overlap Exercise KAKADU there is the potential for significant interference with the activities of military surface vessels, submarines and aircraft within and adjacent to the Operational Area. The physical presence of the survey vessel and towed array, and of the support vessel and helicopters, have the potential to disrupt and interfere with the movements of vessels, submarines and low-flying aircraft engaged in activities during this international military exercise.

During consultation with the Department of Defence (DoD), the DoD informed Finniss that the Beehive 3D MSS would potentially impact the scale of manoeuvre of surface units during the exercise. The proximity to the Blacktip Wellhead Platform (WHP) makes this portion of the NAXA valuable in terms of training scenarios (*Section 4.3*).

The DoD proposed that the Beehive 3D MSS is completed no later than 30 August 2018, or alternatively commencing after the 16 September 2018, as this would be of mutual benefit to both Finniss/Santos and Defence by removing the possibility of unintended impacts on each other's activities. Additionally, DoD also advised that unexploded ordinance (UXO) may be present on and in the sea floor in the area of proposed activities, and that Finniss/Santos must inform itself of the risks associated with conducting activities in the area.

The DoD considered that the noise generated from airgun arrays in the Beehive survey area is unlikely to have acoustic impacts on the activities of submarines and surface ships within the DRA established for Exercise KAKADU.

On 24 February 2018, Finniss/Santos responded to the DoD and confirmed that no survey operations will be undertaken for the Beehive survey during the period 31 August – 15 September 2018, to avoid any overlap with Exercise KAKADU.

<u>Summary</u>

Consequence Level: If the activity does not overlap with the timing of Exercise KAKADU, any potential impacts are of the lowest consequence level (I).

Likelihood Level: If the activity does not overlap with the timing of Exercise KAKADU, localised and short term impacts are considered Likely the likelihood of any impacts occurring is Remote (a).

Commercial Fisheries

Extent and Duration of Exposure and Identified Potential Impact

MMF & NDSMF

As described in *Section 7.1.5.3*, fish catch and effort data has been obtained from the WA DPIRD (Fisheries) for the MMF and NDSMF for the years 2012 to 2016. The data are summarised for coarse 60 nm x 60 nm Catch and Effort System (CAES) blocks, as presented in *Figure 7.2*, with the Beehive Acquisition Area centred on the boundary between CAES blocks 1328 and 1428.

Review of the DPIRD (Fisheries) catch and effort data for 2012 to 2016 indicates that for the full five year period there was no recorded catch in CAES block 1428 for either the MMF or the NDSMF. For CAES block 1328 there was catch recorded in 2012 and 2013 for the MMF, and in 2012 and 2015 for the NDSMF. In other years, the level of catch and effort was below the levels at which DPIRD (Fisheries) are permitted to share data in accordance with the *Fisheries Resources Management Act 1994* (i.e. less than 3 vessels entering the block in total).

Demersal Fishery

Similar data is not currently available from the NT DPIR (Fisheries) for the Demersal Fishery, but the area overlapped by the Beehive Operational and Acquisition areas is not expected to be a key area for the fishery. The Beehive Operational Area covers ~ 2,895 km^2 of the Demersal Fishery (0.84%) and the Acquisition Area covers ~ 300 km^2 of the Demersal Fishery (0.09%).

Therefore, vessels used during the acquisition of the Beehive 3D MSS may potentially encounter vessels from the MMF, NDSMF and/or Demersal Fishery, but the activity is not expected to significantly disrupt fishing activities by displacing vessels from significant fishing grounds or affecting overall catch rates.

Northern Prawn Fishery

As described in *Section 5.7.2*, a seasonal closure for the NPF in the JBG exists in the period 31 March – 15 June (*Figure 5.22*) (AFMA 2017). The seasonal closure is an exclusion zone in place for all licence holders within the NPF, and the purpose of this closure is to protect small juvenile prawns as they migrate offshore to deeper waters in the southern JBG, where the adults are targeted during the trawling operations (see *Figure 5.21*). Any catch south of the seasonal closure line is taken in the second fishing season only (August to November), whereas catch taken north of the closure line is taken during both the first and second seasons.

The Beehive 3D MSS is mostly located within this exclusion zone (~ 11% of the Acquisition Area is outside of this exclusion zone). According to the Northern

Prawn Fishery Directions and Closures (AFMA 2017), the seasonal closure in the JBG will be implemented for the 2018 season.

In a response provided by the Northern Prawn Fishery Industry (NPFI) to Finniss on 28 March 2018, the NPFI indicated that acquisition of the Beehive survey has the potential to negatively impact on traditional NPF prawn trawl operations in the JBG. The NPFI provided catch data for the period 2010-2017, for the actively fished area in the southern JBG. As pointed out by the NPFI, there was (unusually) minimal fishing activity in 2015 and 2016 in the JBG due to heavy concentration of fishing effort on the highly productive stocks in the Gulf of Carpentaria in those years.

The NPFI expressed a concern about seismic acquisition occurring over the seasonal closure area during the periods when the main cohorts of juvenile prawns would be migrating across the area (main cohort November to March, possible second cohort April to June).

Accordingly, the NPFI recommended that the best window of opportunity for acquiring the Beehive survey, which will not directly impact on fishing operations, would be mid-June to 31st July.

As shown by the data provided by the NPFI, there is minimal overlap between catch locations and the Beehive Acquisition Area, and the majority of this catch was during one year out of the eight years covered by the data. So, based on these data it would appear that the Acquisition Area hasn't produced a significant proportion of the catch over the period 2010-2017.

As described in *Section 5.7.2*, due to the large tidal range (6–8 m) in the JBG and its reputed influence on prawn abundance in the region, *F. indicus* are fished on the neap tides, when tidal range and currents are minimal (Tonks et al. 2008). Thus, over a tide cycle, fishing effort is high on the late spring-neap, neap and early neap-spring tides, and low to non-existent at other times when the fleet moves to fishing grounds north of Melville Island and Port Essington, outside the JBG. The extra steaming time that this fishing pattern generates, together with the remoteness of the JBG and the lower price of *F. indicus* in comparison to other species of prawns, makes the JBG a less attractive area to fish than other parts of the NPF. As a result, the annual fishing effort in the JBG fishery is mostly dependent on the catch levels elsewhere in the NPF; if catches are good elsewhere, effort in JBG is low (Loneragan et al. 2002).

Acquisition of the Beehive survey will not commence until after the 15th June, to avoid any overlap with the first fishing season for the NPF in the JBG. The most likely time period for acquisition of the survey is mid-June to late July. There is a low likelihood of overlap with the start of the second fishing season (August to November 2018).

During the second fishing season potential overlap between seismic acquisition and trawling activities will be limited to the period 1 August to 30 August 2018, as the survey will not be acquired during Exercise KAKADU (31 August to 15

September). Given the timing of fishing effort with tidal cycle (described above), during August 2018 there will be two periods of high fishing effort, probably three days either side of the first and last quarters of the moon (i.e. the two neap tides during the month)— 3-8 August and 16-22 August. Outside these two periods of six days each, fishing effort is expected to be low of non-existent—i.e. fishing effort is expected to be concentrated into 12 days of the month, with little activity for the remaining 18 days of the month.

Thus, potential impacts to the NPF in the JBG are limited to physical displacement of trawling activities for a short period, if acquisition of the Beehive survey extends into the second fishing season. Given the limited spatial and temporal extent of the potential overlap with trawling activities, acquisition of the survey is not expected to have significant impacts on overall catch levels for this fishery.

In the operational area, impacts to some of the fisheries can be minimised by coordinating access to fishing areas prior to and after the seismic vessel has surveyed an area. For safe operations, the seismic vessel will require other vessels to maintain a distance of 3 km from the vessel and seismic array to take into account any horizontal movement of the 6-8 km streamers.

For the majority of time that the seismic and support vessels will be within the Acquisition and Operational areas they will be moving at a rate of 4.5 – 5 knots (8-9 km/hr) along the sail lines. The distance from the vessel bow to the streamer tail buoy is ~ 6.5 – 8.5 km, and the extensive Operational Area around the Acquisition Area is required to allow the seismic vessel to turnaround without entanglement of the streamers. It will take approximately eight hours to complete each sail line.

For vessels transiting through the area normal navigation at sea processes are undertaken whereby vessels are not restricted but move through the area using navigational and communication aids to avoid collision. Thus, any potential impacts will be within a localised area that needs to be avoided (vessel/streamers ~ 6.5 – 8.5 km) and short term (~ 1 hr from vessel/streamer to pass).

Coordinating access to fishing areas prior to and after the seismic vessel has surveyed an area will be managed by working with the fishers to coordinate the planned location of the survey vessel, on a frequency (daily, weekly etc.) that allows the fishers to be able to plan ahead.

<u>Summary</u>

Consequence Level: If the activity results in the interaction with commercial fisheries, there is the potential for a localised and short term impact – (II).

Likelihood Level: For this activity, interactions with commercial fisheries resulting in localised and short term impacts is considered Possible (c).

Table 7.21 Marine user interactions risk assessment

ALARP Decision Context			
Decision Context	**Justification**		
B	The potential for interactions with other marine users is limited due to the absence of other offshore activity in the Beehive 3D MSS Acquisition and Operational areas. The management of vessel interactions is well regulated. Although the Beehive 3D MSS Acquisition Area is located within the main fishing area for the NPF in the JBG, most of it is located within the seasonal closure area that covers the first fishing season. Hence, most catch for the area overlapping the Beehive Acquisition Area is taken during the second fishing season. Objection or concerns were raised by the Department of Defence in regards to potential overlap with Exercise KAKADU. Additionally, objections or concerns were raised by the NPFI with regards to negatively impact prawn trawling operations in the JBG. Consequently, Santos believes that decision context B be applied to this hazard.		
Control Measure Identification			
Good Practice Control Measure	**Cost**	**Benefit**	**Applied?**
Navigation Act 2012 (enacted by AMSA Marine Orders 31, Vessel; Surveys and Certification) requires vessel class certification	Legal requirement thus has not been evaluated further.	The marine order requires that the vessel class be certified to ensure that it meets the *Navigational Act 2012* requirements, thus minimising the likelihood of vessel collisions.	Yes
Navigation Act 2012 (enacted by AMSA Marine Orders 30, Prevention of Collisions) requires supply of information to the AHS enabling Notice to Mariners to be published.	Legal requirement thus has not been evaluated further.	Under the *Navigation Act 2012*, it is the responsibility of the Australian Hydrographic Service (AHS) to maintain and disseminate hydrographic and other nautical information and nautical publications including Notices to Mariners (NTM). NTM ensures vessels know about the seismic vessels being in the area and that it has limited capacity to manoeuvre thus minimising the likelihood of vessel collisions.	Yes
COLREGS - International Regulations for Preventing Collisions at Sea - International Regulations for preventing Collisions at Sea, 1972 - Rule 27 requires towed	Legal requirement thus has not been evaluated further.	As required by the COLREGS Rule 27 - Vessels not under command or restricted in their ability to manoeuvre. It is best practice to clearly marked or light streamer tail buoys to identify	Yes

equipment to be identifiable		streamer ends to other users.	
Use of support vessel to alert fishers and other users of the seismic vessel and associated streamers	Increased operating costs of hiring a support vessel.	Two dedicated vessels (support and chase vessel) have been contracted with one to be used to alert fishers and other users of the seismic vessel presence. This will minimise the risk of a vessel collision or vessel running over the streamers.	Yes
Ongoing consultation with fishers and other marine users, prestart notices and daily notifications of planned survey areas to facilitate access where possible and provide adequate notice to fishers and other marine users of activities	Additional costs to facilitate consultation and communications.	Ongoing consultation /communication with fishers and marine will allow fishers to be able to fish in areas before and after the area has been surveyed reducing impacts.	Yes
Timing of survey to avoid peak fishing times	Based on stakeholder consultation with the NPFI there are two seasons for prawn trawling in the JBG: first fishing season (1 April to 15 June); and second fishing season (1 August to 30 November). The NPFI have recommended that the best window of opportunity for seismic acquisition that will not impact directly on fishing operations would be mid-June to 31 July. Santos has responded to the NPFI and informed them that acquisition of the Beehive survey will not commence prior to 15 June. However, Santos cannot commit to completion of the survey by 31 July given the following factors: a) delay to survey start beyond mid-June given delay of completion of Bethany survey; and b) delays to	The commitment to not commence acquisition of the survey prior to 15 June was made to avoid overlap with the first fishing season for the NPF, and to minimise potential overlap with the second fishing season.	Partial

	acquisition of the Beehive survey extending its duration beyond the planned 30 days.		

Residual Risk Ranking			
Potential Impact	**Consequence**	**Likelihood (of Consequence)**	**Residual Risk**
Vessel Collision	II	Possible (c)	Low (2)
Interference with activities of vessels, submarines and aircraft engaged in Exercise KAKADU	I	Remote (a)	Very Low (1)
Disruption of commercial fisheries	II	Possible ©	Low (2)

Environmental Performance Outcomes, Standards & Measurement Criteria		
EPO	**Control Measures & EPS**	**MC**
No vessel collisions with marine users	*Navigational requirements* Class certificate demonstrates vessel complies with the *Navigation Act 2012* and applicable Marine Orders.	Class Certificate.
	Navigational requirements Tail buoys clearly marked / lighted to identify streamer ends to other users.	Pre-start audit.
	Notifications • Notice to Mariners (NTM) via notifications to Australian Hydrographic Service (AHS) a minimum of 3 weeks prior to commencement of activities. • Notification to Department of Defence (DoD) concerning timing of acquisition of the Beehive survey (in relation to Exercise KAKADU).	Notification records to AHS. NTM. Notification records to DoD.
No interactions with vessels, submarine and aircraft engaged in Exercise KAKADU	*Survey Timing* • Acquisition of the Beehive survey will not overlap the period 31 August – 15 September 2018.	Daily Reports Stakeholder consultation records
	Notifications • Notification to Department of Defence (DoD) concerning timing of acquisition of the Beehive survey (in relation to Exercise KAKADU). • This notification will be provided 4 weeks prior to survey commencement.	Survey commencement and cessation notifications to DoD.

	• The DoD will be notified when the survey is completed.	
Minimise disruption of prawn trawling activities in the JBG	*Survey Timing* • Acquisition of the Beehive survey will not commence prior to 15 June.	Daily reports
	Notifications • Notification to the NPFI and AFMA concerning timing of acquisition of the Beehive survey (in relation to the second fishing season for the NPF). • This notification will be provided 4 weeks prior to survey commencement. • NPFI and AFMA will be notified when the survey is completed.	Stakeholder consultation records. Survey commencement and cessation notifications to NPFI and AFMA.
	Communication • A handout on the Beehive 3D survey will be provided to the NPFI, who will distribute this handout during the pre-season briefings for the second fishing season, or via email to fleet managers / vessel skippers. • If the survey overlaps the second fishing season for the NPF daily communication will be undertaken with relevant fishers and the NPFI. • At a minimum the daily report will include: ➢ Current survey vessel position ➢ 48 hour look ahead for survey activities and location ➢ Support vessel activities and location ➢ Contact details for the survey and support vessel.	Pre-season handout. Stakeholder consultation records. Daily communication report to fishers.
	Support and Chase Vessels • Two dedicated vessels (support and chase vessel) will be engaged to alert fishers and other users of the seismic vessel and towed streamers.	Daily report showing engagement of support and chase vessels.
Demonstration of Acceptability		

<table>
<tr><td>Is residual risk determined to be 1 and the ALARP Decision Framework A applied?
If No ALARP must be demonstrated and the following must be met.</td><td>No</td></tr>
<tr><th colspan="2">Demonstration of ALARP</th></tr>
<tr><td colspan="2">Based on the outcomes of the environmental risk assessment process and through the implementation of appropriate and comprehensive controls during the survey, Santos considers that the potential impacts to marine users are reduced to ALARP.
Relevant legislative requirements and standard industry practices/guidelines have been applied to control the impact.
Additional controls have been evaluated and where practicable, have been adopted. Additional controls, where there is no reduction in the level impact or the cost of implementation is grossly disproportionate to the potential reduction in the level of impact have not.</td></tr>
<tr><th colspan="2">Demonstration of Acceptability</th></tr>
<tr><td colspan="2">As described in Section 7.9.5, impacts to marine users from being displaced from the seismic survey area for the period of the survey (up to 30 days) were evaluated to identify the potential level of impact (consequence). In the worst case this was identified to be localised (within the operational area) and short term (30 days) for the Northern Prawn Fishery area in the Joseph Bonaparte Gulf – Consequence level – II.
Based upon the evaluation below, the potential impacts to marine users if they are displaced from the operational area for all or part of the survey duration is considered acceptable.</td></tr>
<tr><td>Principles of ecologically sustainable development met?</td><td>Decision making processes integrated long and short term economic, environmental, social and equitable considerations by selecting a time period for acquisition of the survey that avoids overlap with the first fishing season for the NPF in the JBG, minimises overlap with the second fishing season, and avoids any overlap with Exercise KAKADU.
No threats of serious of irreversible environmental damage were identified from the risk assessment.
The principal of inter-generational equity are not compromised as potential disturbance impacts were identified to be localised and short term (days or weeks).
Conservation of biological diversity and ecological integrity are not relevant to this hazard.
Cost benefit analysis has been used to determine applicable controls.</td></tr>
<tr><td>Legal and other requirements met?</td><td>The applicable navigational requirements will be implemented to minimise the likelihood of a vessel collision.</td></tr>
<tr><td>Santos policy and standards met?</td><td>As per the EHS Policy Santos is committed to manage the impact of our operation on the environment. Santos has through its stakeholder consultation made a genuine effort to ensure impacts to stakeholders are minimised and that there is no significant impacts to commercial fishing licence holders from Santos' activities.</td></tr>
</table>

	Environmental considerations were taken into account in the business planning and decision making process for the survey such as timing and area of acquisition. Via consultation with stakeholders Santos has been able to understand the impacts of the survey on marine users and implement controls to manage those impacts. All relevant laws will be implemented. Santos has been pro-active and collaborative when working with stakeholders to understand any objection or concerns and implement appropriate controls.
Stakeholder expectations met?	No concerns were raised in regards to displacement from fishing areas from the MMF, NDSMF and Demersal Fishery. Concerns have been raised by the NPFI in regards to the potential for the survey to negatively impact on NPF trawling activities in the JBG. Santos has committed to a number of control measures that minimise the potential for physical displacement of prawn trawlers in the Acquisition and Operational areas. If the survey overlaps the start of the second fishing season for the NPF, daily communications will also be implemented to coordinate each party’s activities so as not to restrict either party. The Department of Defence request that there be no overlap in timing of the survey and Exercise KAKADU has been addressed and the relevant control will be complied with. This has been communicated to Defence accordingly.

7.10 *INTRODUCTION OF MARINE PESTS*

7.10.1 *Hazard*

The following activities have the potential to result in the introduction of marine pests to the project area:

- Vessel ballast water discharge containing foreign species.
- Biofouling of vessel hull or in-water equipment.

7.10.2 *Environment that May Be Affected by the Hazard*

The area that may be affected by this hazard is limited to the survey Operational Area.

7.10.3 *Sensitive Environmental Receptors with the Potential to occur within the EMBA*

Based upon the receptors identified in *Table 5.1*, those expected to be sensitive to the introduction of a marine pest include:

- Key Ecological Feature – Carbonate bank and terrace system of the Sahul Shelf.

- Commercial Fisheries - Northern Prawn Fishery (Commonwealth), Mackerel Managed Fishery (WA), Northern Demersal Scalefish Managed Fishery (WA) and Demersal Fishery (NT).

7.10.4 *Known and Potential Environmental Impacts*

The known and potential environmental impacts of marine pest introduction are:

- The survival, colonisation and spread of foreign species that may compete with native species for resources, reducing species diversity and abundance.

7.10.5 *Evaluation of Environmental Impacts*

Vessels have the potential to transport and introduce marine pests from ballast water or biofouling. Successful marine pest invasion requires the following three steps:

1. Colonisation and establishment of the marine pest on a vector (e.g. vessel hull) in a donor region (e.g. home port).
2. Survival of the settled marine species on the vector during the voyage from the donor to the recipient region (e.g. project area).
3. Colonisation (e.g. dislodgement or reproduction) of the marine species in the recipient region, followed by successful establishment of a viable new local population.

Marine pests are likely to have little or no natural competition or predation, thus potentially outcompeting native species for food or space, preying on native species or changing the nature of the environment. It is estimated that Australia has over 250 established marine pests, and it is estimated that approximately one in six introduced marine species becomes pests (DoE 2015).

Contracted vessels for the survey are likely to be sourced from within Australia but if vessels from overseas are contracted they will be required to be compliant with Australian quarantine requirements.

<u>Extent and duration of exposure and identified potential impact</u>

In the event that a marine pest is introduced into the Acquisition or Operational areas, there is the potential for this pest to become established within a KEF.

The Carbonate bank and terrace system of the Sahul Shelf KEF is regionally important and as they provide areas of hard substrate in an otherwise soft sediment environment. In the event that a marine pest was introduced and became established in this area, it is expected that this would result in a localised but medium term impact to an area of significant environmental value.

The vessels will be required to meet all quarantine requirements in regards to biofouling and ballast management, and the Operational Area is in water depths greater than 30 m reducing the likelihood of establishment. As such there is a low likelihood that if a marine pest was on a vessel it would be able to establish.

Summary

Consequence Level: If the activity results in the introduction and establishment of marine pests, there is potential for a localised and medium term impact to an area of significant environmental value – (III).

Likelihood Level: For this activity, the introduction and establishment of a marine pest resulting in a localised and medium term impact to an area of significant environmental is considered Remote (a).

Table 7.22 Invasive marine species risk assessment

ALARP Decision Context	
Decision Context	**Justification**
A	The introduction of marine pests is not a planned activity. As such there is an inherently low risk that it would occur. The use of vessels offshore is well practiced and the pathways for the introduction of an invasive marine pest well understood and regulated. Given the location of the Beehive 3D MSS, no particular sensitive environmental receptors have been identified and the level of potential environmental impact is considered to be low. The introduction of marine pests was raised by the WA DPIRD and advice was provided in relation to guidance material to minimise the risk of an introduction. These guidelines have been identified as control measures, and consequently Santos believes that decision context A be applied to this hazard.
Control Measure Identification	
Good Practice Control Measure	**Control Measure Source**
Biosecurity Act 2015	*Biosecurity Act 2015* specifically: Pre-arrival information must be reported through the Maritime Arrivals Reporting System (MARS) prior to arrival in Australian waters.
Australian Ballast Water Management Requirements (DAWR 2017)	DAWR Australian Ballast Water Management Requirements, specifically: • Reporting of ballast water discharges; • Maintain a ballast water record system.

Guidelines for the Control and Management of Ships' Biofouling to Minimize the Transfer of Invasive Aquatic Species (Biofouling Guidelines) MPEC.207(62)) 2011	The Guidelines for the control and management of ships' biofouling to minimize the transfer of invasive aquatic species (Biofouling Guidelines) MPEC.207(62)) 2011 Specifically required to be available and maintained: • Biofouling management plan; • Biofouling record book.
Protection of the Sea (Harmful Anti-fouling Systems) Act 2006 (enacted by AMSA Marine Order Part 98 (Marine pollution - anti-fouling systems)	An anti-fouling certificate is required to be in place for vessels.

Residual Risk Ranking

Potential Impact	Consequence	Likelihood (of Consequence)	Residual Risk
Introduction and establishment of marine pests	III	Remote (a)	Very Low (1)

Environmental Performance Outcomes, Standards & Measurement Criteria

EPO	Control Measures & EPS	MC
No introduction of marine pest species	*AQIS requirements* Overseas vessels contracted will receive AQIS clearance to enter Australian waters.	Records of formal AQIS quarantine clearance.
	Ballast Water requirements Vessels will meet the DAWR Australian Ballast Water Management Requirements.	Ballast water records.
	Biofouling Requirements Vessels will meet the requirements of the IMO Guidelines for the Control and Management of Ship's Biofouling to Minimise the Transfer of Invasive Aquatic Species.	Antifouling certificate. Biofouling Management Plan. Biofouling Record Book.
	In-water equipment inspection In-water equipment will be inspected for biofouling and cleaned prior to deployment.	In-water equipment inspection records.
	Reporting Suspected or confirmed marine pests or diseases will be reported to the WA DPIRD as per the requirements in *Section 8.7*.	Notification to WA DPIRD.

Demonstration of Acceptability

Is residual risk determined to be 1 and the ALARP Decision Framework A applied? If No ALARP must be demonstrated and the following must be met.	Yes

Principles of ecologically sustainable development met?	Evaluation not required.
Legal and other requirements met?	Evaluation not required.
Santos policy and standards met?	Evaluation not required.
Stakeholder expectations met?	Evaluation not required.

7.11 *DIESEL REFUELLING SPILL*

7.11.1 *Hazard*

Bunkering of diesel is unlikely given the short time period of the survey, but has been included in case it is required. Bunkering is undertaken at sea so that the survey can continue as quickly as possible rather than take time out to return to port.

The following have the potential to result in a marine diesel oil (MDO) spill to the marine environment whilst refuelling:

- Refuelling hose leak or connection failure.

Spills resulting from overfilling or from on board coupling or connection failure will be contained within the vessels drains and slops system and hence will not reach the external marine environment.

7.11.2 *Environment that May Be Affected by the Hazard*

The area that may be affected by this hazard is expected to be localised within the Operational Area.

7.11.3 *Sensitive Environmental Receptors with the Potential to occur within the EMBA*

Based upon the receptors identified in *Table 5.1*, those with the potential to be exposed to a diesel spills include:

- Plankton including commercially important fish larvae/eggs.
- Invertebrates including commercial species.
- Fish.
- Sharks and rays including whale sharks.
- Turtles.
- Marine birds.
- Marine mammals – whales and dolphins (cetaceans).

7.11.4 *Known and Potential Environmental Impacts*

The potential environmental impacts of a MDO spill are:

- Toxic effects to the marine environment including marine fauna.

7.11.5 *Evaluation of Environmental Impacts*

A refuelling hose leak or dry-break connection failure could result in MDO being discharged to the marine environment as the refuelling hose is in direct contact with the water. AMSA's guideline for indicative maximum credible spill volumes (AMSA 2015) recommends that the maximum credible spill volume during refuelling with continuous supervision is calculated as: transfer rate x 15 minutes flow. The shut in time of 15 minutes for refuelling with continuous supervision is very conservative and would typically be undertaken within minutes.

Based on an expected transfer rate of 150 m^3/hr an MDO spill of 37.5 m^3 was calculated. This volume is lower than the MDO spill volume for a vessel collision (280 m^3) and hence the evaluation of impacts to receptors is discussed in *Section 7.12* rather than repeated here. Based on the modelling undertaken for the larger 280 m^3 spill, a smaller refuelling spill would be likely to spread and dissipate more quickly (i.e. within days) and be more localised.

In the unlikely event of a refuelling incident impacts to fauna of environmental value would be localised and short term (days) as the diesel would rapidly dissipate.

<u>Summary</u>

Consequence Level: If the activity results in a diesel spill during refuelling, there is potential for toxic effects to the marine environment resulting in localised and short term impacts to animals of environmental value – (II).

Likelihood Level: For this activity, a refuelling incident resulting in short term and localised impacts to animals of environmental value is considered Unlikely (b).

Table 7.23 Vessel refuelling risk assessment

<table>
<tr><th colspan="4">ALARP Decision Context</th></tr>
<tr><td>Decision Context</td><td colspan="3">Justification</td></tr>
<tr><td>A</td><td colspan="3">A MDO refuelling spill has an inherently low risk that it would occur. Offshore refuelling (bunkering) of vessels is a frequently practiced activity with the causes of spills well understood and managed. Although there is the potential for sensitive receptors to be present within the Acquisition Area, exposure to surface hydrocarbons would be low due to the dispersive nature of MDO. No objections or concerns were raised by relevant stakeholders regarding potential spills from refuelling. Consequently, Santos believes that decision context A be applied to this hazard.</td></tr>
<tr><th colspan="4">Control Measure Identification</th></tr>
<tr><td colspan="2">Good Practice Control Measure</td><td colspan="2">Control Measure Source</td></tr>
<tr><td colspan="2">Vessel Bunkering Procedure</td><td colspan="2">It is considered good practice to have a ship-ship bunkering procedure in place to ensure that procedural controls are followed and specified equipment is in place to minimise impacts and risks to the environment.</td></tr>
<tr><td colspan="2">MARPOL Annex I (enacted by AMSA Marine Order Part 91, Marine pollution prevention – oil) requirement for an approved SOPEP</td><td colspan="2">Under Marine Order 91 – a Shipboard Oil Pollution Emergency Plan is required to be in place and approved.</td></tr>
<tr><td colspan="2">OPGGS (Environment) Regulations requirement for an approved OPEP</td><td colspan="2">Under the OPGGS (Environment) Regulations, NOPSEMA require that the petroleum activity have an accepted Oil Pollution Emergency Plan in place prior to that activity commencing.</td></tr>
<tr><th colspan="4">Residual Risk Ranking</th></tr>
<tr><td>Potential Impact</td><td>Consequence</td><td>Likelihood (of Consequence)</td><td>Residual Risk</td></tr>
<tr><td>Toxic effects to the marine environment including marine fauna</td><td>II</td><td>Unlikely (b)</td><td>Very Low (1)</td></tr>
<tr><th colspan="4">Environmental Performance Outcomes, Standards & Measurement Criteria</th></tr>
<tr><td>EPO</td><td colspan="2">Control Measures & EPS</td><td>MC</td></tr>
<tr><td>No spills to the marine environment.</td><td colspan="2">Vessel Bunkering Procedure
Bunkering undertaken as per the vessel bunkering procedure which includes:
• Bunkering during daylight hours only.
• Continuous monitoring of bunker hose and receiving tank.
• Bunker hose is certified to maximum transfer pressures and is visually inspected prior to use.</td><td>Bunkering records.</td></tr>
</table>

	Bunkering Equipment At a minimum bunkering hose will have floats and dry-break couplings.	Vessel inspection
Oil spill response implemented in accordance with accepted OPEP to minimise impacts from spilled hydrocarbons.	*SOPEP Response* Vessel SOPEP implemented for spills on-board vessel.	Records from oil spill response incident
	OPEP implementation Beehive Oil Pollution Emergency Plan (OPEP) implemented for spills to water.	Records from oil spill response incident
Demonstration of Acceptability		
Is residual risk determined to be 1 and the ALARP Decision Framework A applied? If No ALARP must be demonstrated and the following must be met.		Yes.
Principles of ecologically sustainable development met?		Evaluation not required.
Legal and other requirements met?		Evaluation not required.
Santos policy and standards met?		Evaluation not required.
Stakeholder expectations met?		Evaluation not required.

7.12 *DIESEL SPILL FROM VESSEL COLLISION*

7.12.1 *Hazard*

A review of receptors within the Beehive seismic survey area identified limited commercial fishing activity and shipping activity, thus a vessel collision is unlikely but is classified as a credible scenario.

A MDO tank rupture resulting from vessel grounding is not seen as a credible scenario as there are no emergent features within the seismic survey area.

7.12.2 *Environment that May Be Affected by the Hazard*

To understand the potential consequences of a MDO spill and the response preparedness required, stochastic modelling was undertaken (RPS-APASA 2017).

The following modelling inputs were used.

Spill Volume

AMSA's guideline for indicative maximum credible spill volumes for other, non-oil tanker, vessel collision (AMSA 2015) is the volume of the largest fuel tank. The loss of a full tank is most likely an overestimate as hydrostatic pressure would limit the release and pumping of material to another tank could also restrict the amount lost.

Based on the type of seismic and survey vessel that may be used, the largest MDO tank volume of 280 m^3 has been used to undertake the impact assessment.

Location

The spill location selected for modelling was chosen based on the closet point that the survey vessel would be to shore (*Figure 7.4*).

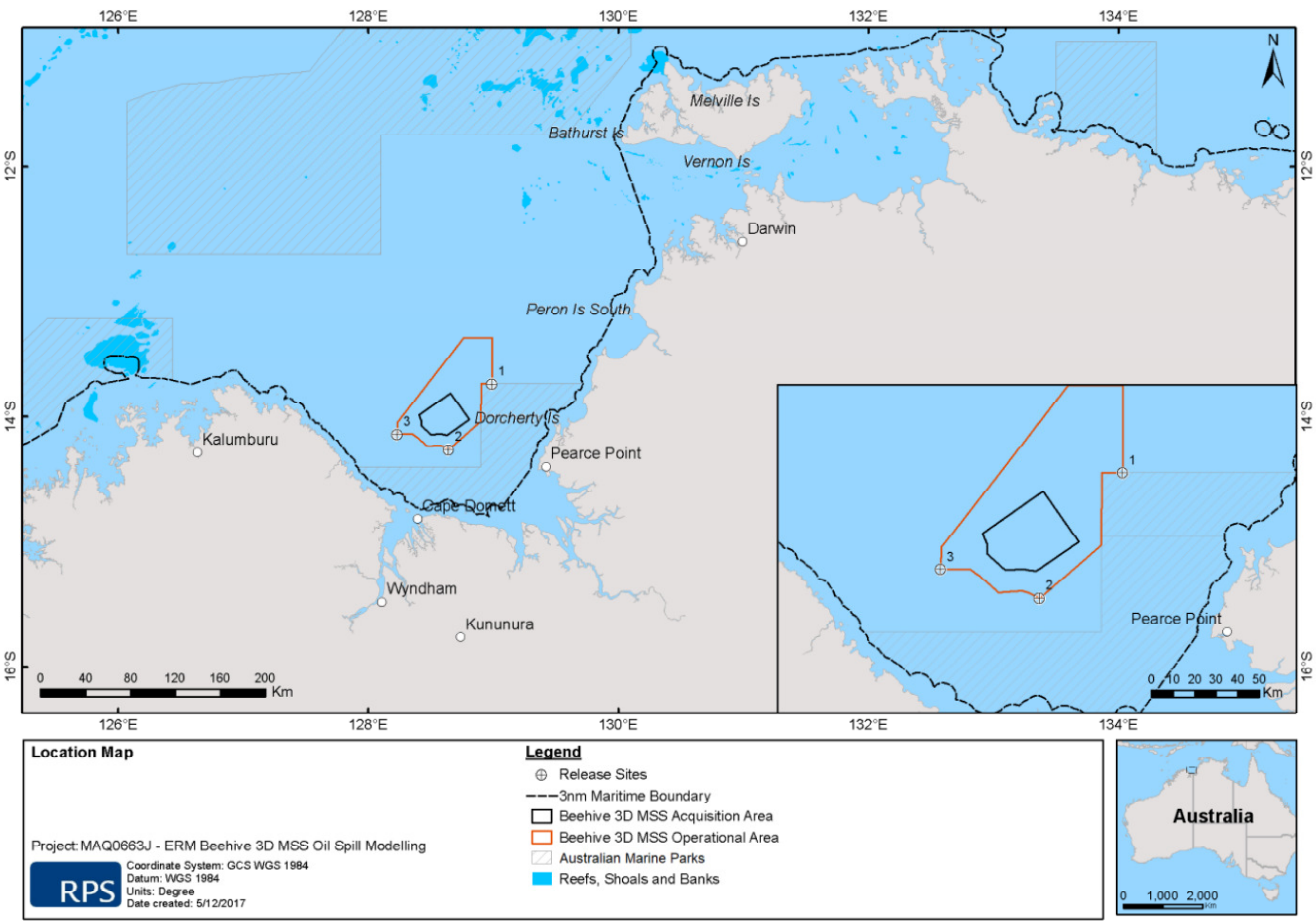

Figure 7.4 Diesel spill modelling locations

Marine Diesel Oil Properties

Marine diesel oil (MDO) is the common marine fuel used in vessel engines and is a mixture of both volatile (95%) and persistent (5%) hydrocarbons and is classified as a Group III hydrocarbon (*Table 7.24*). The general behaviour of MDO at sea includes the following aspects:

- Spreads very rapidly with the slick elongated in the direction of prevailing wind and current.
- Evaporation is the dominant process contributing to the removal of spilled MDO from the sea surface and can account for 60-70% loss (depending on wind conditions and sea temperature).
- Residues usually consist of heavy compounds which may persist longer and will tend to disperse as oil droplets into the upper layers of the water column.

Table 7.24 MDO Properties

		Marine Diesel Oil
API Gravity		37.6
Density @ 25°C g/mL		0.83
Viscosity @ 20 °C (cSt)		4.0@25°C
Pour Point °C		-14
Distillation % mass	Volatiles (< 180°C)	6
	Semi-Volatile (180°C -265°C)	34.6
	Low Volatility (265°C -380°C)	54.4
	Residual (> 380°C)	5
Group		**Group III**

Modelling Overview

- The spill modelling was performed using an advanced three-dimensional trajectory and fates model, SIMAP (Spill Impact Mapping Analysis Program). The SIMAP model calculates the transport, spreading, entrainment and evaporation of spilled hydrocarbons over time, based on the prevailing wind and current conditions and the physical and chemical properties.
- The SIMAP system, the methods and analysis presented herein use modelling algorithms which have been anonymously peer reviewed and published in international journals. Further, RPS-APASA warrants that this work meets and exceeds the ASTM Standard F2067-13 "Standard Practice for Development and Use of Oil Spill Models".
- The modelling study was carried out in several stages. Firstly, a five year current dataset (2008–2012) that includes the combined influence of ocean

and tidal currents was developed. Secondly, the currents, local winds and detailed hydrocarbon characteristics were used as inputs in the three-dimensional oil spill model (SIMAP) to simulate the drift, spread, weathering and fate of the spilled oil.

- As spills can occur during any set of wind and current conditions, modelling was conducted using a stochastic (random or non-deterministic) approach, which involved running 50 spill simulations per release site during the period April to September, with each simulation having the same spill information (spill volume, duration and composition of hydrocarbons) but varying start time. This ensured that each spill trajectory was subjected to varying wind and current conditions.

The SIMAP model is able to track hydrocarbons to levels lower than biologically significant or visible to the naked eye. Therefore, reporting thresholds have been specified (based on the scientific literature) to account for "exposure" on the sea surface and "contact" to shorelines at meaningful levels. *Table 7.25* details the threshold levels and the information used to determine the thresholds.

Table 7.25 Oil spill modelling thresholds

Threshold Value	Description of Potential Effect
Surface Hydrocarbons	
Low exposure: 0.5 – 10 g/m^2	The 0.5 g/ m^2 threshold equates approximately to an average thickness of ~0.5 µm. Oil of this thickness is described as a silvery to rainbow sheen in appearance, according to the Bonn Agreement Oil Appearance Code (Bonn Agreement 2009) and is also considered the practical limit of observing oil in the marine environment (AMSA, 2012). This threshold is considered below levels which would cause environmental harm and it is more indicative of the areas perceived to be affected due to its visibility on the sea surface.
Moderate exposure: 10 - 25 g/ m^2	Ecological impact has been estimated to occur at 10 g/ m^2 as this level of oiling has been observed to mortally impact birds and other wildlife (French et al. 1996, French-McCay 2009.
High exposure: > 25 g/ m^2 or µm	Studies have indicated that a concentration of surface oil above 25 g/ m^2 or greater would be harmful to marine birds that come in contact with the oil (Scholten et al. 1996, Koops et al. 2004).
Shoreline Accumulated Hydrocarbons	
Low exposure: 10 - 100 g/ m^2	French et al. (1996) and French-McCay (2009) have defined an oil exposure threshold for shorebirds and wildlife (furbearing aquatic mammals and marine reptiles) on or along the shore at 100 g/ m^2, which is based on studies for sub-lethal and lethal impacts. These thresholds have been used in previous environmental risk assessment studies (French-McCay 2003, French-McCay et al. 2004, French-McCay et al. 2011, NOAA 2013). Observations by Lin and Mendelssohn (1996), demonstrated that more than 1,000 g/ m^2 of oil during the growing season would be required to impact marsh or mangrove plants significantly.
Moderate exposure: 100 - 1,000 g m^2	
High exposure: > 1,000 g/ m^2	

Dissolved Aromatic Hydrocarbons	
Low: 576 ppb.hrs (6 ppb for 96 hrs)	Studies indicate that the dissolved aromatic compounds (typically the mono-aromatic hydrocarbons and the two and three ring poly-aromatic hydrocarbons) are commonly the largest contributor to the toxicity of solutions generated by mixing oil into water (Di Toro et al. 2007). The threshold value for species toxicity in the water column is based on global data from French et al. 1999 and French-McCay, 2002, 2003, which showed that species sensitivity (fish and invertebrates) to dissolved aromatics exposure > 4 days (96-hour LC50) under different environmental conditions varied from 6 to 400 µg/l (ppb) with an average of 50 ppb. This range covered 95% of aquatic organisms tested, which included species during sensitive life stages (eggs and larvae). Based on scientific literature, a minimum threshold of 6 parts per billion (ppb) over 96-hours or equivalent was used to assess in-water low exposure zones (Engelhardt 1983; Clark 1984; Geraci and St. Aubin 1988; Jenssen 1994; Tsvetnenko 1998. French-McCay 2002) indicates that an average 96 hour LC50 of 50 ppb and 400 ppb could serve as an acute lethal threshold to 5% and 50% to biota, respectively. Hence, the thresholds were used to represent the moderate and high exposure zones, respectively.
Moderate: 4,800 ppb.hrs (50 ppb for 96 hrs)	
High: 38,400 ppb.hrs (400 ppb for 96 hrs)	
Entrained Hydrocarbon Droplet	
Low Exposure: 67,200 ppb.hrs (700 ppb for 96 hrs)	Considering that entrained oil has undergone processes analogous to weathering and/or water-washing (i.e., many of the toxic soluble hydrocarbons have been removed through evaporation and/or dissolution), its toxicity is representative of true 'dispersed oil' phase impacts. OSPAR (2012) has published predicted no effect concentrations (PNEC) for 'dispersed oil' in produced formation water (PFW) discharges. Dispersed oil in PFW discharges are small, discrete droplets suspended in the discharged water which are very similar to insoluble dispersed oil droplets formed from subsea blowouts. In essence the oil has been partitioned (naturally separated) from gas/oil/water mixture by solubility (water washing) and vapour pressure (evaporation) based on the individual hydrocarbon chemical properties. Appropriate threshold values were extrapolated from the No effect concentrations examined in Smit et al., 2009 based on effects ranging from oxidative stress to impacts on growth, reproduction and survival and are represented by: 7 µg/l (7ppb) (for 1% affected fraction of species), 70.5µg/l (70ppb) (for 5% affected fraction of species) and 804 µg/l (804 ppb) (for 50% affected fraction of species). Utilising methodologies contained in ANZECC (2000), PNECs can be back-calculated to determine LC50 values by applying a factor of 100 to the PNEC values. This approach is supported by assessment factor criteria contained within the European Chemicals Agency (2008) and the OECD Existing Chemicals Programme 2002 (OECD, 2002). Employing these criteria, the following conservative threshold values for entrained hydrocarbons are applied: • LC50 (99% species protection): 700 µg/l (ppb) • LC50 (95% species protection): 7,050 µg/l (ppb); and • LC50 (50% species protection): 80,400 µg/l (ppb).
Moderate Exposure: 676,800 ppb.hrs (7,050 ppb for 96 hrs)	
High Exposure 7,718,400 ppb.hrs (80,400 ppb for 96 hrs)	

Modelling Results

The modelling predicted (RPS-APASA 2017):

- No shoreline contact was predicted for this scenario.
- No floating oil, at or above the lowest threshold (0.5 g/m^2), was shown to reach WA or NT waters.
- The Joseph Bonaparte Gulf Marine Park was shown to be exposed to floating oil from up to 41% of spills within an hour of release.
- Due to all three release sites being situated within the green turtle foraging area, this region has a 100% probability of being exposed to floating oil at all thresholds immediately after the spill occurred.
- Two of the release sites were located on the boundary of the flatback turtle 'habitat critical to the survival of a species', which caused that area to have 67% probability of exposure to all thresholds immediately after the spill occurred. Site 1 did not impact this area.
- Site 1 was located within the Demersal Fishery waters, which caused that area to have 33% probability of exposure to all thresholds immediately after the spill occurred.
- No entrained exposure (equal to or greater than the minimum reporting threshold 67,200 ppb.hrs) was predicted for this scenario.
- No dissolved aromatic exposure (equal to or greater than the minimum reporting threshold 576 ppb.hrs) was predicted for this scenario during any modelling period.

Figure 7.5 details the zone of potential exposure for surface oils at the moderate and low exposure thresholds. This shows the furthest area a spill would travel from the three release locations on the southeast boundary of the Operational Area.

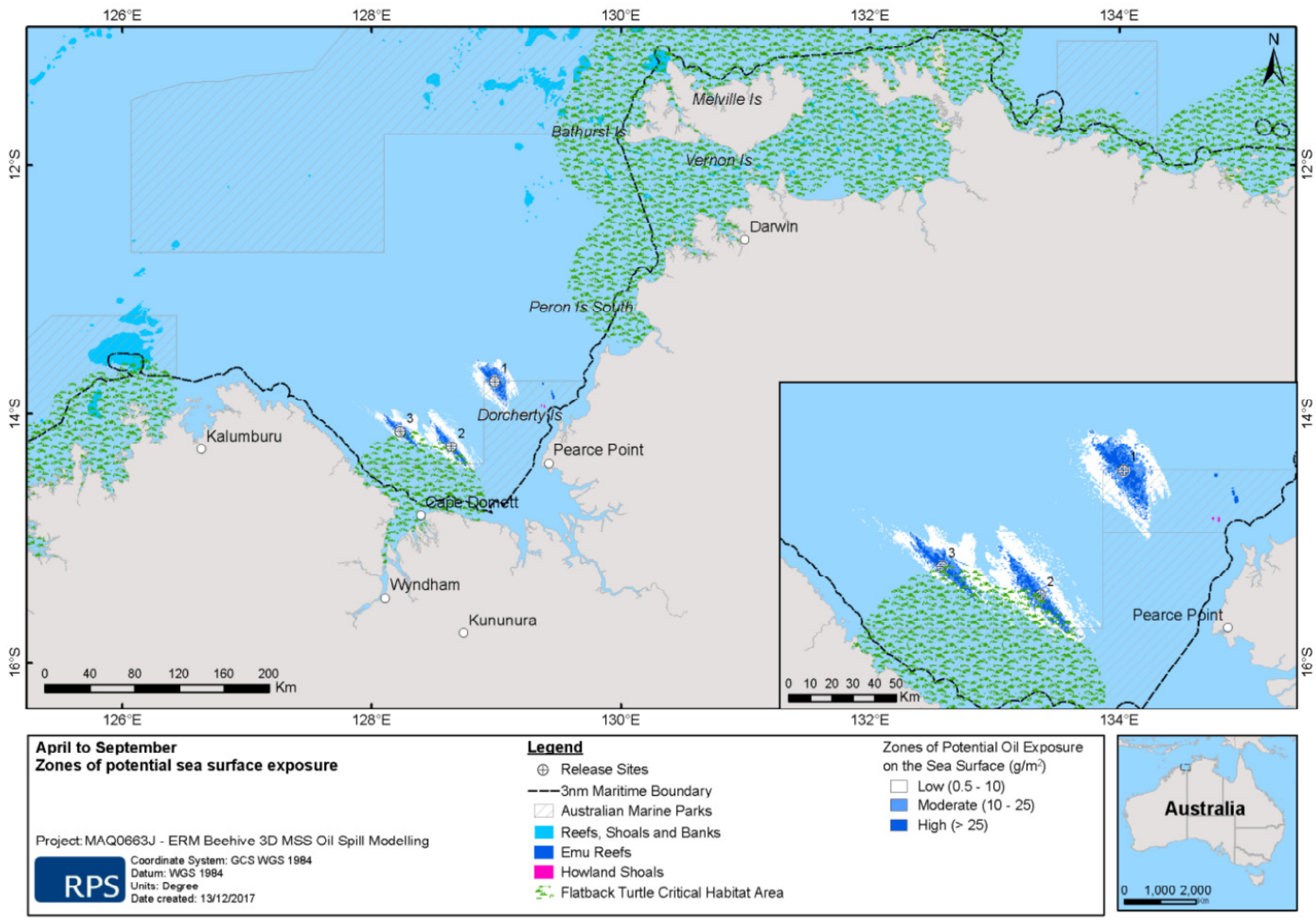

Figure 7.5 Zones of potential exposure on the sea surface, in the event of a 280 m³ surface release of MDO over 6 hours, tracked for 20 days

To determine the area that might be affected by a vessel collision MDO spill a review of receptors in *Table 5.1* was undertaken to identify those sensitive to surface oil exposure. It was identified that there were no social receptors that could be affect by the low exposure threshold where oil is potentially visible on the sea surface. Thus, the moderate exposure threshold at which ecological impacts may occur was used to determine the environment that might be affected (EMBA). This area is detailed in *Figure 7.6*.

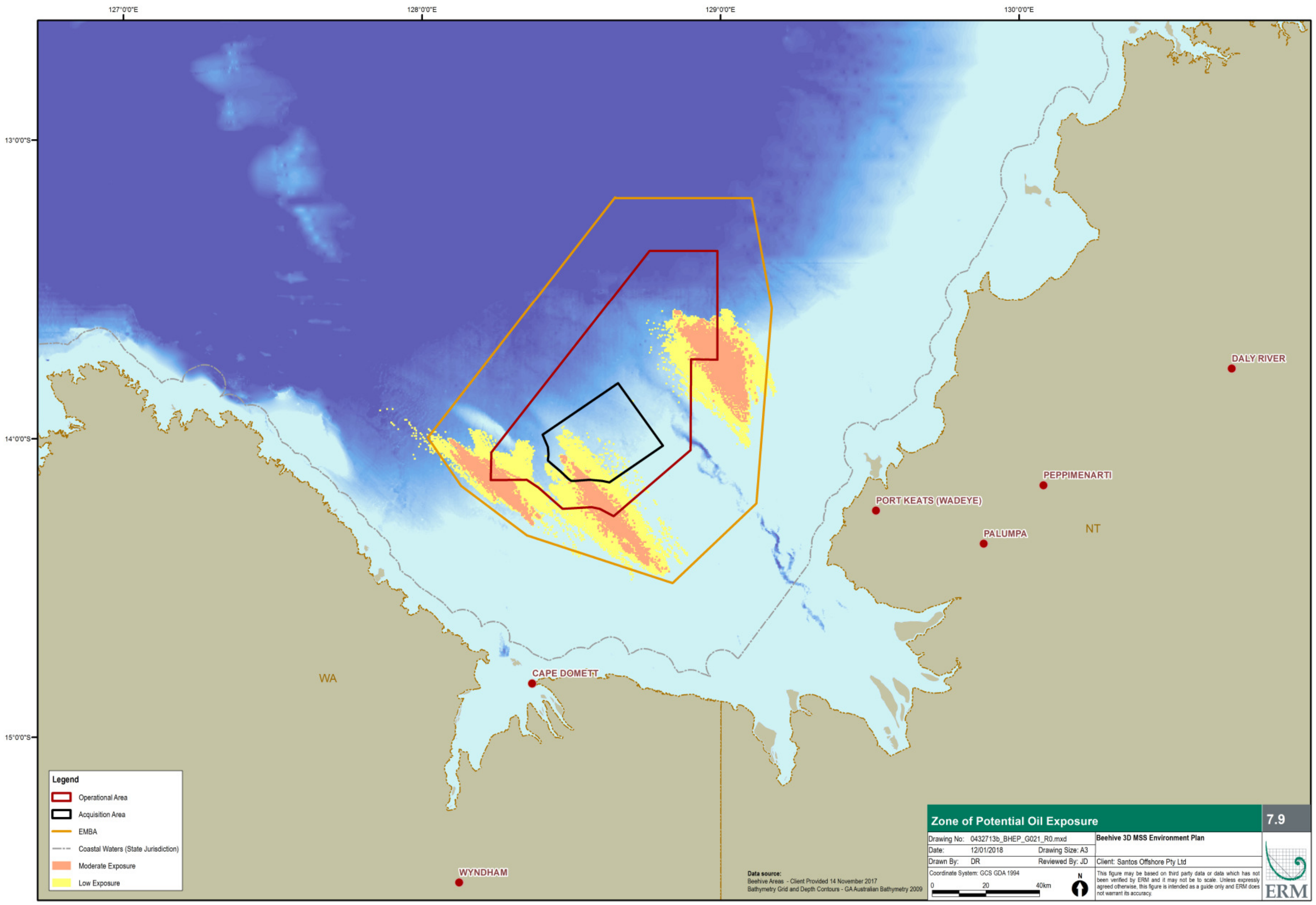

Figure 7.6 Vessel collision MDO spill Environment that May Be Affected (EMBA)

7.12.3 *Sensitive Environmental Receptors with the Potential to occur within the EMBA*

A review of receptors in *Table 5.1* identified those receptors within the EMBA sensitive to surface oil exposure. These are detailed in *Table 7.26*.

7.12.4 *Known and Potential Environmental Impacts*

The potential environmental impacts of a MDO spill are:

- Toxic effects to the marine environment including marine fauna.

7.12.5 *Evaluation of Environmental Impacts*

Potential receptors and an assessment of impacts from a MDO spill are detailed in *Table 7.26*. As detailed in *Section 7.12.2*, modelling predicted that entrained and aromatic concentrations would not trigger the lowest exposure thresholds. Thus, the impact assessment was undertaken on surface oil exposure. For this assessment the moderate surface oil threshold was used as this is the threshold at ecological impact has been estimated to occur as no social receptors were identified that could be affected by surface oil exposure.

Potential impacts are only likely to occur to fauna present on the ocean surface or when air breathing fauna, such as turtles and cetaceans, surface to breathe. In these situations, fauna may come into contact directly with the MDO or indirectly via vapours as the MDO breaks down. Most evaporation of MDO is within the first 48 hours (RPS-APASA 2017) hence, fauna would be exposed to vapours for a short time frame.

Due to the weathering nature of MDO a spill spreads rapidly and thinly and hence is not expected to result in fauna ingesting significant volumes or result in persistent oiling.

Based on the threshold levels, impacts to fauna would be limited to within the EMBA and would be short term, hydrocarbons are predicted not persist beyond 22 days.

Thus, though a vessel collision would be remote, impacts would be extensive (within the EMBA) and short term (up to 22 days) to fauna of environmental value.

Table 7.26 Impact assessment of MDO spill on receptors

Environment Receptor	Potential Impact to Receptor	Summary of Potential Impacts
Shoreline	No	No shoreline contact.
Benthic habitats	No	No impact as entrained and aromatic concentrations did not trigger the lowest exposure thresholds.
Sharks and rays	No	No BIA (biological important areas) within moderate threshold surface exposure area. No impact as entrained and aromatic concentrations did not trigger the lowest exposure thresholds.
Turtles	Yes	May encounter surface hydrocarbons. The Acquisition and Operational areas overlap foraging BIA for green and olive ridley turtles, and flatback turtles ay encounter surface hydrocarbons within 'habitat critical to the survival of a species' adjacent to Cape Domett. Consequently, there is the potential for a larger number of individuals to be present in these areas. As such, turtles may encounter surface hydrocarbons given their presence in the BIA and 'habitat critical to the survival of a species'. Sea turtles can be affected by oil spills via oiling, direct ingestion of oil and prolonged exposure to oil vapours (NOAA 2010). Contact with spilt hydrocarbons can result in coating of body surfaces causing irritation of mucous membranes in the nose, throat and eyes which can result in inflammation and infection. Potential impacts to the respiratory system may also result from inhalation of oil vapours when they come to the surface to breathe. Due to the weathering nature of MDO a spill spreads rapidly and thinly and consequently, turtles are not expected to ingest significant volumes or result in persistent oiling. Most evaporation of MDO is within the first 48 hours (RPS-APASA 2017) hence, turtles would be exposed to vapours for a short time frame. Thus, impacts to turtles that may foraging in, or transiting through, the area are likely to be localised and short term in nature.
Marine Birds	Yes	May encounter surface hydrocarbons. No BIA within moderate threshold surface exposure area. Consequently, it is only expected that transient individuals could be exposed to surface hydrocarbons above thresholds that could result in an impact. Marine birds may become exposed to oil from diving to obtain food or resting on the sea surface. They can be affect by oiling, exposure to oil vapours and direct and indirect ingestion of oil. Oiling of feathers can impact on the bird's ability to thermo-regulate (IPIECA 2017). Due to the weathering nature of MDO a spill spreads rapidly and thinly and hence marine birds are not expected to ingest significant volumes or result in persistent oiling. Most evaporation of MDO is within the first 48 hours (RPS-APASA 2017) hence, marine birds would be exposed to vapours for a short time frame. Thus, impacts to marine birds that may feeding or resting in the area are likely to be localised and short term in nature.
Cetaceans	Yes	May encounter surface hydrocarbons. No BIAs within moderate threshold surface exposure area, consequently it is only expected that transient individuals could be exposed to surface hydrocarbons above thresholds that could result in an impact. Cetaceans may become exposed to oil on surfacing to breathe where they can be affect by oiling, exposure to oil vapours and ingestion of oil. There is little documented evidence of effects of oiling on whales (IPIECA 2017).

Environment Receptor	Potential Impact to Receptor	Summary of Potential Impacts
		Due to the weathering nature of MDO a spill spreads rapidly and thinly and hence cetaceans are not expected to ingest significant volumes or result in persistent oiling. Most evaporation of MDO is within the first 48 hours (RPS-APASA 2017) hence, cetaceans would be exposed to vapours for a short time frame. Thus, impacts to cetaceans that may present in the area are likely to be localised and short term in nature.
Commercial fisheries	No	Northern Prawn Fishery fishing area in the southern JBG is within the EMBA, but entrained and aromatic concentrations did not trigger the lowest exposure thresholds. Consequently, this fishery is not expected to be significantly impacted by this type of event.
Recreational activities	No	No recreational activities identified.
Maritime Heritage	No	No historic shipwrecks identified.
State or Territory Protected Areas	No	No surface oil, at or above the lowest threshold, predicted to reach WA or NT waters.
Commonwealth Protected Areas	Yes	Surface hydrocarbons at low and moderate thresholds predicted to contact Joseph Bonaparte Gulf Marine Park Special Purpose Zone and Multiple Use Zone. Entrained and aromatic concentrations did not trigger the lowest exposure thresholds.
Key Ecological Features	No	Carbonate banks and terrace systems of the Sahul Shelf KEF is comprised of submerged features and entrained and aromatic concentrations did not persist in the water column long enough to trigger the lowest exposure thresholds.

Summary

Consequence Level: If the activity results in a diesel spill from a vessel collision, there is potential for toxic effects to the marine environment resulting in extensive and short term impacts to animals of environmental value – (III).

Likelihood Level: For this activity, a vessel collision incident resulting in extensive and short term impacts to animals of environmental value is considered Remote (a).

Table 7.27 Vessel collision spill risk assessment

<table>
<tr><th colspan="4">ALARP Decision Context</th></tr>
<tr><th>Decision Context</th><th colspan="3">Justification</th></tr>
<tr><td>A</td><td colspan="3">The potential for a vessel collision is limited due to low level of other vessel activity in the Beehive survey area. The management of offshore vessels is well regulated and understood. Risks are well understood and managed. No objections or concerns were raised by relevant stakeholders regarding vessel collisions or resulting spill events. Consequently, Santos believes that decision context A be applied to this hazard.</td></tr>
<tr><th colspan="4">Control Measure Identification</th></tr>
<tr><th colspan="2">Good Practice Control Measure</th><th colspan="2">Control Measure Source</th></tr>
<tr><td colspan="2">Navigation Act 2012 (enacted by AMSA Marine Orders 31, Vessel; Surveys and certification)</td><td colspan="2">The marine order requires that the vessel class be certified to ensure that it meets the Navigational Act 2012 requirements.</td></tr>
<tr><td colspan="2">Navigation Act 2012 (enacted by AMSA Marine Orders 30, Prevention of Collisions)</td><td colspan="2">Under the Navigation Act 2012, it is the responsibility of the Australian Hydrographic Service to maintain and disseminate hydrographic and other nautical information and nautical publications including Notices to Mariners.</td></tr>
<tr><td colspan="2">OPGGS(E) Regulations requirement for an approved OPEP</td><td colspan="2">Under the OPGGS(E) Regulations, NOPSEMA require that the petroleum activity have an accepted Oil Pollution Emergency Plan in place prior to that activity commencing. In the event of a vessel collision the OPEP will be implemented.</td></tr>
<tr><th colspan="4">Residual Risk Ranking</th></tr>
<tr><th>Potential Impact</th><th>Consequence</th><th>Likelihood (of Consequence)</th><th>Residual Risk</th></tr>
<tr><td>Toxic effects to the marine environment including marine fauna</td><td>III</td><td>Remote (a)</td><td>Very Low (1)</td></tr>
<tr><th colspan="4">Environmental Performance Outcomes, Standards & Measurement Criteria</th></tr>
<tr><th>EPO</th><th colspan="2">Control Measures & EPS</th><th>MC</th></tr>
<tr><td>No spills to the marine environment</td><td colspan="2">Navigational requirements
Class certificate demonstrates vessel complies with the Navigation Act 2012 and applicable Marine Orders.</td><td>Class Certificate.</td></tr>
</table>

	Notifications Notice to Mariners (NTM) via notifications to Australian Hydrographic Service (AHS) a minimum of 3 weeks prior to commencement of activities.	Notification records to AHS. NTM.
Oil spill response implemented in accordance with accepted plans to minimise impacts from spilled hydrocarbons	*OPEP implementation* Beehive OPEP implemented for spills to water.	Records from oil spill response incident.

Demonstration of Acceptability	
Is residual risk determined to be 1 and the ALARP Decision Framework A applied? If No ALARP must be demonstrated and the following must be met.	Yes
Principles of ecologically sustainable development met?	Evaluation not required
Legal and other requirements met?	Evaluation not required
Santos policy and standards met?	Evaluation not required
Stakeholder expectations met?	Evaluation not required

8 *IMPLEMENTATION STRATEGY*

Finniss is the sole titleholder of exploration permit WA-488-P. Finniss is a wholly owned subsidiary of Melbana Energy Limited (formerly MEO Australia). Pursuant to an Operations Services Agreement dated 21 November 2017 between Finniss, Melbana and Santos, Finniss has engaged Santos to perform certain operational services in connection with the acquisition of 3D seismic survey data over exploration permit WA-488-P, including undertaking the Beehive 3D MSS.

Santos will undertake the Beehive survey for and behalf of Finniss. The Beehive survey will be carried out by a contracted seismic company under a seismic acquisition contract. Under the seismic acquisition contract, Santos administers the contract as the agent of Finniss.

As Santos will be undertaking the Beehive survey on behalf of Finniss, it will be Santos' management systems and processes that will apply during the course of the Beehive survey to manage the environmental impacts and risk of the activity.

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

The Melbana Energy HSE Committee Charter, which includes the company's Environment Policy, is provided in Appendix 1. The Santos Environment, Health and Safety Policy is also provided in Appendix 1.

8.1 *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 framework for the SMS is provided in *Figure 8.1* and includes:

- Constitution, Board Charters, Delegation of Authority - These documents define the purpose and authorities of the Santos Limited Board, Board Committees
- 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 Standard and Policy requirements by providing detail of 'How' to achieve performance requirements.

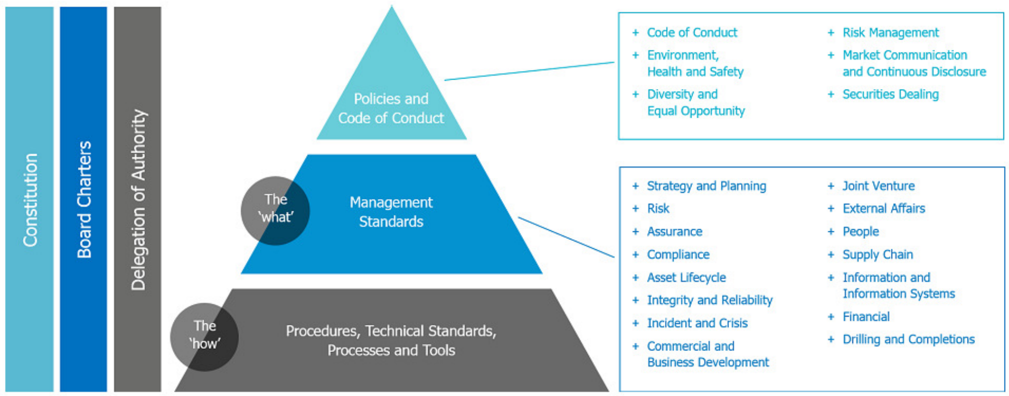

Figure 8.1 Santos Management System Framework

8.2 ROLES AND RESPONSIBILITIES

The organisation structure for the Beehive 3D MSS is detailed in *Figure 8.2*. Key roles and environmental responsibilities for the survey are detailed in *Table 8.1*and will be communicated to these positions prior to the survey commencing and when any changes are made to these positions.

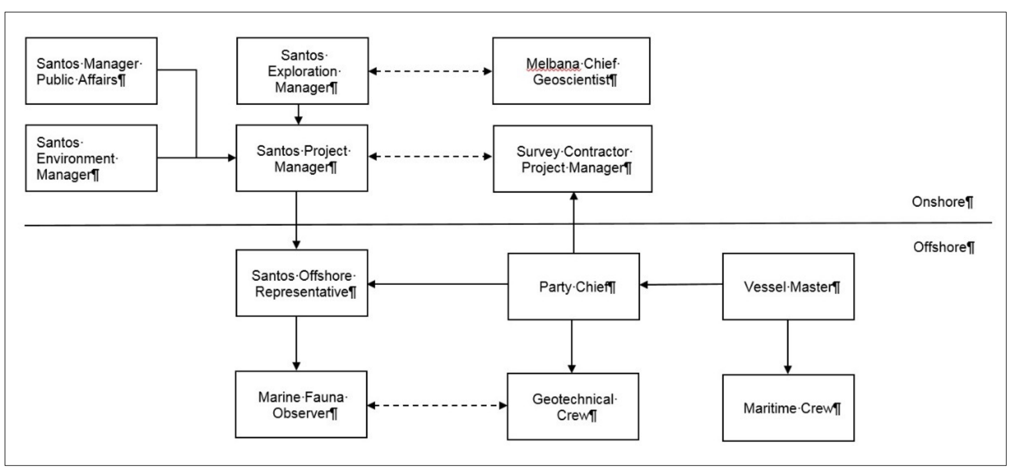

Figure 8.2 Beehive 3D MSS organisation structure

Table 8.1 Beehive 3D MSS key personnel roles and environmental responsibilities

Role	Responsibilities
Santos Exploration Manager	Ensure compliance with SMS including the EHS Policy. Ensure adequate resources are in place to meet the requirements within the EP and OPEP. Ensure adequate emergency response capability is in place for the survey. Ensure incidents and non-conformances are managed as per *Section 8.7 and 8.8.4*, respectively. Notify NOPSEMA of a change in titleholder, a change in the titleholder's nominated liaison person or a change in the contact details for either (*Section 8.4*). Review information received from external sources in regards to lessons learnt and non-conformances, relevant to the survey, with the project team to identify if there are actions relevant to the survey. If actions are relevant implement as per *Section 8.8.4*.
Melbana Chief Geoscientist	Ensure Santos is compliant with the accepted EP via: Review of daily reports. Review of audit, performance and non-conformance reports (*Sections 8.8.3* and *8.8.4*). Submit incident reports for incidents (*Table 8.3*) that occur in WA-488-P permit and ensure investigations undertaken. Ensure the EP Performance Report is prepared and submitted to NOPSEMA (*Section 8.8.5*). Review information received from internal (Melbana) and external sources in regards to lessons learnt and non-conformances relevant to the survey, and communicating to the Santos Exploration Manager.
Santos Project Manager	Ensure compliance with SMS including the EHS Policy. Ensure overall compliance with the EP. Ensure relevant environmental legislative requirements, performance outcomes, control measures, performance standards, measurement criteria and requirements in the implementation strategy in this EP are: • Communicated to the onshore and offshore survey key personnel as detailed in *Table 8.3*. • Included in the HAZID and resulting risk register. • Audited to inform the EP Performance Report. Ensure contractors are competent for the role they are employed for (*Section 8.3*). Ensure the response arrangements in the OPEP are tested prior to the survey commencing as per *Section 8.3* of the OPEP. Report environmental incidents to the Santos Exploration Manager and Melbana Chief Geoscientist, and ensure reporting (*Table 8.3*) and investigations are undertaken. Provide copies of all incident reports to the Melbana Chief Geoscientist. Ensure records and documents are managed so they are available and retrievable (*Section 8.8.2*). Ensure non-conformances identified are communicated, raised in EHS Toolbox and corrective actions completed (*Section 8.8.4*). Review information received from external sources in regards to lessons learnt and non-conformances, relevant to the survey, with the project team to identify if there are actions relevant to the survey. If actions are relevant implement as per *Section 8.8.4*.

Role	Responsibilities
	Review daily Santos Incident Summary Report and communicate relevant incidents and learnings to the Santos Offshore Representative (*Section 8.8.4*). Ensure the EP Performance Report is prepared and submitted to NOPSEMA (*Section 8.8.5*).
Santos Public Affairs Manager	Undertake consultation with relevant persons. Document consultation with relevant persons. Ensure any commitments to relevant persons are undertaken. Review information received from external sources in regards to lessons learnt and non-conformances, relevant to the survey, with the project team to identify if there are actions relevant to the survey. If actions are relevant implement as per *Section 8.8.4*.
Santos Environment Manager	Identify and communicate relevant environmental legislative requirements, performance outcomes, control measures, performance standards, measurement criteria and requirements in the implementation strategy in this EP and OPEP to the Exploration Manager, Project Manager and Offshore Representative. Develop the environmental component of the survey induction (*Section 8.3*). Assess any environmentally relevant changes (*Section 8.4*). Review any non-conformances relevant to environment performance to ensure corrective actions are appropriate to prevent recurrence (*Section 8.8.4*). Review information received from external sources in regards to lessons learnt and non-conformances, relevant to the survey, with the project team to identify if there are actions relevant to the survey. If actions are relevant implement as per *Section 8.8.4*. Prepare and submit the annual EP Performance Report to NOPSEMA within 3 months of the activity finishing (*Section 8.8.5*).
Santos Offshore Representative	Ensure compliance with relevant environmental legislative requirements, performance outcomes, control measures, performance standards, measurement criteria and requirements in the implementation strategy in this EP. Ensure survey inductions undertaken all offshore personnel (*Section 8.3*). Ensure changes are assessed and approved by Santos (*Section 8.4*). Ensure chemicals that have the potential to be discharged to the marine environment are assessed and approved using the Santos Offshore Chemical Assessment Process (Section 8.6). Report all incidents to the Santos Project Manager (*Section 8.7*). Ensure relevant monitoring records (*Section 8.8.2*) are collated and provided to the Santos Project Manager on completion of the program. Ensure non-conformances and actions are discussed at the vessel daily meeting including those relevant from other areas of Santos. Ensure corrective actions identified from incidents or inspections are implemented (*Section 8.7 and 8.8.4*).
Survey Contractor Project Manager	Ensure compliance with relevant environmental legislative requirements, performance outcomes, control measures, performance standards, measurement criteria and requirements in the implementation strategy in this EP. Ensure adequate resources are in place to meet the requirements within this EP. Ensure adequate emergency response capability is in place for the survey.

Role	Responsibilities
Party Chief	Ensure compliance with relevant environmental legislative requirements, performance outcomes, control measures, performance standards, measurement criteria and requirements in the implementation strategy in this EP.
Geotechnical Crew	Ensure compliance with relevant environmental legislative requirements, performance outcomes, control measures, performance standards, measurement criteria and requirements in the implementation strategy in this EP.
Vessel Master	Ensure compliance with relevant environmental legislative requirements, performance outcomes, control measures, performance standards, measurement criteria and requirements in the implementation strategy in this EP.
Maritime Crew	Ensure compliance with relevant environmental legislative requirements, performance outcomes, control measures, performance standards, measurement criteria and requirements in the implementation strategy in this EP.

8.3 *TRAINING AND COMPETENCE*

Key roles for the Beehive 3D MSS, as detailed in *Section 8.2*, have position descriptions that outline the competency requirements including experience, training and qualifications. Specific requirements set out in this EP will be communicated to key personnel prior to commencement of the survey and if personnel change.

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

All offshore personnel will be required to complete an induction that will cover the requirements in this EP and OPEP. At a minimum the induction will cover:

- Activity description
- Key receptors in the area
- Environmental impacts and risks, and associated controls to be implemented
- Management of change process
- Roles and responsibilities
- Incident and non-conformance reporting and management
- Oil spill response

8.4 *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 this standard; and
- authorised in the existing management plans, procedures, work instructions, or maintenance plans.

b) proposed changes to activities, assets, equipment, survey parameters as per *Section 3*, 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 EP;

e) identification of a new relevant stakeholder; and

f) the final management plan for the North-west Marine Parks Network, which includes the Joseph Bonaparte Gulf Marine Park, was approved by the Minister for the Environment and Energy on 25 January 2018 and introduced into Parliament on 21 March 2018. The management plan commences on 1 July 2018. If this plan comes into force prior to or during the survey, the MoC process will be used to ensure activities are not inconsistent with the principles and plans in force.

Where an environmentally relevant change is identified, the Offshore Environment Management of Change Process is undertaken by an Environmental Adviser and if required appropriate technical and/or legal advice is sought. The MoC assessment is made against the in-force EP and is undertaken to ensure that impacts and risks from the change can be managed to ALARP and acceptable levels.

In the event that the proposed change 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 EP will be revised and submitted for re-assessment and acceptance by the regulator.

Where a change results in the EP being updated, the change/s are to be logged in the EP Change Register.

Section 1.2 details the WA-488-P titleholder, survey nominated liaison person and contact details for both. A change in any of these details are required to be notified to NOPSEMA.

8.5 EMERGENCY RESPONSE

Contracted vessels will have an Emergency Response Plan (ERP) and a Shipboard Oil Pollution Emergency Plan (SOPEP). For vessel emergencies, the vessel contractor documentation and processes will be implemented. For an oil spill to water, the Santos Beehive 3D MSS OPEP will be implemented.

The response arrangements in the OPEP will be tested prior to commencing the survey as per *Section 8.3* of the OPEP.

8.6 CHEMICAL ASSESSMENT PROCESS

HSHS08 Chemical Management mandates that new chemicals must be approved prior to use and that EHSMS12 Management of Change is used to identify the hazards associated with the way the chemical will be used, stored and disposed of and consider potential consequences to personal health and safety, the environment and process safety. The Santos Offshore Chemical Environmental Risk Assessment Process (0010-650-RIS-0001) is used to assess chemicals that have the potential to be discharged to the marine environment to ensure the lowest toxicity chemicals are selected that meet the technical requirements. A summary of the process is detailed in *Table 8.2*.

Table 8.2 Santos offshore chemical environmental risk assessment process summary

Step No.	Evaluation Step	Inputs	Action
1	Determine chemical proposed for use	Confirm: Chemical name and supplier Chemical Function/purpose Formulation, CAS number Ecotoxicity data, where available Estimated use, dosage and discharge	Proceed to Step 2
2	Determine whether the chemical is to be discharged to the marine environment	Refer to EP to determine proximity to priority sensitivities	Where chemical is to be used in a closed loop system no further action is required.
			Where chemical is to be discharged – proceed to Step 3

Step No.	Evaluation Step	Inputs	Action
3	Determine whether the chemical is on the OSPAR PLONOR List	Refer to OSPAR PLONOR List	Where the chemical is listed as PLOONR no further action required. Where the chemical Is not listed go to Step 4
4	Determine whether the chemical is on the OCNS Definitive Ranked Lists of Registered Substances and the Hazard Quotient	Refer to the Definitive Ranked Lists of Registered Substances and determine the Hazard Quotient	Is the HQ Band "Gold" or "Silver," or OCNS Group "E" or "D"? If yes go to Step 5 Where the chemical is not listed go to Step 6
5	Determine whether the chemical has a substitution or product warning	Refer to OCNS Definitive Ranked Lists of Registered Substances or obtain from the current CEFAS template.	Where the chemical does not have a product or substitution warning no further action is required. Where the chemical has a product or substitution warning go to Step 7.
6	Assess the Eco-toxicity	LC50 or EC50 concentrations for representative species; Octanol-water partition coefficient (logPow); and Biodegradation information (% biodegradation in 28 days).	Requires a Hazard Assessment and ALARP justification where: Toxicity = LC50 <100 mg/L or EC50 <100mg/L Bioaccumulate = Log Pow >3 Biodegradability <20%
7	Consider an alternative or complete ALARP justification	Technical justification required to proceed with selected chemical	If there is no technical justification for the chemical it is not accepted for use. If there is a technical justification complete Chemical Selection ALARP Justification form. Approval required from Environmental Team Lead.

8.7 *INCIDENT REPORTING*

EHSMS15 Incident Investigation and Response sets out the requirements for incident notification, reporting and investigation. 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 8.3 details the external incident notification, reporting requirements and timeframes for environmental incidents associated with the Beehive 3D MSS.

Santos will undertake any initial notification reporting requirements for incidents within WA-488-P. Melbana will be responsible for any further reporting requirements. Where an incident is not associated with the WA-488-

P permit area, Santos will be responsible for all notifications and reporting and will provide Melbana copies of all documentation for their records.

Table 8.3 Incident reporting requirements

Requirements	How and By When
Incident involving cetacean	
Death or injury to a cetacean (whales and dolphins). All cetaceans are protected in Commonwealth waters and, the EPBC Act requires that all collisions with whales in Commonwealth waters are reported and submitted to the National Ship Strike Database.	Secretary of the Commonwealth Department of Environment and Energy (DoEE) within seven days. 1800 803 772 protected.species@environment.gov.au https://data.marinemammals.gov.au/report/shipstrike
Recordable Incident Reporting	
A recordable incident is a breach of an environmental performance outcome or environmental performance standard, in the environment plan that applies to the activity; and is not a reportable incident.	Submit written report to NOPSEMA by 15th of every month
The recordable incident report must contain: (i) a record of all recordable incidents that occurred during the calendar month; 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 stop, control or remedy the recordable incident; and (v) the corrective action that has been taken, or is proposed to be taken, to prevent similar recordable incident.	
Reportable Incident Notification	
A reportable incident is an incident relating to the activity that has caused, or has the potential to cause, moderate to significant environmental damage. Based on the Santos Risk Matrix this is an incident that has an actual or potential consequence ≥ III. Incidents should also be reported to NOPSEMA, WA DMP and NT DPIR if it has been reported to another government department or agency or there is the potential for media or stakeholder interest.	Report verbally (or by email if phone contact is not possible) to NOPSEMA as soon as practicable and in any case not less than 2 hours. As soon as practicable provide a written record of the notification to
The verbal notification must include: (vi) all material facts and circumstances concerning the reportable incident that the	

Requirements	How and By When
titleholder knows or is able, by reasonable search or enquiry, to find out; and (vii) any actions taken to avoid or mitigate any adverse environmental impacts; and (viii) any corrective actions that have been taken, or is proposed to be taken, to stop, control or remedy the reportable incident. Written notification: The titleholder is not required to include in the record anything that was not included in the notification.	NOPSEMA, the Titles Administrator (NOPTA) and WA DMIRS. NOPSEMA +61 8 6461 7090 submissions@nopsema.gov.au WA DMIRS + 61 419 960 621 petroleum.environment@dmp.wa.gov.au NT DPIR 08 8999 6350 petroleum.operations@nt.gov.au NOPTA info@nopta.gov.au
Reportable Incident Reporting	
The initial notification of a reportable incident must be followed up by a written report. As a minimum, the written incident report will include: (i) all material facts and circumstances concerning the reportable incident that the titleholder knows or is able, by reasonable search or enquiry, to find out; and (ii) any actions taken to avoid or mitigate any adverse environmental impacts; and (iii) the corrective action that has been taken, or is proposed to be taken, to stop, control or remedy the reportable incident; and (iv) the action that has been taken, or is proposed to be taken, to prevent a similar incident occurring in the future. Within 7 days after giving a copy of the reportable incident report to the NOPSEMA a copy must be given to the Titles Administrator, WA DMP and NT DPIR.	As soon as practicable, and not later than 3 days following the incident NOPSEMA submissions@nopsema.gov.au WA DMIRS + 61 419 960 621 petroleum.environment@dmp.wa.gov.au NT DPIR 08 8999 6350 petroleum.operations@nt.gov.au NOPTA info@nopta.gov.au
Vessel Based Oil Spill in Commonwealth Waters	
AMSA must be notified immediately of a vessel based oil spill incident in Commonwealth waters.	Oil spill: +61 2 6230 8111 mdo@amsa.gov.au
DoNP must be notified as soon as possible of a vessel based oil spill incident within the Joseph Bonaparte Gulf Marine Park. Notification should include: • Titleholder details • Time and location of the incident • Proposed response strategies as per OPEP • Contact details for the response.	Marine Reserve Compliance Duty Officer +61 419 293 465

Requirements	How and By When
Suspected or Confirmed Marine Pest or Disease	
The WA DPIRD (Fisheries) is to be notified within 24 hours of a suspected or confirmed presence of any marine pest or disease. This includes any organism listed in the WA Prevention List for Introduced Marine Pests and any other non-endemic organism that demonstrates invasive characteristics. http://www.fish.wa.gov.au/Documents/biosecurity/epa_introduced_marine_pests.pdf	Email: biosecurity@fish.wa.gov.au Telephone: Fishwatch 1800 815 507

8.8 ENVIRONMENTAL PERFORMANCE MONITORING AND REPORTING

8.8.1 *Emissions and Discharges Monitoring*

Table 8.4 details the monitoring that will be undertaken for planned emissions and discharges associated with the activity.

Table 8.4 Emission and discharge monitoring

Aspect	Monitoring	Frequency	Requirement
Atmospheric emissions	Vessel fuel use	Daily	Total fuel used
Bilge water discharge	Bilge water OIW content	Daily (if discharged)	Bilge water OIW exceedance > 15 ppm
Waste	Waste sent onshore Waste incinerated	As required	Volume of waste sent onshore Volume of waste incinerated
Ballast water discharge	Discharge of vessel ballast water	As required	Volume discharged and location
Waste	Discharge of putrescible waste	As required	Volume of food scraps discharges, ensuring they are <25 mm in size and discharged >3 nm from land
Waste	Waste	As required	Volumes and location of waste accidentally discharged overboard
Spills	Spills	As required	Volumes and location of fuel spilled to sea

8.8.2 *Record Management*

SMS Information and Information Systems detail the requirements to ensure that information is kept current and accurate, stored in a manner to facilitate retrieval, and is accessible to personnel who need it.

Document control and record keeping requirements including record retention periods are specified in the SMS. Where no record retention requirement is specified, the default for physical records is 10 years and 'life of plant' for electronic records.

8.8.3 *Audit*

To ensure that the EP requirements have been effectively implemented and that the performance outcomes and standards in the EP have been met the following audits will be undertaken:

- Contractor Pre-start– to ensure the EP requirements will be implemented by the contractor.
- Contractor During the activity – to ensure EP requirements have been implemented by the contractor.
- Santos Pre-start – to ensure EP requirements will be implemented by Santos.
- Santos During the activity – to ensure EP requirements have been implemented by Santos.

These audits will be undertaken by a qualified third party.

Audits findings including actions will be communicated to the Santos Exploration Manager, Melbana Chief Geoscientist, Santos Environment Manager, Santos and Contractor Project Managers and Santos Offshore Representative via an audit report.

Actions are agreed with the Environment Manager, Santos and Contractor Project Managers 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 manger who receive notification of the overdue action.

8.8.4 *Management of Non-Conformances*

For the activity a non-conformance is classed as:

- A breach of an environmental performance outcome or environmental performance standard. 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 (*Section 8.8.3*)

- Emissions and discharge monitoring (*Section 8.8.1*)
- Incident reporting and investigations (*Section 8.7*)
- Preparation of the Annual Performance Report (*Section 8.8.5*)

Where a non-conformance is identified actions are implemented to correct the non-conformance and prevent reoccurrence. Effectiveness of the actions is reviewed via auditing (*Section 8.8.3*) and performance reporting (*Section 8.8.5*) to ensure that non-conformances are not re-occurring and environmental performance is improving.

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

- Communicated to the Santos Exploration Manager and Melbana Chief Geoscientist via the daily report, weekly meetings and the appropriate reports (i.e. audit, performance, incident investigation) to ensure they are made aware of non-conformances and the corrective actions to help prevent recurrence of similar incidents.
- Communicated to the Project and Contract Managers and Santos Offshore Representative 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 survey vessel and support vessels crews at daily pre-start meeting via the Santos Offshore Representative 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.
- Agreed with the Santos and Contractor Project Manager and actions assigned an actioner and required completion date.
- 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.
- Reported externally as per the requirements are detailed in *Section 8.7* and *Section 8.8.5*.

The Santos EHS Toolbox consists of modules for recording audits, incidents, emergency response exercises, obligations, and actions. The toolbox includes initial notification of non-conformances to be sent at a minimum to the responsible manager though other personnel can be selected as required. The toolbox also has an action tracking and reporting component 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 manger who receive notification of the overdue action.

For incidents a companywide daily report is sent to registered personnel, which for the survey would be at a minimum the Santos Project Manager and Environment Manager. This allows for the sharing of incidents and lesson learnt between different parts of the business. Any incidents raised from other parts of the business applicable to the survey will be communicated to the Santos Offshore Representative to discuss at the daily meeting.

The Santos Exploration Manager, Melbana Chief Geoscientist, Santos Project Manager, Environment Manager and Public Affairs Manager receive formal and informal information via industry associations, engagement with stakeholders including community, other oil and gas companies, regulators and Joint Ventures. Where information is received from external sources in regards to lessons learnt and non-conformances, relevant to the survey, these will be discussed by the project team to identify if there are actions relevant to the survey. If actions are relevant they will be implement as per Santos non-conformance process detailed in this Section.

8.8.5 Annual Performance Report

Melbana and Santos will submit an EP Performance Report to NOPSEMA with sufficient information to enable the regulator to determine whether the environmental performance outcomes and standards in the EP have been met.

The report will be submitted within 3 months of the end of the activity.

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Appendix 1: Melbana & Santos Corporate Environment Policies

Melbana Energy

Health, Safety and Environment Committee Charter

Approved by the Board on 22 June 2017

The Board will act as the health, safety and environment committee by considering specific agenda items at every board meeting.

1 Safety

- The Board will adopt as required, project and activity specific Safety, Health and Environment (SH&E) Policies and related procedures, and ensure compliance with these policies.
- The Company conducts its operations in accordance with the PACIA and APPEA Codes of practice.
- The Managing Director is accountable for providing executive leadership to ensure the company's SH&E policies and procedures are complied with on a day to day basis.

The Company's policy is to conduct its operations in a manner that protects the safety of employees, contractors, customers and the public. The Company will seek to prevent all accidents and injuries. The Company will seek to identify and eliminate or manage safety risks associated with its activities. To this end the Company's policy is to:

- Build and maintain facilities, establish management and operational systems and provide the necessary training to ensure operations of the Company safeguard people and property.
- Ensure all employees and contractors understand their responsibility and accountability for the safe performance of their duties.
- Respond effectively to emergencies or accidents resulting from its operations in harmony with authorised government agencies.
- Comply with all applicable Laws and Regulations.
- Evaluate its operations to ensure, and have measurement systems in place to monitor, compliance with this policy and to improve safety performance.

Melbana Energy

2 Health

It is the Company's policy to:

- Identify and evaluate health risks related to its operations that potentially affect its employees, contractors and the public.
- Implement appropriate protective measures and programs to manage such risks.
- Determine from time to time the medical fitness of employees to do their work without undue risk to themselves and their co-workers are appropriate. Review and put in place appropriate procedures to achieve that.
- Comply with all applicable Laws and Regulations and apply responsible standards where regulations do not exist.
- Evaluate its operations to ensure compliance with this policy.

3 Environment

To prevent or minimize any possible environmental impact because of its operations, Melbana Energy Limited and all its subsidiary companies commit, and will encourage its employees and those companies providing services to Melbana Energy Limited or its subsidiaries to commit, to:

- Develop and maintain management systems to identify, control and monitor risks and compliance with government regulations and industry guidelines;
- Comply with applicable laws, regulations, standards and guidelines for the protection of the environment and in their absence, adopt the best practicable means to prevent or minimise adverse environmental impacts;
- Work and consult with appropriate government agencies drafting policies laws, regulations or procedures to protect the environment;
- Ensure that waste management practices are carried out in accordance with best industry practices for prevention, minimisation, recycling, treatment and disposal of wastes;
- Provide adequate training to enable employees to adopt environmentally responsible work practices and to be aware of their environmental responsibilities;
- Develop emergency plans and procedures so that incidents can be managed in a timely and effective manner; in harmony with authorised government agencies.

Melbana Energy

- Monitor environmental effects and assess environmental performance at all stages of exploration, development, production and rehabilitation; and communicate openly with government, non-government bodies and the public in a timely manner on environmental issues, which relate to Melbana Energy Limited operations.

Environment, Health and Safety Policy

Santos

Our Commitment

Santos is committed to a workplace where we all go home without injury or illness and manage the impact of our operations on the environment.

Our Actions

We will:

1. implement a structured and systematic approach to environmental, health and safety management and monitor its effectiveness
2. include environmental, health and safety considerations in business planning and decision-making processes
3. understand and manage the impact of our operations on the environment
4. comply with all relevant environmental, health and safety laws
5. promote a strong and consistent safety culture across all aspects of business
6. work pro-actively and collaboratively with our stakeholders and the communities in which we operate
7. set, measure and review objectives and targets which drive continuous improvement
8. report publicly on our environmental, health and safety performance

Governance

The Environment Health Safety & Sustainability Committee is responsible for reviewing the effectiveness of this policy.

This Policy will be reviewed at appropriate intervals and revised when necessary to keep it current.

Kevin Gallagher

Managing Director & CEO

Status: APPROVED

Document Owner:	Naomi James, Executive Vice President, EHS & Governance		
Approved by:	The Board	Version:	1

APPROVED 28 October 2016

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Appendix 2: Stakeholder Consultation Records

Stakeholder	Date	Engagement Method	Supplementary Information	Sent / Received	Summary of contact / correspondence	Assessment of Merit	Subsequent Actions Undertaken.
Department or agency of the Commonwealth to which the activities to be carried out under the environment plan, or the revision of the environment plan, may be relevant							
Australian Fisheries Management Authority (AFMA)	22/11/2017	Email	Survey Figure	Sent	Initial email to stakeholders informing them about the proposed Beehive 3D MSS. AFMA was informed that the Northern Prawn Fishery was identified as relevant - ERM requesting confirmation if any other fisheries are relevant.	N/A	N/A
Australian Fisheries Management Authority (AFMA)	23/11/2017	Email	N/A	Received	Response from AFMA informing ERM that the Northern Prawn Fishery is the only relevant commonwealth fishery in the area. AFMA provided the contact details for the NPF.	N/A	Updated stakeholder registry AFMA to be provided with a notification, 4 weeks prior to survey commencement. In addition, AFMA will be notified of survey completion.
Department of Defence (DoD)	22/11/2017	Email	Survey Figure	Sent	Initial email to stakeholders informing them about the proposed Beehive 3D MSS. A figure of the acquisition and operational areas was provided.	N/A	N/A
Department of Defence (DoD)	28/11/2017	Email	Survey Figure	Sent	Email sent to the DoD, requesting additional information about NAXA and Exercise Kakadu. The following questions were raised: 1. As I understand it, during the operational window of operation Kakadu (31/8/18 – 15/08/18) the DRA is a complete exclusion zone. Does this complete exclusion include all of the NAXA areas – i.e. NAXA NE and NAXA SW or is it just limited to the DRA area as marked. 2. If operation Kakadu does not have any operations planned for NAXA SW, is there any restrictions on us during the operation Kakadu timeframe or any restrictions during other times in that area for our Beehive survey? 3. Whilst the DRA is a complete exclusion zone during the exercise, If we were to operate outside the DRA area (but adjacent to the boundary) on Bethany during Operation Kakadu, would the noise generated from our airgun arrays have an impact on the defence operations?	N/A	N/A
Department of Defence (DoD)	11/12/2017	Email	N/A	Received	Email response to email dated 28/11/2017. The Defence informed that the Beehive 3D MSS would potentially have an impact on the scale of manoeuvre of surface ships during the exercise. The proximity to the Blacktip Racon B well head makes this portion of the NAXA valuable in terms of training scenarios. The Defence has no concerns regarding Santos operating adjacent to the DRA. Defence noted that units will operate right up to the boundary of DRA, will commensurate levels of radiated noise that may affect surveying activities. Defence considers that the noise generated from airgun arrays is unlikely to impact in the Beehive area. The Defence has requested additional information on the larger Operational Area of the survey.	N/A - Advice / request for further information only. No objection or claim made.	N/A
Department of Defence (DoD)	12/12/2017	Email	Other	Sent	Email update sent to stakeholders, informing stakeholders of the agreement between Melbana Energy and Santos Limited. The press release was also provided.	N/A	N/A
Department of Defence (DoD)	13/12/2017	Email	Other	Received	Email response sent from the Defence. The following information was provided: • Portions of the proposed survey area are within the Northern Australian Exercise Area (NAXA). • Exercise KAKADU 2018 is occurring between 31 August - 15 September 2018. • Defence proposes that the Beehive 3D MSS is completed no later than 30 August 2018, or commencing the survey after 16 September 2018. • Defence also advises that unexploded ordnance (UXO) may be present on and in the sea floor in the area of the proposed activities.	N/A - Advice / request for further information only. No objection or claim made.	Updated ongoing consultation section. Updated stakeholder registry.

Stakeholder	Date	Engagement Method	Supplementary Information	Sent / Received	Summary of contact / correspondence	Assessment of Merit	Subsequent Actions Undertaken.
					• Defence requires a minimum of 14 days notification prior to commencement of activities. Provided to ADF.Airspace@defence.gov.au & Offshore.Petroleum@defence.gov.au • Communicate with AHS three weeks prior to commencement of activities.		
Department of Defence (DoD)	23/01/2018	Email	Other	Sent	Email sent to Defence, responding to the initial email of 13 December 2017. The Defence were informed that Santos and Melbana Energy have entered into an agreement. Santos has proposed to acquire the Beehive 3D MSS during the period 1 May - 31 October 2018. However, Santos will endeavour to not acquire the Beehive 3D MSS during the period 31 August - 15 September 2018, to avoid having any impact on Exercise KAKADU 2018. Santos acknowledges that unexploded ordnance (UXO) may be present on and in the sea floor in the area and therefore Santos has acknowledge and assessed the risks associated with conducting activities in the area.	N/A	Department of Defence to be provided with a commencement notification (14 days prior to start). Notification to AHS a minimum of 3 weeks prior to the commencement of activities.
Department of Defence (DoD)	13/02/2018	Email	N/A	Sent	Update email sent to stakeholders, with information on the submission of the Beehive 3D MSS EP to NOPSEMA. Stakeholders were informed that the EP will be with NOPSEMA for 30 days. In addition stakeholders were reminded that the seismic survey will be acquired within the period 1 May to 31 October 2018 or 2019.	N/A	N/A
Department of Defence (DoD)	24/02/2018	Email	N/A	Sent	Email sent to Defence, informing Defence, that Beehive will not be acquired during the period 31 August - 15 September 2018, to avoid overlap with Exercise Kakadu. Santos will notify Defence prior to the commencement of each survey and will follow up with a further notification upon cessation of acquisition and completion of the survey. Santos also acknowledge the possibility of unexploded ordinance in the survey area.	N/A	N/A
Department of Defence (DoD)	26/02/2018	Email	N/A	Received	Email received from Defence in response email dated 24/02/2018. Defence acknowledging receipt of the email and the information has been passed on to the relevant stakeholders for their awareness.	N/A	N/A
Director of National Parks (DNP)	22/11/2017	Email	Survey Figure	Sent	Initial email to stakeholders informing them about the proposed Beehive 3D MSS. A figure of the acquisition and operational areas was provided, with the Australian Marine Parks included.	N/A	N/A
Director of National Parks (DNP)	12/12/2017	Email	Other	Sent	Email update sent to stakeholders, informing stakeholders of the agreement between Melbana Energy and Santos Limited. The press release was also provided.	N/A	N/A
Director of National Parks (DNP)	13/02/2018	Email	N/A	Sent	Update email sent to stakeholders, with information on the submission of the Beehive 3D MSS EP to NOPSEMA. Stakeholders were informed that the EP will be with NOPSEMA for 30 days. In addition stakeholders were reminded that the seismic survey will be acquired within the period 1 May to 31 October 2018 or 2019.	N/A	N/A
Director of National Parks (DNP)	03/04/2018	Email	N/A	Sent	Email sent to stakeholder requesting feedback on the proposed activities. The Beehive 3D MSS Acquisition and Operational Areas do not overlap any Australian Marine Parks (a figure was attached). The Beehive 3D MSS Acquisition Area is located ~10 km from the Joseph Bonaparte Gulf Marine Park. Santos have undertaken a risk assessment process, which identifies the potential impacts and risks to Australian Marine Parks.	N/A	N/A
Director of National Parks (DNP)	06/04/2018	Telephone	N/A	Sent	Telephone conversation was conducted with the DNP, requesting feedback on the Santos Beehive 3D MSS. DNP informed ERM that a response will be issued today and apologised for the delay.	N/A	N/A
Director of National Parks (DNP)	06/04/2018	Telephone	N/A	Received	Telephone conversation was conducted with DNP. DNP wanting to clarify if any activity will be conducted in the JBG marine park. ERM informed DNP that the Acquisition and Operational Areas do not overlap the JBG Marine Park, however the EMBA does. Santos have undertaken a risk assessment process, which identifies the potential impacts and risks to Australian Marine Parks.	N/A - Advice / request for further information only. No objection or claim made.	N/A

Stakeholder	Date	Engagement Method	Supplementary Information	Sent / Received	Summary of contact / correspondence	Assessment of Merit	Subsequent Actions Undertaken.
Director of National Parks (DNP)	06/04/2018	Email	N/A	Received	DNP note that the planned activities do not overlap any Australian Marine Parks. The closest are the adjacent Joseph Bonaparte Gulf Marine Park and the Oceanic Shoals Marine Park. Therefore there is no authorisation requirements from the DNP. DNP confirm they do not require further notification of progress made in relation to this activity unless details regarding the activity change and result in an overlap with a marine park or for emergency responses. In planning for emergency response actions that are likely to occur within a marine park, DNP request the Environment Plan and/or Oil Pollution Emergency Plan considers the potential impacts on the park values and demonstrate how the environmental impacts and risks of that activity will be of an acceptable level and reduced to ALARP. DNP should be made aware of oil/gas pollution incidents which occur within marine parks or are likely to impact on a park as soon as possible. This function can be fulfilled through notification to the 24 hour Marine Compliance Duty Officer.	N/A - Advice / request for further information only. No objection or claim made. Section 8.7 of the EP (Incident Reporting) already incorporates the requirement to notify the DNP of oil pollution incidents which occur within marine parks or are likely to impact on a marine park.	Response to DNP.
Director of National Parks (DNP)	06/04/2018	Email	N/A	Sent	Email sent to DNP. Santos notes that the Director of National Parks (DNP) does not require further notification of progress made in relation to this activity unless details regarding the activity change and result in an overlap with a marine park or for emergency responses. The section of the Beehive Environment Plan relating to incident reporting already includes the stated requirements for notification of the DNP of oil/gas pollution incidents which occur within marine parks or are likely to impact on a park.	N/A	N/A
Director of National Parks (DNP)	09/04/2018	Email	N/A	Received	Email received from DNP. DNP acknowledging receipt of email, and thanking Santos for including the notification to DNP regarding oil/gas pollution incidents which occur within marine parks or are likely to impact on a park.	N/A	N/A
Department or agency of the State or the Territory to which the activities to be carried out under the environment plan, or the revision of the environment plan, may be relevant and the Department of the responsible State Minister.							
WA Department of Primary Industries and Regional Development (Fisheries) (DPIRD)	22/11/2017	Email	Survey Figure	Sent	Initial email to stakeholders informing them about the proposed Beehive 3D MSS. A figure of the acquisition and operational areas was provided. DPIRD was contacted via their online portal.	N/A	N/A
WA Department of Primary Industries and Regional Development (Fisheries) (DPIRD)	23/11/2017	Email	N/A	Received	Confirmation of receipt of information - a response will be provided within 10 days.	N/A	N/A
WA Department of Primary Industries and Regional Development (Fisheries) (DPIRD)	28/11/2017	Email	N/A	Received	Email response from the Department of Fisheries. Fisheries considers itself a 'relevant person' with respect to seismic surveys and formally requests to be provided with sufficient information (see below) to allow it to make an informed assessment of the possible consequences of the proposed activities on its functions, interests and activities. Fisheries also requests to be provided with a period of 4-6 weeks to respond. Fisheries expects proponents of seismic surveys to demonstrate that: 1. An informed assessment has been conducted of the risks and potential impacts associated with the proposed activities on potentially affected fisheries and aquatic resources; and 2. Appropriate impact management and risk control measures will be in place (where necessary) to ensure residual impacts will not only be as low as reasonably practicable (ALARP) but also acceptable, as defined by the Regulator.	N/A - Advice / request for further information only. No objection or claim made.	N/A
WA Department of Primary Industries and Regional Development (Fisheries) (DPIRD)	12/12/2017	Email	Survey Figure	Sent	Email sent to DPIRD with information on the agreement between Melbana and Santos Limited. Additional information was provided to the DPIRD on the location and timing of the MSS. The DPIRD were informed that a response to the initial email from the DPIRD will sent through once the outcomes of the assessment is conducted.	N/A	N/A
WA Department of Primary Industries and Regional Development (Fisheries) (DPIRD)	08/01/2018	Face-to-face meeting	N/A	N/A	ERM requesting an extract from the public registry for the Mackerel Managed Fishery and Northern Demersal Scalefish Fishery. Payment was provided.	N/A	N/A

Stakeholder	Date	Engagement Method	Supplementary Information	Sent / Received	Summary of contact / correspondence	Assessment of Merit	Subsequent Actions Undertaken.
WA Department of Primary Industries and Regional Development (Fisheries) (DPIRD)	12/01/2018	Email	N/A	Received	Email received from the DPIRD, attached was an extract from the public registry for contact details for the Mackerel Managed Fishery and Northern Demersal Scalefish Fishery.	N/A	N/A
WA Department of Primary Industries and Regional Development (Fisheries) (DPIRD)	24/01/2018	Email	Risk Assessment Sections	Sent	Email sent to the Fisheries. ERM requesting information on when the Guidance Statement may be released. Santos has proposed to acquire the Beehive 3D MSS during the period of 1 May to 31 October 2018 or 2019 and will take a maximum of 30 days. The Fisheries were informed that the Mackerel Managed Fishery, Northern Demersal Scalefish Managed Fishery license holders, NPFI, PPA, NWSA, AFMA, CFA and NT Department of Primary Industries and Resources (Fisheries). Attached to the email was the seismic underwater noise risk assessment section of the EP. Santos will also adhere to relevant biosecurity regulations, as advised by the Fisheries. Fisheries were informed if they have any further comments, to provide those comments by 08/02/2018.	N/A - Advice / request for further information only. No objection or claim made.	N/A
WA Department of Primary Industries and Regional Development (Fisheries) (DPIRD)	24/01/2018	Email	N/A	Received	Automatic response received from Senior Management Officer. Officer on leave till 31/01/2018.	N/A	N/A
WA Department of Primary Industries and Regional Development (Fisheries) (DPIRD)	12/02/2018	Email	N/A	Received	Email received from DPIRD, informing ERM that the Department plans to review the information provided and respond in the coming days. The Department requests 4-6 weeks to review information. The Department asking whether WAFIC has been consulted.	N/A - Advice / request for further information only. No objection or claim made.	N/A
WA Department of Primary Industries and Regional Development (Fisheries) (DPIRD)	12/02/2018	Email	N/A	Sent	Email sent to DPIRD, informing the Department that WAFIC has been consulted and ERM look forward to receiving a response from the Department. ERM informing the Department that the EP is expected to be submitted this week.	N/A	N/A
WA Department of Primary Industries and Regional Development (Fisheries) (DPIRD)	12/02/2018	Email	N/A	Received	Email received, from the Department requesting a clear map of the survey area and surrounds (with bathymetric data). Department also requesting ERM to confirm if the survey is being conducted within the period of 1 May to 31 October regardless of whether it's conducted in 2018 or 2019.	N/A - Advice / request for further information only. No objection or claim made.	Provided the Department with a figure of the survey area.
WA Department of Primary Industries and Regional Development (Fisheries) (DPIRD)	12/02/2018	Email	Survey Figure	Sent	Email sent to the Department confirming that the survey will be conducted between the period of 1 May to 31 October 2018 or 2019. Attached was a clear figure of the Beehive survey area.	N/A	N/A
WA Department of Primary Industries and Regional Development (Fisheries) (DPIRD)	12/02/2018	Email	N/A	Received	Email received from the Department acknowledging receipt of information.	N/A	N/A
WA Department of Primary Industries and Regional Development (Fisheries) (DPIRD)	13/02/2018	Email	N/A	Sent	Update email sent to the DPIRD, with information on the submission of the Beehive 3D MSS EP to NOPSEMA. Stakeholders were informed that the EP will be with NOPSEMA for 30 days. In addition stakeholders were reminded that the seismic survey will be acquired within the period 1 May to 31 October 2018 or 2019. ERM informed the DPIRD that consultation is ongoing and the feedback provided by the DPIRD will be taken into consideration. ERM suggesting a face-to-face conversation to discuss the Beehive 3D MSS.	N/A	N/A
WA Department of Primary Industries and Regional Development (Fisheries) (DPIRD)	14/02/2018	Email	N/A	Received	Email received from the DPIRD, noting the following points: • The Department notes that the Beehive 3D acquisition area is well-defined; confined to a spatial envelope of ~1000 km2; involves the use of a relatively low-capacity airgun array (2000 cui); will be undertaken within a 30 day period; and is proposed to be conducted within the period between 1 May – 31 October in either 2018 or 2019. This greatly facilitates the identification and assessment of potential impacts on aquatic resources and fisheries. • The Department notes that while some localised, short term impacts may occur, the risk that these will be of effect at the level (scale) of biological stocks is very low. • There is also no evidence that any of the biological stocks (of potentially vulnerable aquatic resources) in this area, at this point in time, is in a state that may warrant a more detailed risk assessment.	N/A - Advice / request for further information only. No objection or claim made.	Provide DMIRS with a notification of commencement and cessation, as specified in the Environment Plan.

Stakeholder	Date	Engagement Method	Supplementary Information	Sent / Received	Summary of contact / correspondence	Assessment of Merit	Subsequent Actions Undertaken.
					• The survey is proposed to be conducted in areas and over habitat for which there is no evidence of particular significance for aquatic resources or fisheries. Disturbance to fishing operations is expected to be minimal and the proponent has indicated that consultation with WAFIC and potentially affected fisheries is ongoing.In conclusion, the Department does not object to this survey being undertaken as proposed.		
NT Department of Primary Industries and Resources (Primary Industries and Fisheries) (DPIR)	22/11/2017	Email	Survey Figure	Sent	Initial email to stakeholders informing them about the proposed Beehive 3D MSS. A figure of the acquisition and operational areas was provided. DPIR was informed that the Demersal Fishery, Spanish Mackerel Fishery and Offshore Net and Line Fishery were identified as relevant.	N/A	N/A
NT Department of Primary Industries and Resources (Primary Industries and Fisheries) (DPIR)	12/12/2017	Email	Other	Sent	Email update sent to stakeholders, informing stakeholders of the agreement between Melbana Energy and Santos Limited. The press release was also provided.	N/A	N/A
NT Department of Primary Industries and Resources (Primary Industries and Fisheries) (DPIR)	12/01/2018	Telephone	N/A	Sent	Telephone conversation was conducted with the NT fisheries licencing centre, to gain an extract from the public registry for the Demersal Fishery.	N/A	N/A
NT Department of Primary Industries and Resources (Primary Industries and Fisheries) (DPIR)	15/01/2018	Email	N/A	Received	Email received from the NT DPIR, with the attached contact details for the Demersal Fishery.	N/A	N/A
NT Department of Primary Industries and Resources (Primary Industries and Fisheries) (DPIR)	13/02/2018	Email	N/A	Sent	Update email sent to stakeholders, with information on the submission of the Beehive 3D MSS EP to NOPSEMA. Stakeholders were informed that the EP will be with NOPSEMA for 30 days. In addition stakeholders were reminded that the seismic survey will be acquired within the period 1 May to 31 October 2018 or 2019.	N/A	N/A
Department of the responsible State Minister, or the responsible Northern Territory Minister							
WA Department of Mines, Industry Regulation and Safety (DMIRS)	22/11/2017	Email	Survey Figure	Sent	Initial email to stakeholders informing them about the proposed Beehive 3D MSS. A figure of the acquisition and operational areas was provided.	N/A	N/A
WA Department of Mines, Industry Regulation and Safety (DMIRS)	24/11/2017	Email	N/A	Received	Email received from DMIRS acknowledging receipt of information. The DMIRS do not require any more information. DMIRS notes that the wider operational area overlaps the Joseph Bonaparte Gulf CMR.	N/A	N/A
WA Department of Mines, Industry Regulation and Safety (DMIRS)	28/11/2017	Email	N/A	Sent	Response to the DMIRS acknowledging receipt of information and informing DMIRS that Finniss will assess the potential impacts to the JBG marine reserve and controls will be implemented to ensure impacts are managed to ALARP.	N/A	N/A
WA Department of Mines, Industry Regulation and Safety (DMIRS)	12/12/2017	Email	Other	Sent	Email update sent to stakeholders, informing stakeholders of the agreement between Melbana Energy and Santos Limited. The press release was also provided.	N/A	N/A
WA Department of Mines, Industry Regulation and Safety (DMIRS)	12/12/2017	Email	N/A	Received	Email received from DMIRS acknowledging receipt of information. The DMIRS have no further comment. No further correspondence required.	N/A	Provide DMIRS with a notification of commencement and cessation. A pre-start notification to be provided at least 10 days prior to activity commencement.
WA Department of Mines, Industry Regulation and Safety (DMIRS)	13/02/2018	Email	N/A	Sent	Update email sent to stakeholders, with information on the submission of the Beehive 3D MSS EP to NOPSEMA. Stakeholders were informed that the EP will be with NOPSEMA for 30 days. In addition stakeholders were reminded that the seismic survey will be acquired within the period 1 May to 31 October 2018 or 2019.	N/A	N/A
NT Department of Primary Industries and Resources (Mines and Energy) (DPIR)	22/11/2017	Email	Survey Figure	Sent	Initial email to stakeholders informing them about the proposed Beehive 3D MSS. A figure of the acquisition and operational areas was provided.	N/A	N/A

Stakeholder	Date	Engagement Method	Supplementary Information	Sent / Received	Summary of contact / correspondence	Assessment of Merit	Subsequent Actions Undertaken.
NT Department of Primary Industries and Resources (Mines and Energy) (DPIR)	12/12/2017	Email	Other	Sent	Email update sent to stakeholders, informing stakeholders of the agreement between Melbana Energy and Santos Limited. The press release was also provided.	N/A	N/A
NT Department of Primary Industries and Resources (Mines and Energy) (DPIR)	13/02/2018	Email	N/A	Sent	Update email sent to stakeholders, with information on the submission of the Beehive 3D MSS EP to NOPSEMA. Stakeholders were informed that the EP will be with NOPSEMA for 30 days. In addition stakeholders were reminded that the seismic survey will be acquired within the period 1 May to 31 October 2018 or 2019.	N/A	N/A
Person or organisation whose functions, interests or activities may be affected by the activities to be carried out under the environment plan, or the revision of the environment plan.							
Western Australian Fishing Industry Council (WAFIC)	22/11/2017	Email	Survey Figure	Sent	Initial email to stakeholders informing them about the proposed Beehive 3D MSS. A figure of the acquisition and operational areas was provided.	N/A	N/A
Western Australian Fishing Industry Council (WAFIC)	24/11/2017	Email	N/A	Received	Email response from the administration department in WAFIC - suggesting we send the information to the following fisheries: -Kimberley Mud Crab Fishery-Mackerel Fishery – area 1-Northern Demersal Scalefish Fishery – area 1-Kimberley Gillnet and Barramundi Fishery-P. maxima Pearl Oyster Fishery-Marine Aquarium Fishery-Specimen Shell Fishery-Hermit Crab Fishery.	N/A - Advice / request for further information only. No objection or claim made.	N/A
Western Australian Fishing Industry Council (WAFIC)	01/12/2017	Email	N/A	Sent	Email sent to WAFIC acknowledging receipt of information. ERM informing WAFIC additional information will be supplied shortly as ERM are in the early stages of EP development. WAFIC will be kept informed of the EP development progress.	N/A	N/A
Western Australian Fishing Industry Council (WAFIC)	12/12/2017	Email	Other	Sent	Email update sent to stakeholders, informing stakeholders of the agreement between Melbana Energy and Santos Limited. The press release was also provided.	N/A	N/A
Western Australian Fishing Industry Council (WAFIC)	12/12/2017	Email	N/A	Sent	Email received from WAFIC informing ERM to direct all engagement to eora@wafic.org.au.	N/A	Updated stakeholder registry
Western Australian Fishing Industry Council (WAFIC)	12/12/2017	Email	N/A	Sent	Email sent to WAFIC acknowledging that all future correspondence will be sent to eora@wafic.org.au and that ERM are currently still in the process of developing the EP.	N/A	N/A
Western Australian Fishing Industry Council (WAFIC)	13/12/2017	Email	N/A	Received	Email received from WAFIC inquiring about what fisheries we have identified as being relevant for the Beehive 3D MSS.	N/A - Advice / request for further information only. No objection or claim made.	N/A
Western Australian Fishing Industry Council (WAFIC)	13/12/2017	Email	N/A	Sent	Email sent to WAFIC. Santos have identified the following commercial fisheries as being relevant: • Northern Demersal Scalefish Managed Fishery (WA) • Mackerel Managed Fishery (WA) • Demersal Fishery (NT) • Northern Prawn Fishery (Commonwealth) WAFIC were informed that ERM have also contacted Pearl Producers Association, Northern Prawn Fishing Industry Pty Ltd, AFMA, Northern Wildcatch Seafood Australia, Commonwealth Fisheries Association, WA Department of Primary Industries and Regional Development (Fisheries) and the NT Department of Primary Industries and Resources (Fisheries).	N/A	N/A
Western Australian Fishing Industry Council (WAFIC)	13/02/2018	Email	N/A	Sent	Update email sent to stakeholders, with information on the submission of the Beehive 3D MSS EP to NOPSEMA. Stakeholders were informed that the EP will be with NOPSEMA for 30 days. In addition stakeholders were reminded that the seismic survey will be acquired within the period 1 May to 31 October 2018 or 2019.	N/A	N/A
Commonwealth Fisheries Association (CFA)	23/11/2017	Email	Survey Figure	Sent	AFMA suggested contacting CFA in regards to the NPF. Sent an initial email to stakeholders informing them about the proposed Beehive 3D MSS. A figure of the acquisition and operational areas was provided.	N/A - Advice / request for further information only. No objection or claim made.	Updated stakeholder registry. Contact was made with Commonwealth Fisheries Association.

Stakeholder	Date	Engagement Method	Supplementary Information	Sent / Received	Summary of contact / correspondence	Assessment of Merit	Subsequent Actions Undertaken.
Commonwealth Fisheries Association (CFA)	12/12/2017	Email	Other	Sent	Email update sent to stakeholders, informing stakeholders of the agreement between Melbana Energy and Santos Limited. The press release was also provided.	N/A	N/A
Commonwealth Fisheries Association (CFA)	13/02/2018	Email	N/A	Sent	Update email sent to stakeholders, with information on the submission of the Beehive 3D MSS EP to NOPSEMA. Stakeholders were informed that the EP will be with NOPSEMA for 30 days. In addition stakeholders were reminded that the seismic survey will be acquired within the period 1 May to 31 October 2018 or 2019.	N/A	N/A
Pearl Producers Association (PPA)	22/11/2017	Email	Survey Figure	Sent	Initial email to stakeholders informing them about the proposed Beehive 3D MSS. A figure of the acquisition and operational areas was provided.	N/A	N/A
Pearl Producers Association (PPA)	12/12/2017	Email	Other	Sent	Email update sent to stakeholders, informing stakeholders of the agreement between Melbana Energy and Santos Limited. The press release was also provided.	N/A	N/A
Pearl Producers Association (PPA)	13/02/2018	Email	N/A	Sent	Update email sent to stakeholders, with information on the submission of the Beehive 3D MSS EP to NOPSEMA. Stakeholders were informed that the EP will be with NOPSEMA for 30 days. In addition stakeholders were reminded that the seismic survey will be acquired within the period 1 May to 31 October 2018 or 2019.	N/A	N/A
Northern Prawn Fishing Industry Pty Ltd (NPFI)	22/11/2017	Email	Survey Figure	Sent	Initial email to stakeholders informing them about the proposed Beehive 3D MSS. A figure of the acquisition and operational areas was provided.	N/A	N/A
Northern Prawn Fishing Industry Pty Ltd (NPFI)	23/11/2017	Email	N/A	Received	Email from NPF requesting the acquisition and operational area shape files and informing ERM the proposed survey area is over important fishing grounds.	N/A - Advice / request for further information only. No objection or claim made.	Supplied NPFI with shape files for the Acquisition and Operational Areas.
Northern Prawn Fishing Industry Pty Ltd (NPFI)	24/11/2017	Email	Other	Sent	Email sent to NPFI with the proposed acquisition and operational area shape files.	N/A	N/A
Northern Prawn Fishing Industry Pty Ltd (NPFI)	12/12/2017	Email	Survey Figure	Sent	Email sent to NPFI with information on the agreement between Melbana and Santos Limited. The press release was also provided. Additional information was provided to NPFI on the seasonal closure in the JBG and the two seasons for the NPF.	N/A	N/A
Northern Prawn Fishing Industry Pty Ltd (NPFI)	13/12/2017	Email	N/A	Received	Email received from NPFI, informing ERM that the CEO of NPFI will provide a response soon to the proposed Beehive 3D MSS.	N/A	N/A
Northern Prawn Fishing Industry Pty Ltd (NPFI)	09/01/2018	Email	N/A	Sent	Email sent to NPFI, touching base to see how the CEO of NPFI is going on providing a response to the proposed Beehive 3D MSS.	N/A	N/A
Northern Prawn Fishing Industry Pty Ltd (NPFI)	10/01/2018	Email	N/A	Received	Email received from NPFI, informing ERM that the CEO of NPFI is currently on leave and a response with be provided at the end of the month.	N/A	N/A
Northern Prawn Fishing Industry Pty Ltd (NPFI)	22/01/2018	Email	N/A	Sent	Email sent to NPFI, touching base to see how the CEO of NPFI is going on providing a response to the proposed Beehive 3D MSS. NPFI were informed that Santos would appreciate feedback as soon as possible, to incorporate the response into the EP.	N/A	N/A
Northern Prawn Fishing Industry Pty Ltd (NPFI)	24/01/2018	Email	N/A	Received	Email received from NPI, informing ERM that CEO is on leave till the end of the week (25/01/2018). NPFI will provide a response next week.	N/A	N/A
Northern Prawn Fishing Industry Pty Ltd (NPFI)	24/01/2018	Email	N/A	Sent	Email sent to NPFI, acknowledging receipt of information and thanking for keeping ERM informed.	N/A	N/A
Northern Prawn Fishing Industry Pty Ltd (NPFI)	31/01/2018	Telephone	N/A	Sent	ERM called NPFI. There was no response. A message was left for NPFI to call ERM back to discuss the proposed Beehive 3D MSS.	N/A	N/A
Northern Prawn Fishing Industry Pty Ltd (NPFI)	02/02/2018	Telephone	N/A	Sent	ERM called NPFI. There was no response. A message was left for NPFI to call ERM back to discuss the proposed Beehive 3D MSS.	N/A	N/A
Northern Prawn Fishing Industry Pty Ltd (NPFI)	02/02/2018	Email	N/A	Sent	Email sent to NPFI, requesting feedback on the proposed Beehive 3D MSS.	N/A	N/A
Northern Prawn Fishing Industry Pty Ltd (NPFI)	05/02/2018	Email	N/A	Received	Email sent from NPFI, apologising for missing ERM's calls last week. NPFI providing contact details for the CEO, for ERM to conduct directly for a response regarding the Beehive 3D MSS.	N/A	Updated stakeholder registry

Stakeholder	Date	Engagement Method	Supplementary Information	Sent / Received	Summary of contact / correspondence	Assessment of Merit	Subsequent Actions Undertaken.
Northern Prawn Fishing Industry Pty Ltd (NPFI)	05/02/2018	Email	N/A	Sent	Email sent to NPFI, acknowledging receipt of information and informing NPFI, ERM will contact the CEO directly requesting feedback on the proposed Beehive 3D MSS.	N/A	N/A
Northern Prawn Fishing Industry Pty Ltd (NPFI)	05/02/2018	Email	N/A	Sent	Email sent to the CEO of the NPFI, requesting feedback. CEO was informed that ERM are particularly interested in understanding the location of the main fishing areas for the NPF within the Joseph Bonaparte Gulf.	N/A	N/A
Northern Prawn Fishing Industry Pty Ltd (NPFI)	05/02/2018	Email	N/A	Received	Email received from NPFI CEO, informing ERM that a response to the proposed Beehive 3D MSS, will be provided next week.	N/A	
Northern Prawn Fishing Industry Pty Ltd (NPFI)	13/02/2018	Email	N/A	Sent	Update email sent to stakeholders, with information on the submission of the Beehive 3D MSS EP to NOPSEMA. Stakeholders were informed that the EP will be with NOPSEMA for 30 days. In addition stakeholders were reminded that the seismic survey will be acquired within the period 1 May to 31 October 2018 or 2019. ERM informed the NPFI that consultation is ongoing and the feedback provided by the NPFI will be taken into consideration.	N/A	N/A
Northern Prawn Fishing Industry Pty Ltd (NPFI)	22/03/2018	Telephone	N/A	Sent	ERM called NPFI. There was no response. A message was left for NPFI to call ERM back to discuss the proposed Beehive 3D MSS.	N/A	N/A
Northern Prawn Fishing Industry Pty Ltd (NPFI)	22/03/2018	Telephone	N/A	Sent	ERM called NPFI CEO. CEO has informed ERM that NPFI will provide a response to the proposed Beehive 3D MSS by 23 March. NPFI CEO indicated the Beehive 3D MSS is located within the NPF main fishing grounds. NPFI also advised that Santos have already been provided the relevant information on the NPFI, however NPFI would are still keen to provide a response. NPFI is aware that Santos have submitted the EP to NOPSEMA and have received a RFWI.	N/A - Advice / request for further information only. No objection or claim made.	Email was sent directly to CEO, following up on telephone conversation.
Northern Prawn Fishing Industry Pty Ltd (NPFI)	22/03/2018	Email	N/A	Sent	Email sent to CEO at NPFI requesting feedback on the Santos Beehive 3D MSS following up with phone call.	N/A - Advice / request for further information only. No objection or claim made.	N/A
Northern Prawn Fishing Industry Pty Ltd (NPFI)	23/03/2018	Telephone	N/A	Sent	ERM called NPFI. There was no response. A message was left for NPFI to call ERM back to discuss the proposed Beehive 3D MSS.	N/A	N/A
Northern Prawn Fishing Industry Pty Ltd (NPFI)	26/03/2018	Email	N/A	Sent	ERM called NPFI. There was no response. A message was left for NPFI to call ERM back to discuss the proposed Beehive 3D MSS.	N/A	N/A
Northern Prawn Fishing Industry Pty Ltd (NPFI)	27/03/2018	Email	N/A	Received	Email received from CEO at NPFI. Delay in providing a response due to flight cancellations and cyclones but will be back in the office on 27/03/2018. NPFI have updated the data and will provide a response on 28/03/2018.	N/A	N/A
Northern Prawn Fishing Industry Pty Ltd (NPFI)	27/03/2018	Email	N/A	Sent	Email sent to NPFI in response to NPFI email dated 27/03/2018 - requesting feedback no later than 28 March 2018 to incorporate NPFI response into the RFWI.	N/A	N/A

Stakeholder	Date	Engagement Method	Supplementary Information	Sent / Received	Summary of contact / correspondence	Assessment of Merit	Subsequent Actions Undertaken.
Northern Prawn Fishing Industry Pty Ltd (NPFI)	28/03/2018	Email	N/A	Received	Email received from CEO of NPFI providing feedback on the Beehive 3D MSS. The following information was provided: • Both the operations and acquisition area's overlap extremely important fishing grounds in the Joseph Bonaparte Gulf for the Northern Prawn Fishery. • NPFI provided confidential data on fish catch data in the JBG (this data is not included in the EP Public Summary). • A total closure is in place in the JBG for the first season (1 April - 15 June). The purpose of the closure is to protect small juvenile prawns. • NPFI expressing concern about the seismic survey being undertaken during the season (August - November) given the lack of available scientific data. • NPFI recommends survey be conducted mid-June to 31 July. • NPFI have experienced considerable changes in the productivity of the JBG since seismic activities commenced in the area.	Stakeholder has raised concerns re survey timing, potential impacts from seismic on prawns, and on trawling operations in the southern JBG. Stakeholder concerns addressed in the RFWI response.	Email response to NPFI addressing concerns. Santos has committed to not commencing acquisition of the Beehive survey until after 15th June, to avoid overlap with the first fishing season. Details of the additional control measures that will be implemented to minimise physical displacement of prawn trawlers have been provided to the NPFI. NPFI has been provided with the relevant risk assessment sections from the EP. Concerns raised by NPFI have been included in the RFWI response.
Northern Prawn Fishing Industry Pty Ltd (NPFI)	06/04/2018	Email	Risk Assessment Sections	Sent	Email sent to CEO of NPFI in response to email dated 28/03/2018. The following points were raised: • Santos note your concern regarding the potential for the proposed Beehive 3D survey to negatively impact on NPF trawling operations in the JBG overlapped by the Acquisition and Operational areas. Santos also acknowledge the NPFI's concern about any seismic activity taking place in the seasonal closure area. • Santos can confirm that acquisition of the Beehive survey will not commence until after the 15th June, to avoid any overlap with the first fishing season for the NPF in the JBG. Therefore, the most likely time period for acquisition of the survey is mid-June to late July as per your suggested best window of opportunity, with a maximum duration of 30 days. There is a possibility of overlap with the start of the second fishing season in August, which could happen if a) the survey does not commence until early July; or b) there are delays to acquisition that result in the duration exceeding 30 days. • During the second fishing season any potential overlap between seismic acquisition and trawling activities would be limited to the period 1 August to 30 August 2018, as the survey will not be acquired during Exercise KAKADU (31 August to 15 September). • Given the timing of fishing effort with tidal cycle in the Joseph Bonaparte Gulf, our understanding is that during August 2018 there will be two periods of high fishing effort, probably three days either side of the first and last quarters of the moon (i.e. the two neap tides during the month)—3-8 August and 16-22 August. Outside these two periods of six days each, fishing effort is expected to be low or non-existent—i.e. fishing effort is expected to be concentrated into 12 days of the month, with little activity for the remaining 18 days of the month. Thus, potential impacts to the NPF in the JBG are limited to physical displacement of trawling activities for a short period, if acquisition of the Beehive survey extends into the second fishing season. As shown in the catch location figure that you provided, there is minimal overlap between catch locations and the Beehive Acquisition Area, and the majority of this catch was during one year out of the eight years covered by the data. Based on the data it would	Assessment of merits provided in the response to the NPFI.	NPFI and AFMA to be provided with a notification, 4 weeks prior to survey commencement. In addition, NPFI and AFMA will be notified of survey completion. If survey timing overlaps the second fishing season for the NPF Santos will provide skippers of prawn trawlers operating in the JBG (as advised by the NPFI) with a daily report unless advised they have no need for this information.

Stakeholder	Date	Engagement Method	Supplementary Information	Sent / Received	Summary of contact / correspondence	Assessment of Merit	Subsequent Actions Undertaken.
					appear that the Acquisition Area has not produced a significant proportion of the catch over the period 2010-2017. • Santos does recognise the need to minimise the potential for disruption to prawn trawling activities and has included a number of additional management measures within the EP. Specifically, if survey timing overlaps the second fishing season for the NPF skippers of prawn trawlers operating in the JBG (as advised by the NPFI) will be provided with a daily report, unless advised they have no need for this information. -Santos will provide a notification to the NPFI and AFMA concerning timing of acquisition of the Beehive survey. This notification will be provided 4 weeks prior to survey commencement. Additionally, the NPFI and AFMA will be notified when the survey is completed. • With regards to the catch data provided for the JBG for the period 2010-2017 Santos wishes to get the NPFI's consent to include just the catch location image (the Google Earth image with overlay of catch locations with Acquisition and Operational areas, and seasonal closure line) in the Environment Plan (EP) for the Beehive survey. • Attached for your information are the sections from the Beehive EP that relate to impacts of seismic noise on plankton (including prawn larval stages) and prawns, which incorporate the findings of studies published over the past two years.		
Northern Prawn Fishing Industry Pty Ltd (NPFI)	20/04/2018	Telephone	N/A	N/A	ERM called NPFI CEO. There was no response. A message was left for NPFI to call ERM back to discuss the proposed Beehive 3D MSS.	N/A	N/A
Northern Prawn Fishing Industry Pty Ltd (NPFI)	23/04/2018	Telephone	N/A	N/A	ERM called NPFI CEO. There was no response. A message was left for NPFI to call ERM back to discuss the proposed Beehive 3D MSS.	N/A	N/A
Northern Prawn Fishing Industry Pty Ltd (NPFI)	23/04/2018	Telephone	N/A	N/A	ERM called NPFI CEO. There was no response. A message was left for NPFI to call ERM back to discuss the proposed Beehive 3D MSS.	N/A	N/A
Northern Prawn Fishing Industry Pty Ltd (NPFI)	23/04/2018	Email	N/A	Received	Email received from NPFI CEO in response to email dated 06.04.2018. The following points were raised: • After consultation with NPF fleet managers, I'm advised that the most likely fishing windows will be slightly longer either side of the first and last quarters of the moon than the periods suggested below and will be from 1-11 August and 13-25 August. Please note these two periods are slightly longer than identified in your email dated 06.04.2018 based on expectation of fleet behaviour this year. As such any overlap is likely to occur between 1 August to 30 August however NPFI would strongly urge that the survey commences early enough to avoid this potential overlap if at all possible. • With regard to the catch data provided, NPFI authorises Santos to include only the catch location image (the Google Earth image with overlay of catch locations with Acquisition and Operational areas, and seasonal closure line) in the Environment Plan (EP) for the Beehive survey, noting that Santos understands the commercial sensitivity of the catch level data (tonnages) and will not share or publish these data in anyway. NPFI requests Santos to not include this image in the EP Summary, which is publicly released via NOPSEMA's website following acceptance of the EP. • NPFI is aware of those scientific reports and notes that whilst of some value, there is limited data available about the direct impacts of seismic activities on tropical prawn species – as such, NPFI continues to hold grave concerns about the potential for seismic activities to negatively impact the productivity of prawns in the JBG.	NPFI made a comment that "there is limited data available about the direct impacts of seismic activities on tropical prawn species". Whilst the majority of studies examining the potential impacts of seismic surveys on crustaceans have involved temperate water species, the evaluation of impacts and risks in Section 7.1.5.2 of the Beehive EP incorporates the findings of the Andriguetto-Filho et al. (2005) study, which examined bottom trawl yields of a non-selective Brazilian shrimp fishery before and after exposure to seismic sources. The EP also incorporates the findings and conclusions of three comprehensive reviews of seismic noise impacts to invertebrates; Carroll et al. (2017), Edmunds et al. (2016) and DoF (2016).	ERM will ensure that the catch level data (tonnages) provided by the NPFI are not included in the EP Summary.

Stakeholder	Date	Engagement Method	Supplementary Information	Sent / Received	Summary of contact / correspondence	Assessment of Merit	Subsequent Actions Undertaken.
Northern Prawn Fishing Industry Pty Ltd (NPFI)	23/04/2018	Telephone	N/A	N/A	Telephone conversation with the Project Officer from NPFI. Project Officer advised they are on leave for the next 2 weeks and to contact the CEO of NPFI.	N/A	N/A
Northern Prawn Fishing Industry Pty Ltd (NPFI)	24/04/2018	Telephone	N/A	N/A	Telephone conversation with CEO at NPFI. ERM requesting to organise a meeting for CEO, Santos and ERM to discuss NPFI concerns. CEO was open to having a discussion with ERM and Santos. CEO raised concerns around the lack of scientific data available on the impacts to tropical prawn species and the timing of the Beehive 3D MSS.	N/A - Advice / request for further information only. See above regarding "lack of scientific data available on the impacts to tropical prawn species".	ERM called NPFI to organise a phone discussion for Santos/ERM to discuss NPFI concerns.
Northern Prawn Fishing Industry Pty Ltd (NPFI)	24/04/2018	Telephone	N/A	N/A	Telephone conversation with CEO at NPFI, organising a time for a phone discussion with Santos and ERM. CEO advised ERM of available on the 30 April 2018.	N/A	N/A
Northern Prawn Fishing Industry Pty Ltd (NPFI)	27/04/2018	Telephone	N/A	N/A	ERM called NPFI CEO to confirm 11 am (AEST) Monday 30 April 2018 for a phone discussion. There was no response. A message was left for NPFI to call ERM back.	N/A	N/A
Northern Prawn Fishing Industry Pty Ltd (NPFI)	30/04/2018	Telephone	N/A	N/A	ERM called NPFI CEO to confirm 11 am (AEST) Monday 30 April 2018 for a phone discussion. There was no response. A message was left for NPFI to call ERM back.	N/A	N/A
Northern Prawn Fishing Industry Pty Ltd (NPFI)	30/04/2018	Telephone	N/A	N/A	Telephone conversation with CEO at NPFI. Technical Director at ERM joined the call.	N/A	N/A
Northern Prawn Fishing Industry Pty Ltd (NPFI)	30/04/2018	Email	N/A	Sent	Email sent to NPFI CEO providing a summary of the telephone conversation. The following points were discussed: • Bethany 3D Seismic Survey, acquisition is proposed to commence in early May for a duration of approximately 60 days (maximum of 75 days). During the preparation of the Bethany Environment Plan (EP), Santos did consult with the NPFI. As ERM has only been providing Santos with support on the Bethany survey since December 2017, we are not fully aware of the location of the scampi grounds you mentioned during our conversation. Santos is happy to provide the NPFI with a daily report for the Bethany survey if the NPFI wishes to receive this notification. Following the completion of the Bethany survey, the seismic vessel and support fleet will transit to the location of the Beehive 3D MSS. The Beehive survey will not commence until after the 15 June to avoid any overlap with the first fishing season in the JBG. Beehive is likely to commence in early July, with an estimated duration of approximately 20 days (maximum 30 days). As mentioned, there is a possibility of overlap with the start of the second fishing season in August, which could happen if a) the survey does not commence until early-July; or b) there are delays to acquisition that result in the duration exceeding 30 days. • Santos notes, that the NPF fleet managers have advised that the most likely fishing windows will be from 1-11 August and 13-25 August (either side of the first and last quarters of the moon) and therefore any overlap is likely to occur between 1 August to 30 August. • Santos acknowledge that that the NPFI will be conducting a pre-season briefing for the second fishing season in late July. Following this briefing, Santos would appreciate if the NPFI could provide Santos with additional information on the location and timing of fishing within the JBG. • Santos will provide the NPFI with a handout on the Beehive 3D MSS. The handout will also contain the contact details for the seismic survey vessel and the support fleet. Santos would appreciate if the NPFI could pass on this handout via the pre-season briefing or via email to fleet managers/skippers. At this point, Santos will request contact details for any prawn trawl vessels and skippers that may be operating in the southern Joseph Bonaparte Gulf during August, so they can be provided with the daily reports for Beehive.	N/A – email sent to NPFI CEO	N/A

Stakeholder	Date	Engagement Method	Supplementary Information	Sent / Received	Summary of contact / correspondence	Assessment of Merit	Subsequent Actions Undertaken.
					• Santos appreciates the NPFI allowing Santos to include the catch location image in the RFWI response to NOPSEMA. Santos understands the commercial sensitivity of the catch level data and agrees to not share or publish the data. Santos will not include this image in the EP Summary published on NOPSEMA's website.		
Northern Prawn Fishing Industry Pty Ltd (NPFI)	08/05/2018	Email	N/A	Received	Email received from NPFI in response to ERM's email dated 30.04.2018. The following points were raised: • The main concerns for the JBG relate to the potential for noise impacts on the stock in the Beehive 3D acquisition area and the unknown impacts of prawns in general. However on reflection, in relation to Beehive 3D, there is potential for significant disruption to fishing operations and potential loss of catch for operators fishing in JBG if the survey goes into August. The catch and effort data which NPFI provided shows that in any given year, varying amounts of fishing effort and catch is taken from the operations area in particular, but also from the acquisition area. The timing of the Beehive survey is clearly critical to fishing operations/potential catch. • NPFI appreciates the efforts of Santos to try and schedule the survey to take place in July to avoid disruption to the Northern Prawn Fishery fleet. However, in anticipation that this may not occur and that the survey may run into August, NPFI proposes that the 'Compensation Protocol' which has been included in the Bethany EP should also be included in the EP for Beehive 3. NPFI has consistently adopted a collaborative approach to working with the oil and gas industry to try and get the best outcomes and least disruption for both our sectors. Including the Pascoe et al 'Compensation Protocol' in the Beehive EP would give our members some comfort that their concerns are recognised and legitimate impacts will be addressed through including the Protocol in the EP. • Your earliest advice on the above proposal would be appreciated. In the meantime, all NPF operators have been advised that the survey is due to commence in July and advised of the communication process that will be adopted by Santos. To your point about who may be affected if the survey goes into August, all 52 NPF boats are entitled to fish in the JBG during the fishing seasons, however we will endeavour to determine who is more likely to fish there in August and advise accordingly.	See response sent to NPFI on 10/05/18	Email response to CEO of NPFI on 10/05/18.

Stakeholder	Date	Engagement Method	Supplementary Information	Sent / Received	Summary of contact / correspondence	Assessment of Merit	Subsequent Actions Undertaken.
Northern Prawn Fishing Industry Pty Ltd (NPFI)	10/05/2018	Email	N/A	Sent	Email sent to NPFI in response to NPFI email dated 08.05.2018. The following points were raised: -Santos acknowledges the concerns the NPFI has expressed on potential impacts to the NPF if acquisition extends into August. • As detailed in the email sent to you on 30 April, if acquisition of the Beehive 3D survey extends into August the focus of control measures implemented under the EP will be on minimising the potential for negative interactions between the seismic vessels (survey, support and chase vessels) and any prawn trawlers that may be operating in the operational area at the same time. Primarily, this will involve provision of detailed information in the form of a handout that will be distributed by the NPFI to relevant fleet managers/skippers at the pre-season briefings for the 2nd season, a 4-week pre-start notification to any prawn trawl vessels and skippers that may be operating in the southern Joseph Bonaparte Gulf during August, and a daily report that will be issued to relevant vessels and the NPFI once the survey has commenced. • Santos notes your proposal that the fisheries compensation scheme developed for the Bethany survey be adopted for Beehive, and incorporated into the EP. The Bethany compensation scheme was developed specifically to address concerns and issues related to potential impacts to fishers operating in the Timor Reef Fishery (TRF), which—as you are no doubt aware—is a relatively small fishery with only 13 licences covering an area of ~30,170 km². The Bethany operational area overlaps about 30% of the total TRF. It would not be appropriate to apply the Bethany compensation scheme to the Beehive survey. • Santos appreciates the steps that the NPFI has taken to advise all NPF operators of the Beehive survey, and of the communications process that will be adopted to provide operators with information concerning on-the-water operations both prior to, and during, the survey.-Santos would appreciate receiving information regarding vessels that may be operating in the JB Gulf during the start of the 2nd season this year, as soon as these details become available. In the meantime, we will prepare a handout for dissemination at the pre-season briefings, as outlined above.	NPFI proposes that the 'Compensation Protocol' which has been included in the Bethany EP should also be included in the EP for Beehive. The Bethany compensation scheme was developed specifically to address concerns and issues related to potential impacts to fishers operating in the Timor Reef Fishery (TRF), which is a relatively small fishery with only 13 licences covering an area of ~30,170 km². The Bethany operational area overlaps about 30% of the total TRF.By comparison, the Beehive Operational Area overlaps ~26.5% of the actively fished area for the NPF in the JB Gulf (~13,594 km²), and ~0.4% of the total area of the NPF fishery (~880,000 km²). It would not be appropriate to apply the Bethany compensation scheme to the Beehive survey, particularly as operators in the NPF have very large areas that they can access, both within the JB Gulf and across the rest of the fishery area. Access to loss of catch or relocation expenses schemes could provide an incentive for operators to target the southern JB Gulf area when they might not otherwise have been planning to do so.	N/A
Northern Wildcatch Seafood Australia (NWSA)	22/11/2017	Email	Survey Figure	Sent	Initial email to stakeholders informing them about the proposed Beehive 3D MSS. A figure of the acquisition and operational areas was provided.	N/A	N/A
Northern Wildcatch Seafood Australia (NWSA)	12/12/2017	Email	Other	Sent	Email update sent to stakeholders, informing stakeholders of the agreement between Melbana Energy and Santos Limited. The press release was also provided.	N/A	N/A
Northern Wildcatch Seafood Australia (NWSA)	13/02/2018	Email	N/A	Sent	Update email sent to stakeholders, with information on the submission of the Beehive 3D MSS EP to NOPSEMA. Stakeholders were informed that the EP will be with NOPSEMA for 30 days. In addition stakeholders were reminded that the seismic survey will be acquired within the period 1 May to 31 October 2018 or 2019.	N/A	N/A
Northern Territory Seafood Council (NTSC)	22/11/2017	Email	Survey Figure	Sent	Initial email to stakeholders informing them about the proposed Beehive 3D MSS. A figure of the acquisition and operational areas was provided.	N/A	N/A
Northern Territory Seafood Council (NTSC)	12/12/2017	Email	Other	Sent	Email update sent to stakeholders, informing stakeholders of the agreement between Melbana Energy and Santos Limited. The press release was also provided.	N/A	N/A
Northern Territory Seafood Council (NTSC)	13/02/2018	Email	N/A	Sent	Update email sent to stakeholders, with information on the submission of the Beehive 3D MSS EP to NOPSEMA. Stakeholders were informed that the EP will be with NOPSEMA for 30 days. In addition stakeholders were reminded that the seismic survey will be acquired within the period 1 May to 31 October 2018 or 2019.	N/A	N/A

Stakeholder	Date	Engagement Method	Supplementary Information	Sent / Received	Summary of contact / correspondence	Assessment of Merit	Subsequent Actions Undertaken.
WA Mackerel Managed Fishery	15/01/2018	Post	Letter/Survey Figure	Sent	A letter was sent to all license holders within the WA Mackerel Managed Fishery, informing stakeholders of the proposed Beehive 3D MSS. A figure was provided with the acquisition and operational areas. Information was also provided to stakeholder regarding the agreement between Santos & Melbana Energy Limited.	N/A	No concerns were raised from license holders.
WA Northern Demersal Scalefish Managed Fishery	15/01/2018	Post	Letter/Survey Figure	Sent	A letter was sent to all license holders within the WA Northern Demersal Scalefish Managed Fishery, informing stakeholders of the proposed Beehive 3D MSS. A figure was provided with the acquisition and operational areas. Information was also provided to stakeholder regarding the agreement between Santos & Melbana Energy Limited.	N/A	No concerns were raised from license holders.
NT Demersal Fishery	15/01/2018	Post	Letter/Survey Figure	Sent	A letter was sent to all license holders within the NT Demersal Fishery, informing stakeholders of the proposed Beehive 3D MSS. A figure was provided with the acquisition and operational areas. Information was also provided to stakeholder regarding the agreement between Santos & Melbana Energy Limited.	N/A	No concerns were raised from license holders.
Any other person or organisation that the titleholder considers relevant.							
Australian Marine Oil Spill Centre (AMOSC)	5/12/2017	Email	N/A	Sent	Email sent to AMOSC, to inform AMOSC that the Beehive 3D MSS OPEP will need AMOSC's input/review. The OPEP will be available around mid-Jan for review and will be very similar to the Fishburn OPEP. Modelling undertaken has shown no impacts to state or territory waters.	N/A	N/A
Australian Marine Oil Spill Centre (AMOSC)	15/01/2018	Email	Attached the Beehive 3D MSS OPEP.	Sent	Email sent to AMOSC, informing AMOSC the OPEP is ready for review and requesting if AMOSC are available to review/provide input into the OPEP.	N/A	N/A
Australian Marine Oil Spill Centre (AMOSC)	15/01/2018	Email	N/A	Received	Email received from AMOSC, requesting when ERM require the OPEP to be reviewed.	N/A	N/A
Australian Marine Oil Spill Centre (AMOSC)	15/01/2018	Email	N/A	Sent	Email sent to AMOSC, informing AMOSC, the review of the OPEP is required by end of January.	N/A	N/A
Australian Marine Oil Spill Centre (AMOSC)	24/01/2018	Email	N/A	Received	AMOSC provided comments to Santos on the Beehive 3D MSS OPEP. Comments were related to providing details on 'how' rather than just 'what'. Sections of the OPEP do not tell the person how to complete the tasks or what is required.	N/A - Advice / request for further information only. No objection or claim made.	Updated the OPEP, based on feedback from AMOSC. Provide AMOSC a copy of the Beehive 3D MSS OPEP once EP has been accepted. Provide AMOSC notification of survey commencement and cessation.
Kimberley Land Council (KLC)	22/11/2017	Email	Survey Figure	Sent	Initial email to stakeholders informing them about the proposed Beehive 3D MSS. A figure of the acquisition and operational areas was provided.	N/A	N/A
Kimberley Land Council (KLC)	12/12/2017	Email	Other	Sent	Email update sent to stakeholders, informing stakeholders of the agreement between Melbana Energy and Santos Limited. The press release was also provided.	N/A	N/A
Kimberley Land Council (KLC)	13/02/2018	Email	N/A	Sent	Update email sent to stakeholders, with information on the submission of the Beehive 3D MSS EP to NOPSEMA. Stakeholders were informed that the EP will be with NOPSEMA for 30 days. In addition stakeholders were reminded that the seismic survey will be acquired within the period 1 May to 31 October 2018 or 2019.	N/A	N/A
Origin Energy Resources (Lattice Energy)	22/11/2017	Email	Survey Figure	Sent	Initial email to stakeholders informing them about the proposed Beehive 3D MSS. A figure of the acquisition and operational areas was provided. ERM requesting information on any seismic survey activity to be conducted in 2018 or 2019 in the area.	N/A	N/A
Origin Energy Resources (Lattice Energy)	06/12/2017	Email	N/A	Received	Email from Origin Energy informing ERM that Origin have no plans to undertake new seismic acquisition. Origin will keep ERM informed if anything changes. No further correspondence required.	N/A	N/A

Stakeholder	Date	Engagement Method	Supplementary Information	Sent / Received	Summary of contact / correspondence	Assessment of Merit	Subsequent Actions Undertaken.
Origin Energy Resources (Lattice Energy)	06/02/2018	Email	N/A	Sent	Email sent to Lattice Energy, informing Lattice that Santos intends to operate and acquire on behalf of Total and the titleholder Melbana Energy in WA-488-P. The Beehive 3D MSS will extend into the lattice operated NT/P84 title block to allow Santos to fully image up the WA-488-P permit. Santos will send through a draft ingress agreement and more detailed mapping, however in the interim, attached was a basic map with the proposed acquisition area and indicative sail lines, along with the operational area. Requesting contact details of who to contact in Lattice regarding the ingress agreement and in-field operations.	N/A	N/A
Origin Energy Resources (Lattice Energy)	13/02/2018	Email	N/A	Sent	Update email sent to stakeholders, with information on the submission of the Beehive 3D MSS EP to NOPSEMA. Stakeholders were informed that the EP will be with NOPSEMA for 30 days. In addition stakeholders were reminded that the seismic survey will be acquired within the period 1 May to 31 October 2018 or 2019.	N/A	N/A
Origin Energy Resources (Lattice Energy)	13/02/2018	Email	N/A	Received	Email received in response to email dated 06/02/2018. Providing contact details on who to contact re ingress agreement and in-field operations. Additional email correspondence between Santos and Lattice - discussing the ingress agreement into ENI title blocks.	N/A	Additional correspondence between Lattice and Santos in regards to ingress agreements has not been logged in the database - as it is not a relevant stakeholder matter.
Woodside Energy Ltd	22/11/2017	Email	Survey Figure	Sent	Initial email to stakeholders informing them about the proposed Beehive 3D MSS. A figure of the acquisition and operational areas was provided. ERM requesting information on any seismic survey activity to be conducted in 2018 or 2019 in the area.	N/A	N/A
Woodside Energy Ltd	12/12/2017	Email	Other	Sent	Email update sent to stakeholders, informing stakeholders of the agreement between Melbana Energy and Santos Limited. The press release was also provided.	N/A	N/A
Woodside Energy Ltd	27/12/2017	Email	N/A	Received	Email received from Woodside informing ERM, that Woodside plan to acquire in March-April 2018, in permit WA-522-P. No further correspondence required.	N/A	Updated the socio-economic section and associated risk assessment sections of the EP.
Woodside Energy Ltd	08/01/2018	Email	N/A	Sent	Email sent to Woodside, acknowledging receipt of information and noting that Woodside plan to acquire in March-April 2018 in permit WA-522-P.	N/A	N/A
Woodside Energy Ltd	13/02/2018	Email	N/A	Sent	Update email sent to stakeholders, with information on the submission of the Beehive 3D MSS EP to NOPSEMA. Stakeholders were informed that the EP will be with NOPSEMA for 30 days. In addition stakeholders were reminded that the seismic survey will be acquired within the period 1 May to 31 October 2018 or 2019.	N/A	N/A
Engie Bonaparte Pty Ltd	22/11/2017	Email	Survey Figure	Sent	Initial email to stakeholders informing them about the proposed Beehive 3D MSS. A figure of the acquisition and operational areas was provided.	N/A	N/A
Engie Bonaparte Pty Ltd	12/12/2017	Email	Other	Sent	Email update sent to stakeholders, informing stakeholders of the agreement between Melbana Energy and Santos Limited. The press release was also provided.	N/A	N/A
Engie Bonaparte Pty Ltd	13/02/2018	Email	N/A	Sent	Update email sent to stakeholders, with information on the submission of the Beehive 3D MSS EP to NOPSEMA. Stakeholders were informed that the EP will be with NOPSEMA for 30 days. In addition stakeholders were reminded that the seismic survey will be acquired within the period 1 May to 31 October 2018 or 2019.	N/A	N/A
PGS	22/11/2017	Email	Survey Figure	Sent	Initial email to stakeholders informing them about the proposed Beehive 3D MSS. A figure of the acquisition and operational areas was provided. ERM requesting information on any seismic survey activity to be conducted in 2018 or 2019 in the area.	N/A	N/A
PGS	22/11/2017	Email	N/A	Received	PGS informing ERM they are planning on acquiring in the general area in 2018/2019. PGS requesting to be kept informed.	N/A	N/A

Stakeholder	Date	Engagement Method	Supplementary Information	Sent / Received	Summary of contact / correspondence	Assessment of Merit	Subsequent Actions Undertaken.
PGS	28/11/2017	Email	N/A	Sent	Response to PGS acknowledging receipt of information and informing PGS that Finniss will keep PGS updated on the Beehive 3D MSS as requested.	N/A	Update stakeholder registry.
PGS	12/12/2017	Email	Other	Sent	Email update sent to stakeholders, informing stakeholders of the agreement between Melbana Energy and Santos Limited. The press release was also provided.	N/A	N/A
PGS	13/02/2018	Email	N/A	Sent	Update email sent to stakeholders, with information on the submission of the Beehive 3D MSS EP to NOPSEMA. Stakeholders were informed that the EP will be with NOPSEMA for 30 days. In addition stakeholders were reminded that the seismic survey will be acquired within the period 1 May to 31 October 2018 or 2019.	N/A	N/A
TGS	22/11/2017	Email	Survey Figure	Sent	Initial email to stakeholders informing them about the proposed Beehive 3D MSS. A figure of the acquisition and operational areas was provided. ERM requesting information on any seismic survey activity to be conducted in 2018 or 2019 in the area.	N/A	N/A
TGS	24/11/2017	Email	N/A	Received	Email sent from TGS informing ERM that TGS are not planning on conducting a seismic survey in the area between 2018 or 2019. TGS no longer have an EP that overlaps the area (North West Shelf Renaissance North) - TGS have reduced the size which now exclude the NT area and Beehive 3D MSS area.	N/A	Update the socio-economic section and associated risk assessment sections of the EP.
TGS	28/11/2017	Email	N/A	Sent	Response to TGS acknowledging receipt of information and noting that TGS have no plans to acquire in the general area in 2018/19.	N/A	N/A
TGS	28/11/2017	Email	N/A	Received	TGS informing ERM that any further information on Beehive to cc in Tanya Johnstone and Roland Rattray.	N/A	Updated stakeholder registry
TGS	12/12/2017	Email	Other	Sent	Email update sent to stakeholders, informing stakeholders of the agreement between Melbana Energy and Santos Limited. The press release was also provided.	N/A	N/A
TGS	13/12/2017	Email	N/A	Received	Email received from TGS acknowledging receipt of the information. No further correspondence required.	N/A	N/A
TGS	13/02/2018	Email	N/A	Sent	Update email sent to stakeholders, with information on the submission of the Beehive 3D MSS EP to NOPSEMA. Stakeholders were informed that the EP will be with NOPSEMA for 30 days. In addition stakeholders were reminded that the seismic survey will be acquired within the period 1 May to 31 October 2018 or 2019.	N/A	N/A
TGS	14/02/2018	Email	N/A	Received	Email received from TGS, informing ERM that they have no further comments or concerns on this, and acknowledge the updated.	N/A	N/A
Eni Australia	22/11/2017	Email	Survey Figure	Sent	Initial email to stakeholders informing them about the proposed Beehive 3D MSS. A figure of the acquisition and operational areas was provided.	N/A	N/A
Eni Australia	12/12/2017	Email	Other	Sent	Email update sent to stakeholders, informing stakeholders of the agreement between Melbana Energy and Santos Limited. The press release was also provided.	N/A	N/A
Eni Australia	13/02/2018	Email	N/A	Sent	Update email sent to stakeholders, with information on the submission of the Beehive 3D MSS EP to NOPSEMA. Stakeholders were informed that the EP will be with NOPSEMA for 30 days. In addition stakeholders were reminded that the seismic survey will be acquired within the period 1 May to 31 October 2018 or 2019.	N/A	N/A
Eni Australia	13/02/2018	Email	N/A	Received	Email received from the contact person the information was sent to. The contact person informed ERM that they have changed roles and the information provided has been sent to a colleague who will respond.	N/A	N/A
Eni Australia	13/02/2018	Email	N/A	Sent	Additional email correspondence between Santos and ENI - discussing the ingress agreement into ENI title blocks.	N/A	Additional correspondence between Lattice and Santos has not been logged in the database - as it is not a relevant stakeholder matter.

Appendix 3: JASCO Acoustic Modelling Report

Beehive 3-D Marine Seismic Survey

Acoustic Modelling for Assessing Marine Fauna Sound Exposures

Submitted to:

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Disclaimer:

The results presented herein are relevant within the specific context described in this report. They could be misinterpreted if not considered in the light of all the information contained in this report. Accordingly, if information from this report is used in documents released to the public or to regulatory bodies, such documents must clearly cite the original report, which shall be made readily available to the recipients in integral and unedited form.

Suggested citation:

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Executive Summary

Sound models were used to assess underwater noise levels during the proposed Beehive Marine Seismic Survey (MSS), which will be acquired by Santos Offshore Limited. The modelling approach considered source directivity and range-dependent environmental properties in the area, and accounted for the acoustic emission characteristics of a 2380 in^3 seismic airgun array, a surrogate for the maximum airgun array size considered for operation during the survey. These results are required to assess effects of noise exposure on marine mammals, fish, turtles, and plankton in and around the proposed survey acquisition area. Sound levels due to pressure are presented as sound pressure levels (SPL), zero-to-peak pressure levels (PK), peak-to-peak pressure levels (PK-PK), and either single-impulse (i.e., per-pulse) or accumulated sound exposure levels (SEL).

The modelling study for the Beehive 3-D MSS assessed:

- One single-impulse site for water column SPL, PK, PK-PK, and per-pulse SEL;
- One single-impulse site for seafloor PK, PK-PK and seafloor per-pulse SEL; and
- One scenario for accumulated SEL over 24 hours (SEL_{24h}).

The analysis considered several effects criteria, with the corresponding results summarised below for the representative single-impulse sites and accumulated multiple-impulse SEL scenarios:

Mammals

- EPBC Act Policy Statement 2.1 (DEWHA 2008): Airgun sounds did not exceed the unweighted per-pulse SEL criterion for the 1 km low-power zone of 160 dB re 1 µPa^2·s, as the isopleth was predicted to occur at distance of 0.9 km from the airgun array (R_{max} distance).
- United States National Marine Fisheries Service (NMFS 2013) acoustic threshold for behavioural effects in cetaceans: Airgun sounds exceeded the SPL threshold of 160 dB re 1 µPa for behavioural effects on marine mammals within 1.4 km of the airgun array (R_{max} distance).
- NMFS (2016) marine mammal injury criteria: The results considered both metrics within the criteria for Permanent Threshold Shift (PTS; PK and SEL_{24h}). The greatest distance of the three metrics and criteria is required to be applied. The maximum distances along with the relevant metric and the location of the results are summarised in Table 1.

Table 1. Summary of permanent threshold shift (PTS) onset distances for marine mammals. A dash indicates the threshold is not reached.

Relevant hearing group	Metric for PTS onset	Distance R_{max} (m)
Low-frequency cetaceans	SEL_{24h}	300
Mid-frequency cetaceans	PK	–
High-frequency cetaceans	PK	172

Turtle Behavioural Effects

- United States NMFS criterion for behavioural effects in turtles: Airgun sounds exceeded the 166 dB re 1 µPa (SPL) threshold for behavioural effects within 1.1 km of the airgun array (R_{max} distance).

Fish, Turtle Injury, Fish Eggs, and Fish Larvae Mortality

The distance to PK levels relevant to fish at the seafloor is site specific, with no consistent pattern between site depth and distance to isopleth. Considering both per-pulse modelling sites and the associated SEL_{24h} scenario:

- Sound levels associated with either a) mortality and potential mortal injury or b) recoverable injury to fish, based on Popper et al. (2014) using the SEL_{24h} metric, are predicted to occur at ranges

shorter than those predicted using the PK metric. The PK metric is therefore used here to assess these maximum impact distances.

- For mortality and potential mortal injury or recoverable injury, the relevant sound level for the most sensitive fish groups is 207 dB re 1 µPa PK, and the associated maximum distance is 78 m.
- For mortality and potential mortal injury to turtles, fish eggs, and fish larvae, the criterion is also 207 dB re 1 µPa PK, and the maximum distance is the same as for sensitive fish groups: at 78 m.
- The relevant sound level for the least sensitive fish group (fishes without a swim bladder, sharks), is 213 dB re 1 µPa PK, and the associated maximum distance is 58 m.
- Considering the defined 24 h period of exposure, fish (including sharks) could experience temporary threshold shift (TTS) from the proposed seismic survey. It is predicted that this will occur within 410 m of the airgun array.

Plankton

- For comparison to the level reported in McCauley et al. (2017) for potential effects on plankton, the distance to 178 dB re 1 µPa PK-PK in the water column was assessed. The range to this sound level is predicted to be a maximum of 1.95 km.

1. Introduction

JASCO Applied Sciences (JASCO) performed a numerical estimation study of underwater sound levels associated with the Beehive 3-D Marine Seismic Survey (MSS), which will be acquired by Santos Offshore Limited (Santos). The acoustic modelling was commissioned to help assess potential effects of sounds from the proposed seismic survey on marine fauna. Modelled sound levels were generated for a 2380 in^3 airgun array towed at 6.0 m depth. The report presents metrics to assess sound exposure effects primarily on cetaceans, turtles and fish. We also estimated the peak-to-peak pressure metric for assessing potential effects on plankton.

JASCO's specialised Airgun Array Source Model (AASM), predicted the underwater acoustic signature of the array. AASM accounts for individual airgun volumes and array geometry. Complementary underwater acoustic propagation models were used in conjunction with the modelled array signature to estimate sound levels over a large area around the source. Single-impulse sound fields were predicted at a defined location, and accumulated sound exposure fields were predicted for one likely scenario of survey operations over 24 h. A conservative sound speed profile that is most supportive of sound propagation conditions for the period of the survey was defined, and applied at each of the modelling locations to determine both single-impulse and accumulated sound exposure fields. The modelling methodology (Section 3) considered source directivity and range-dependent environmental properties in each of the areas assessed.

Sound levels due to pressure are presented as sound pressure levels (SPL), zero-to-peak pressure levels (PK), peak-to-peak pressure levels (PK-PK), and either single-impulse (i.e., per-pulse) (Section 4.2) or accumulated sound exposure levels (SEL) (Section 4.3) as appropriate.

JASCO defined the general location of the modelling site in consultation with Santos, who also specified the acquisition pattern and the planned line orientation and tow direction for the survey. Table 2 lists the site-specific site location, the position of which is shown in Figure 1.

Table 2. Location details for the site-specific modelled site.

Site	Latitude	Longitude	UTM (WGS84) Zone 52 S		Water depth (m)	Representative tow direction (°)
			X (m)	*Y* (m)		
1	13° 59.55335' S	128° 33.58995' E	452464.018	8453052.825	42.6	55

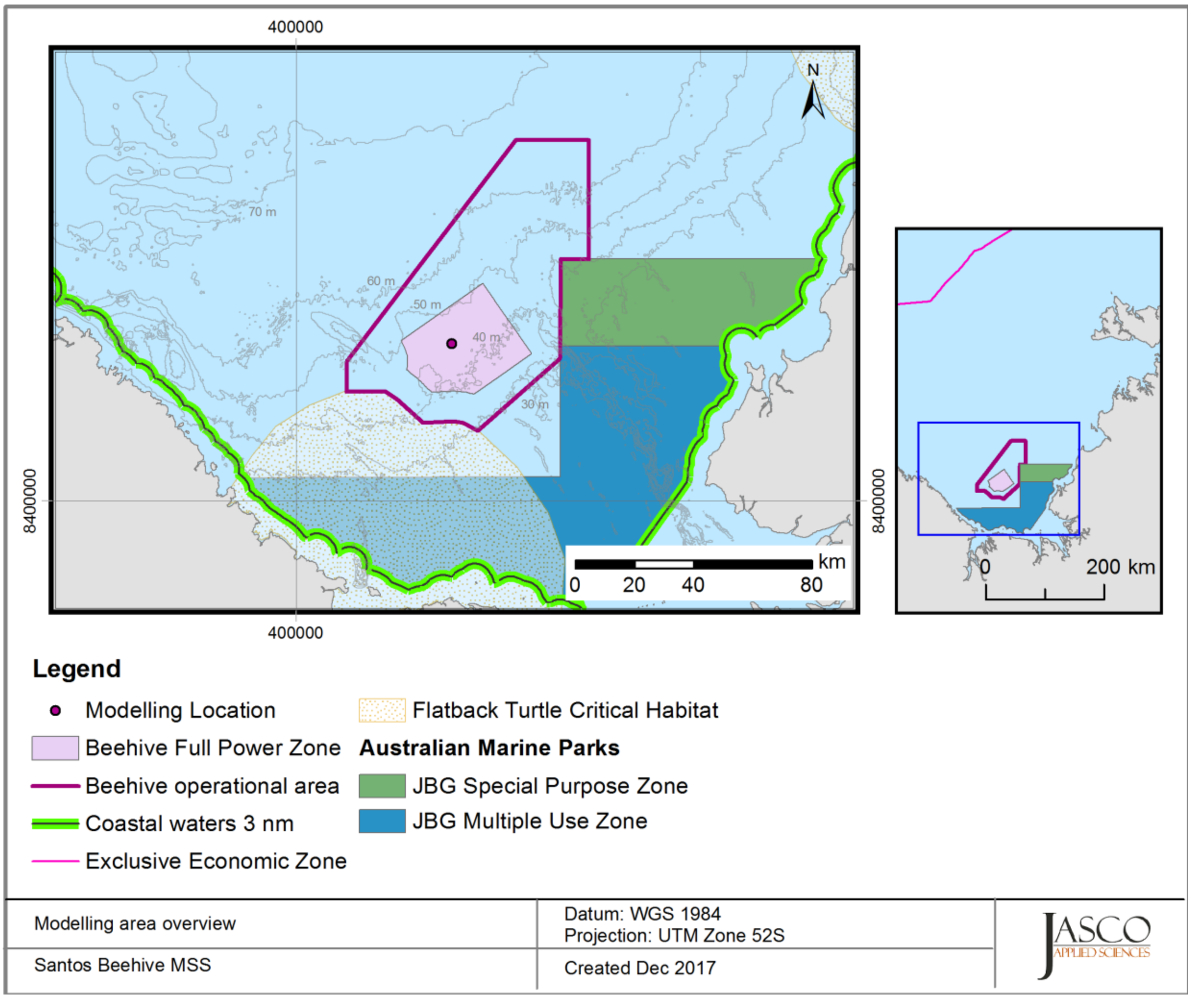

Figure 1. Modelling site locations and features for the Beehive MSS acoustic modelling.

2. Noise Effect Criteria

The perceived loudness of sound, especially impulsive noise such as from seismic airguns, is not generally proportional to the instantaneous acoustic pressure. Rather, perceived loudness depends on the pulse rise-time and duration, and the frequency content. Several sound level metrics, such as PK, SPL, and SEL, are commonly used to evaluate noise and its effects on marine life (Appendix A). The period of accumulation associated with SEL is defined, with this report referencing either a “per pulse” assessment or over 24 h. Appropriate subscripts indicate any applied frequency weighting; unweighted SEL is defined as required. The acoustic metrics in this report reflect the updated ANSI and ISO standards for acoustic terminology, ANSI-ASA S1.1 (R2013) and ISO/DIS 18405.2:2017 (2016).

Whether acoustic exposure levels might injure or disturb marine mammals is an active research topic. Since 2007, several expert groups have investigated an SEL-based assessment approach for injury, with a handful of key papers published on the topic. The number of studies that investigated the level of disturbance to marine animals by underwater noise has also increased substantially.

JASCO chose the following noise criteria for this study because they include standard thresholds and thresholds suggested by the best available science (Sections 2.1–2.2 and Appendix A):

1. Single-impulse threshold for cetaceans (unweighted per-pulse SEL of 160 dB re 1 µPa^2·s) outlined in the Australian Environment Protection and Biodiversity Conservation (EPBC) Act Policy Statement 2.1, Department of the Environment, Water, Heritage and the Arts (DEWHA) (2008).
2. Peak pressure levels (PK; L_{pk}) and frequency-weighted accumulated sound exposure levels (SEL; $L_{E,24h}$) from the U.S. National Oceanic and Atmospheric Administration (NOAA) Technical Guidance (NMFS 2016) for the onset of Permanent Threshold Shift (PTS) in marine mammals.
3. Marine mammal behavioural threshold based on the current interim U.S. National Marine Fisheries Service (NMFS) criterion (NMFS 2013) for marine mammals of 160 dB re 1 µPa SPL for impulsive sound sources.
4. Sound exposure guidelines for fish, fish eggs and larvae, and turtles (Popper et al. 2014).
5. Threshold for turtle behavioural response (NSF 2011), 166 dB re 1 µPa (SPL), applied by the U.S. NMFS.
6. 178 dB re 1 µPa PK-PK in the water column, reported for comparison to McCauley et al. (2017) and potential effects on plankton.

2.1. Marine Mammals

The criteria applied in this study to assess possible effects of airgun noise on marine mammals are summarised in Table 3 and detailed in Sections 2.1.1 and 2.1.2, with frequency weighting explained in Appendix A.3.

Table 3. The unweighted per-pulse SPL, SEL, SEL_{24h} and PK thresholds for acoustic effects on marine mammals.

Hearing group	DEWHA (2008)	NMFS (2013)	NMFS (2016)			
	Unweighted per-pulse SEL (dB re 1 µPa²·s)	Behaviour	Injury (PTS)		TTS	
		SPL (dB re 1 µPa)	Weighted SEL_{24h} (dB re 1 µPa²·s)	PK (dB re 1 µPa)	Weighted SEL_{24h} (dB re 1 µPa²·s)	PK (dB re 1 µPa)
Low-frequency cetaceans	160	160	183	219	168	213
Mid-frequency cetaceans			185	230	170	224
High-frequency cetaceans			155	202	140	196

2.1.1. Behavioural response

Southall et al. (2007) extensively reviewed marine mammal behavioural responses to sounds. They found that most marine mammals exhibited varying responses between 140 and 180 dB re 1 µPa SPL, but inconsistent results between studies made choosing a single behavioural threshold difficult. Studies varied in their lack of control groups, imprecise measurements, inconsistent metrics, and that animal responses depended on study context, which included the animal's activity state. To create meaningful quantitative data from the collected information, Southall et al. (2007) proposed a severity scale that increased with increasing sound levels.

NMFS has historically used a relatively simple sound level criterion for potentially disturbing a marine mammal. For impulsive sounds, this threshold is 160 dB re 1 µPa SPL for cetaceans (NMFS 2013). This threshold has been used to assess behavioural response in this report.

2.1.2. Injury and hearing sensitivity changes

There are two categories of auditory effects considered here: permanent threshold shift (PTS), a physical injury to an animal's hearing organs, and Temporary Threshold Shift (TTS), a temporary reduction in an animal's hearing sensitivity as the result of receptor hair cells in the cochlea becoming fatigued.

For seismic surveys in Australian waters, the EPBC Act Policy Statement 2.1 determines suitable exclusion zones with an unweighted per-pulse SEL threshold of 160 dB re 1 µPa²·s (DEWHA 2008). The Policy Statement claims that the application of this threshold minimises the likelihood of TTS in mysticetes and large odontocetes. The Policy Statement does not apply to smaller dolphins and porpoises as DEWHA noted that these cetaceans have peak hearing sensitivities at higher frequency ranges than those that seismic arrays typically produce.

To assist in assessing the potential for injuries to marine mammals in addition to the application of EPBC Act Policy Statement 2.1, this report applies the criteria recommended by NMFS (2016) as outlined in Appendix A.2, considering both PTS and TTS.

2.2. Fish, Turtles, Fish Eggs, and Fish Larvae

In 2006, the Working Group on the Effects of Sound on Fish and Turtles was formed to continue developing noise exposure criteria for fish and turtles, work begun by a NOAA panel two years earlier. The resulting guidelines included specific thresholds for different levels of effects and for different groups of species (Popper et al. 2014). These guidelines define quantitative thresholds for three types of immediate effects:

- Mortality, including injury leading to death,
- Recoverable injury, including injuries unlikely to result in mortality, such as hair cell damage and minor haematoma, and
- TTS.

Masking and behavioural effects can be assessed qualitatively, by assessing relative risk rather than by specific sound level thresholds. These qualitative effects are not assessed in this report. Because the presence or absence of a swim bladder has a role in hearing, fish's susceptibility to injury from noise exposure varies depending on the species and the presence and possible role of a swim bladder in hearing. Thus, different thresholds were proposed for fish without a swim bladder (also appropriate for sharks and applied to whale sharks in the absence of other information), fish with a swim bladder not used for hearing, and fish that use their swim bladders for hearing. Turtles, fish eggs, and fish larvae are considered separately.

Table 4 lists relevant effects thresholds from Popper et al. (2014). In general, any adverse effects of seismic sound on fish behaviour depends on the species, the state of the individual exposed, and other factors. JASCO notes that, despite mortality being a possibility for fish exposed to airgun sounds, Popper et al. (2014) do not reference an actual occurrence of this effect. Since the publication of that work, newer studies have further examined the question of possible mortality. Popper et al. (2016) adds further information to the possible levels of impulsive seismic airgun sound to which adult fish can be exposed without immediate mortality. They found that the two fish species in their study, with body masses in the range 200–400 g, exposed to a single-impulse of a maximum received level of either 231 dB re 1 µPa (PK) or 205 dB re 1 $\mu Pa^2 \cdot s$ (SEL), remained alive for 7 days after exposure and that the probability of mortal injury did not differ between exposed and control fish.

The SEL metric integrates noise intensity over some period of exposure. Because the period of integration for regulatory assessments is not well defined for sounds that do not have a clear start or end time, or for very long-lasting exposures, it is required to define a time. This is done for marine mammals in the Southall et al. (2007) criteria, where it is either the duration of the activity, if shorter than 24 h, or 24 h, whichever longer. Popper et al. (2014) recommend a standard period should be applied, where this is either defined as a justified fixed period or the duration of the activity; however, the publication also includes caveats about how long the fish will be exposed because they can move (or remain in location) and so can the source. In the discussion of the criteria, Popper et al. (2014) discuss the complications in determining a relevant period of mobile seismic surveys, as the received levels at the fish change between impulses due to the mobile source, and that in reality a revised guideline based on the closest PK or the per-pulse SEL might be more useful than one based on accumulated SEL. This is because exposures at the closest point of approach are the primary exposures contributing to a receiver's accumulated level (Gedamke et al. 2011). Additionally, several important factors determine the likelihood and duration a receiver is expected to be near a sound source (i.e., overlap in space and time between the source and receiver). For example, the accumulation time for fast moving (relative to the receiver) mobile sound sources is driven primarily by the characteristics of source (i.e., speed, duty cycle) (NMFS 2016).

Guidelines for TTS in Popper et al. (2014) are based upon data from Popper et al. (2005) for exposure of several riverine species to a seismic airgun array. In all cases, fish that showed TTS recovered to normal hearing levels within 18–24 hours. Due to this, a period of accumulation of 24 h has been applied in this study for SEL, which is similar to that applied for marine mammals in Southall et al. (2007) and NMFS (2016).

Table 4. Criteria for seismic noise exposure for fish and turtles, adapted from Popper et al. (2014).

Type of animal	Mortality and potential mortal injury	Impairment			Behaviour
		Recoverable injury	TTS	Masking	
Fish: No swim bladder (particle motion detection)	> 219 dB SEL_{24h} or > 213 dB PK	> 216 dB SEL_{24h} or > 213 dB PK	>> 186 dB SEL_{24h}	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low
Fish: Swim bladder not involved in hearing (particle motion detection)	210 dB SEL_{24h} or > 207 dB PK	203 dB SEL_{24h} or > 207 dB PK	>> 186 dB SEL_{24h}	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low
Fish: Swim bladder involved in hearing (primarily pressure detection)	207 dB SEL_{24h} or > 207 dB PK	203 dB SEL_{24h} or > 207 dB PK	186 dB SEL_{24h}	(N) Low (I) Low (F) Moderate	(N) High (I) High (F) Moderate
Turtles	210 dB SEL_{24h} or > 207 dB PK	(N) High (I) Low (F) Low	(N) High (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low
Fish eggs and fish larvae	> 210 dB SEL_{24h} or > 207 dB PK	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low

Notes: Peak sound pressure level dB re 1 µPa; SEL_{24h} dB re 1µPa^2·s. All criteria are presented as sound pressure even for fish without swim bladders since no data for particle motion exist. Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near (N), intermediate (I), and far (F).

2.2.1. Turtle behavioural response

There is a paucity of data regarding responses of turtles to acoustic exposure, and no studies of hearing loss due to exposure to loud sounds. McCauley et al. (2000) observed the behavioural response of caged turtles—green (*Chelonia mydas*) and loggerhead (*Caretta caretta*)—to an approaching seismic airgun. For received levels above 166 dB re 1 µPa (SPL), the turtles increased their swimming activity and above 175 dB re 1 µPa they began to behave erratically, which was interpreted as an agitated state. The 166 dB re 1 µPa level has been used as the threshold level for a behavioural disturbance response by NMFS and applied in the Arctic Programmatic Environment Impact Statement (PEIS) (NSF 2011). At that time, and in the absence of any data from which to determine the sound levels that could injure an animal, TTS or PTS onset were considered possible at an SPL of 180 dB re 1 µPa (NSF 2011). Some additional data suggest that behavioural responses occur closer to an SPL of 175 dB re 1 µPa, and TTS or PTS at even higher levels (Moein et al. 1995), but the received levels were unknown and the NSF (2011) PEIS maintained the earlier NMFS criteria levels of 166 and 180 dB re 1 µPa (SPL) for behavioural response and injury, respectively. Popper et al. (2014) suggested injury to turtles could occur for sound exposures above 207 dB re 1 µPa (PK) or above 210 dB re 1 µPa^2·s (SEL_{24h}) (Table 4). Sound levels defined by Popper et al. (2014) show that animals are very likely to exhibit a behavioural response when they are near an airgun (tens of metres), a moderate response if they encounter the source at intermediate ranges (hundreds of metres), and a low response if they are far (thousands of meters) from the airgun. Both the NMFS criteria for behavioural disturbance (SPL of 166 dB re 1 µPa) and the Popper et al. (2014) injury criteria were included in this analysis, although the analysis did not consider the ranges at which an animal could suffer impairment, as defined by Popper et al. (2014).

3. Methods

This section details the methodology for predicting the source levels, modelling the sound propagation, and assessing distances to the selected impact criteria.

3.1. Acoustic Source Model

The source levels and directivity of the airgun array were predicted with JASCO's AASM, which considers:

- Array layout.
- Volume, tow depth, and firing pressure of each airgun.
- Interactions between different airguns in the array.

Details of the model are described in Appendix B, and the array was modelled over AASM's full frequency range, up to 25 kHz.

3.2. Sound Propagation Models

Three sound propagation models were used to predict the acoustic field around the airgun array for frequencies of 5 Hz to 25 kHz:

- Combined range-dependent parabolic equation JASCO's Marine Operations Noise Model (MONM), and Gaussian beam acoustic ray-trace model (BELLHOP)(MONM-BELLHOP).
- Full Waveform Range-dependent Acoustic Model (FWRAM).
- Wavenumber integration model (VSTACK).

The models were used in combination to characterise the acoustic fields at short and long ranges in terms of SEL, SPL, PK and PK-PK. Appendix C details each model.

3.3. Parameter Overview

The specifications of the airgun array source modelled at all sites and the environmental parameters used in the propagation models, such as bathymetry, sound speed profile and geoacoustics, are described in detail in Appendix D.

The airgun array under consideration for the proposed Beehive 3-D MSS is a 11.2 × 15 m 2380 in^3 seismic array consisting of three strings towed at a 6 m depth (Figure D-4, Table D-2). The firing pressure will be 2000 psi. As described in Section 3.4.2, the modelling is based on 12.5 m shot point interval (based on triple source mode), and a 600 m line space interval.

A single sound speed profile that provided the greatest propagation is applied, which occurs during July.

3.4. Accumulated SEL

3.4.1. Method overview

During a seismic survey, a new portion of sound energy is introduced into the environment with each pulse from the airgun array. While some impact criteria are based on per-pulse energy released, others, such as the marine mammal and fish SEL criteria used in this report (Sections 2.1 and 2.2) account for the total acoustic energy marine fauna is subjected to over a specified period of time, defined in this report as 24 h. An accurate assessment of the cumulative acoustic field depends not only on the parameters of each impulse, but also on the number of impulses delivered in a period and the relative positions of the impulses.

When there are many seismic pulses, it becomes computationally prohibitive to perform sound propagation modelling for every single event. The offset between the consecutive seismic impulses is small enough, however, that the environmental parameters that influence sound propagation are virtually the same for many impulse points. The acoustic fields can, therefore, be modelled for a subset of seismic pulses and estimated at several adjacent ones. After sound fields from representative impulse locations are calculated, they are adjusted to account for the source position for nearby impulses.

Although estimating the cumulative sound field with the described approach is not as precise as modelling sound propagation at every impulse location, small-scale, site-specific sound propagation features tend to blur and become less relevant when sound fields from adjacent impulses are summed. Larger scale sound propagation features, primarily dependent on water depth, dominate the cumulative field. The accuracy of the present method acceptably reflects those large-scale features, thus providing a meaningful estimate of a wide area SEL field in a computationally feasible framework.

3.4.2. Scenario definition

The assessment has considered a single 24 h period of seismic operation, along three sequential lines in the acquisition pattern to assess a conservative scenario in terms of 24 h SEL. The three sequential acquisition lines assessed are 37.026, 28.361 and 37.226 km long, the spacing between sequential lines is 13.805 km, and between adjacent lines 600 m apart. The seismic vessel is assumed to start at the eastern end of the northern line, and traverse the survey lines at ~4.5 knots, with an impulse interval of 12.5 m. The survey has been modelled considering a triple source array, with a source separation of 37.5 m, with each source being activated individually according to a set sequence. The modelling accounts for the location of the active source for each seismic impulse. In total, 8204 impulses are accounted for in the scenario.

Because modelling the thousands of impulses needed to represent 24 h of seismic operation is time consuming, we estimated the acoustic fields based on single-impulse model sites from representative source locations which formed the library of representative footprints. As the geoacoustics are the same throughout the region, only the bathymetry needs to be considered when determining the location of the representative source locations. An analysis of the bathymetry along the acquisition lines in the modelled scenario determined that consideration of one representative site, covering the entire survey region, would provide a sufficient representation. Therefore, all survey lines within the 24 h exposure calculation were classified as this impulse point, based on geographic similarity (Figure 2).

To produce maps of cumulative received sound level distributions and calculate distances to specified sound level thresholds, the maximum-over-depth level and level at the seafloor are calculated at each sampling point within the modelled region. The radial grids of maximum-over-depth and seafloor sound levels for each impulse are then resampled (by linear triangulation) to produce a regular Cartesian grid. The sound field grids from all impulses were summed (Equation A-5) to produce the cumulative sound field grid with cell sizes of 40 m. The contours and threshold ranges are calculated from these flat Cartesian projections of the modelled acoustic fields.

The single-impulse SEL fields are computed over model grids ~200 km × 200 km in range, which encompass the full area of the cumulative grid (the entire survey area). The unweighted (fish) and frequency-weighted SEL_{24h} results are rendered as contour maps, including contours that focus on the relevant criteria-based thresholds. Only contours at ranges larger than the nearfield of the airgun array are rendered.

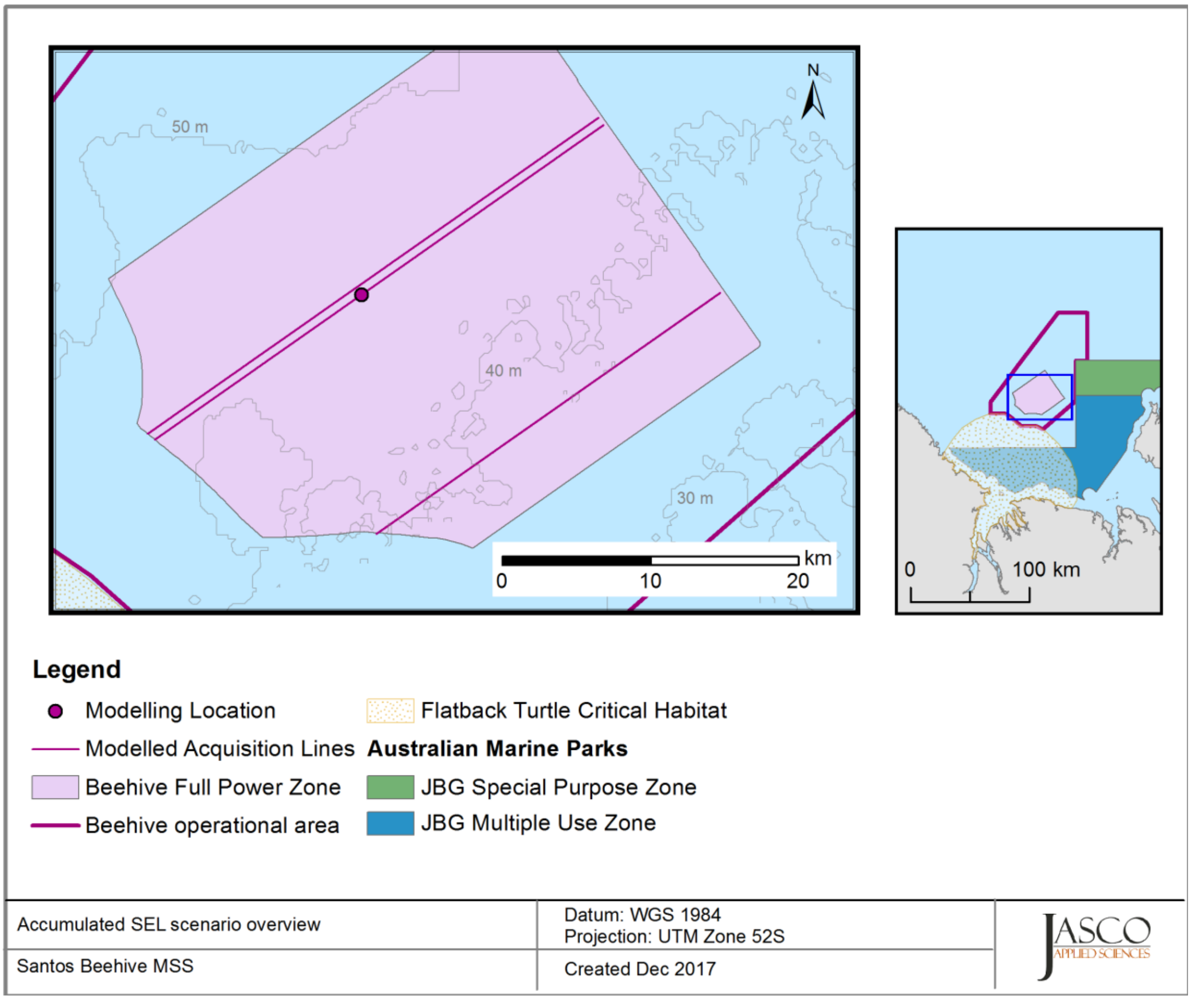

Figure 2. Acquisition lines considered for SEL_{24h} calculations.

3.5. Geometry and Modelled Regions

Using MONM, the sound field is modelled up to distances of 150 km from the source, with a horizontal separation of 40 m between receiver points along the modelled radials. Sound fields are modelled with a horizontal angular resolution of $\Delta\theta$ = 2.5° for a total of N = 144 radial planes. Receiver depths are chosen to span the entire water column over the modelled areas, from 1 m to 300 m, with step sizes that increase with depth. To supplement the MONM results, high-frequency results for propagation loss are modelled using Bellhop for frequencies from 1 to 25 kHz. The MONM and Bellhop results are combined to produce results for the full frequency range of interest.

FWRAM transects out to 99 km with a 20 m range step were modelled. These additional transects are completed along only four radials (broadside and endfire directions) for computational efficiency, from 10 Hz to 1 kHz in 1.0 Hz steps. This is done to compute SEL-to-SPL conversions (Appendix D.2).

VSTACK is used to model PK, PK-PK, and per-pulse SEL at the seafloor. The maximum modelled range for VSTACK is 1000 m. Because VSTACK assumes constant bathymetry, radials are only run in four directions (fore and aft endfire, port and starboard broadside). Received levels were computed for receivers at seafloor.

4. Results

This section presents the model results in formats that include tables of maximum (R_{max}) and 95% ($R_{95\%}$) distances to sound level thresholds and sound field contour maps, which show predicted sound levels at the sites and the various sound level threshold contours.

4.1. Acoustic Source Levels and Directivity

The pressure signatures of the individual airguns and the composite 1/3-octave-band point source equivalent directional levels of the array were modelled with AASM (Section 3.1). Although AASM accounts for notional pressure signatures of each airgun array with respect to the effects of surface-reflected signals on bubble oscillations and inter-bubble interactions, the surface-reflected signal (known as surface ghost) is not included in the far-field source signatures. The acoustic propagation models account for those surface reflections, which are a property of the propagating medium rather than the source.

The horizontal and vertical overpressure signatures and corresponding power spectrum levels, along with the horizontal directivity plots for the 2380 in^3 airgun array, are provided in Appendix B.2.

Table 5 shows the PK and per-pulse SEL source levels for the airgun array in the endfire, broadside, and vertical directions. The vertical source level that accounts for the surface ghost is also presented to make it easier to compare the output of other airgun array source models.

Table 5. Source level specifications in the horizontal plane for the 2380 in^3 array, for a 6 m tow depth. Source levels are per-pulse and unweighted.

Direction	Peak pressure level (dB re 1 µPa @ 1 m)	SEL (dB re 1 µPa^2·s @ 1 m)	
		10–2000 Hz	2000–25000 Hz
Broadside	248.0	223.2	182.7
Endfire	245.9	223.1	187.4
Vertical (no ghost)	254.6	227.8	194.4
Vertical (with ghost)	254.6	230.5	197.4

4.2. Per-pulse Sound Fields

Per-pulse results for the proposed Beehive MSS are presented at a single modelling site for all per-pulse metrics. (see Table 2 for location, depth, and tow direction).

The maximum (R_{max}) horizontal distance from the 2380 in^3 array to modelled maximum-over-depth PK-PK relevant for plankton, 178 dB re 1 µPa, was 1.95 km, assessed along the four FWRAM modelling transects.

4.2.1. Tabulated results

4.2.1.1. Maximum-over-depth results

Tables 6–9 show the estimated ranges for the various applicable per-pulse effects criteria and isopleths of interest as maximum-over-depth for the 2380 in^3 airgun array towed at 6 m.

Table 6. Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the 2380 in^3 array to modelled maximum-over-depth DEWHA (2008) criterion and applied marine mammal and turtle behavioural response thresholds.

Threshold	R_{max} (km)	$R_{95\%}$ (km)
DEWHA (2008), Unweighted per-pulse SEL: 160 dB re 1 µPa^2·s	0.9	0.8
NMFS (2013) Marine mammal behaviour, SPL: 160 dB re 1 µPa	1.4	1.3
Turtle behaviour, SPL: 166 dB re 1 µPa (NSF 2011)	1.1	1.1

Table 7. Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the 2380 in^3 array to modelled maximum-over-depth per-pulse SEL isopleths. A dash indicates the threshold is not reached.

Per-pulse SEL (dB re 1 µPa^2·s)	R_{max} (km)	$R_{95\%}$ (km)
200	–	–
190	0.05	0.05
180	0.14	0.14
170	0.30	0.30
160	0.88	0.83
150	1.51	1.43
140	3.18	3.02
130	6.25	5.46
120	14.94	13.11
110	63.33	48.95

Table 8. Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the 2380 in^3 array to modelled maximum-over-depth SPL isopleths. A dash indicates the threshold is not reached.

SPL (dB re 1 µPa)	R_{max} (km)	$R_{95\%}$ (km)
200	–	–
190	0.24	0.24
180	0.37	0.37
170	0.63	0.60
160	1.40	1.35
150	3.02	2.78
140	5.65	5.03
130	14.21	12.31
120	50.94	42.70

Table 9. Maximum (R_{max}) horizontal distances (in m) from the 2380 in^3 array to PTS and TTS PK levels for marine mammals. A dash indicates the threshold is not reached.

Hearing group	PTS PK Threshold (dB re 1 µPa)	Distance R_{max} (m)	TTS PK Threshold (dB re 1 µPa)	Distance R_{max} (m)
Low-frequency cetaceans	219	24	213	54
Mid-frequency cetaceans	230	–	224	<20
High-frequency cetaceans	202	172	196	280

4.2.1.2. Seafloor results

The estimated ranges for the various applicable per-pulse effects criteria and isopleths of interest at the seafloor for the 2380 in^3 airgun array towed at 6 m are shown in Tables 10–12.

Table 10. Maximum (R_{max}) horizontal distances (in m) from the 2380 in^3 array to modelled seafloor PK levels from four transects.

Peak pressure level (dB re 1 µPa)	Distance R_{max} (m)
230	-
225	-
220	18
215	47
213†	58
210	66
207‡	78
205	110
200	220
195	338

Defined in Popper et al. (2014) as being associated with mortality and potential mortal injury and recoverable injury:
† Fish: No swim bladder
‡ Fish: Swim bladder not involved in hearing, Swim bladder involved in hearing, Turtles, fish eggs, and larvae

Table 11. Maximum (R_{max}) horizontal distances (in m) from the 2380 in^3 array to modelled seafloor PK-PK levels from four transects.

PK-PK (dB re 1 µPa)	Distance R_{max} (m)
230	-
225	18
220	43
215	63
210	123
205	208
202	265
200	313

Table 12. Maximum (R_{max}) horizontal distances (in m) from the 2380 in^3 array to modelled seafloor SEL per-pulse levels from four transects.

SEL (dB re 1 $\mu Pa^2 \cdot s$)	Distance R_{max} (m)
200	-
195	29
190	49
185	74
180	139
175	209
170	306

4.2.2. Maps and graphs

Figures 3 and 4 show maps of the estimated sound fields, threshold contours and isopleths of interest for the per-pulse SEL and SPL results for the proposed Beehive MSS at the single modelling site (see Table 2 for details).

Figures 5 presents vertical slices of the estimated sound fields for per-pulse SEL and SPL. Figure 6 shows seafloor PK and PK-PK plots.

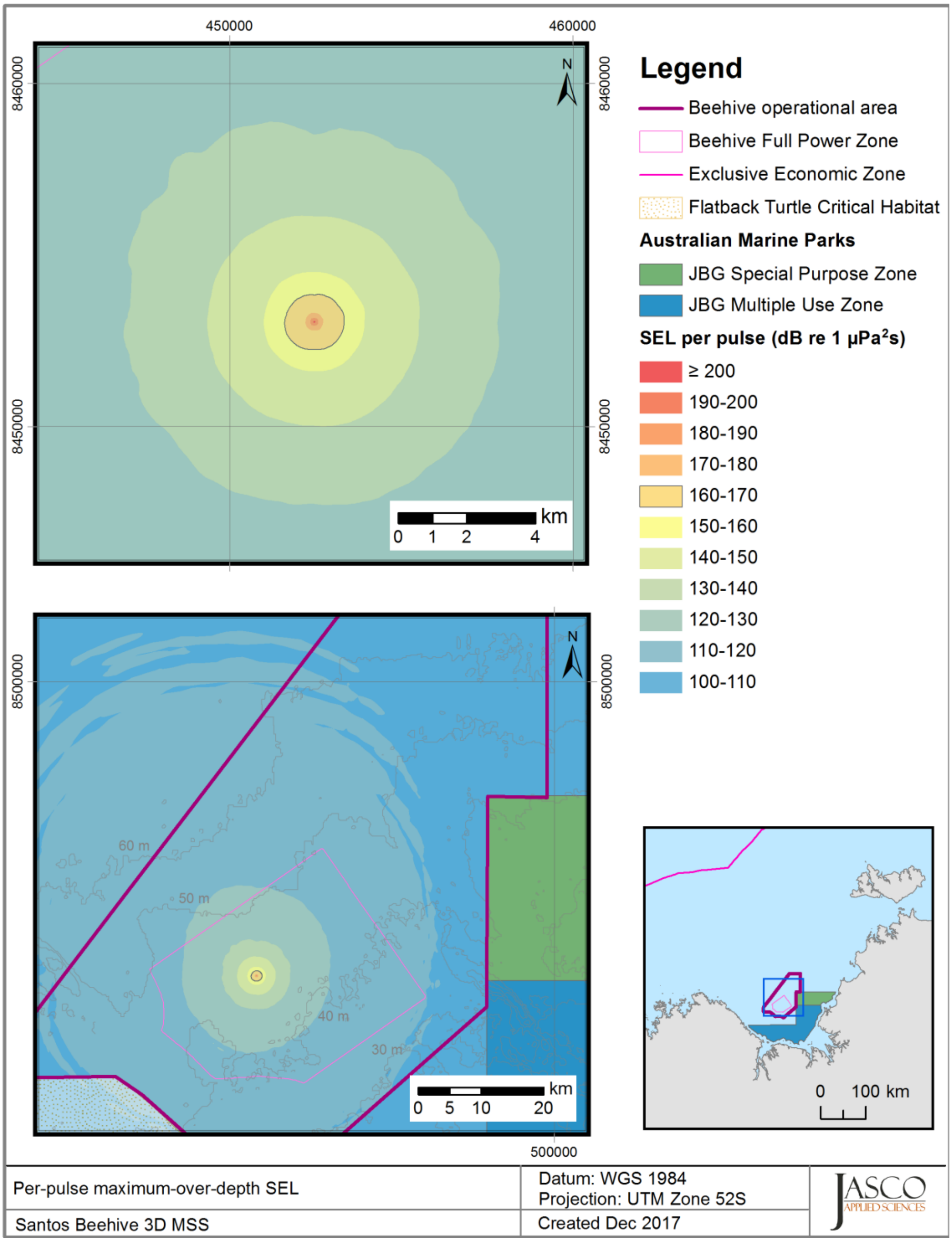

Figure 3. Sound level contour map showing unweighted maximum-over-depth per-pulse SEL results for the 2380 in^3 array.

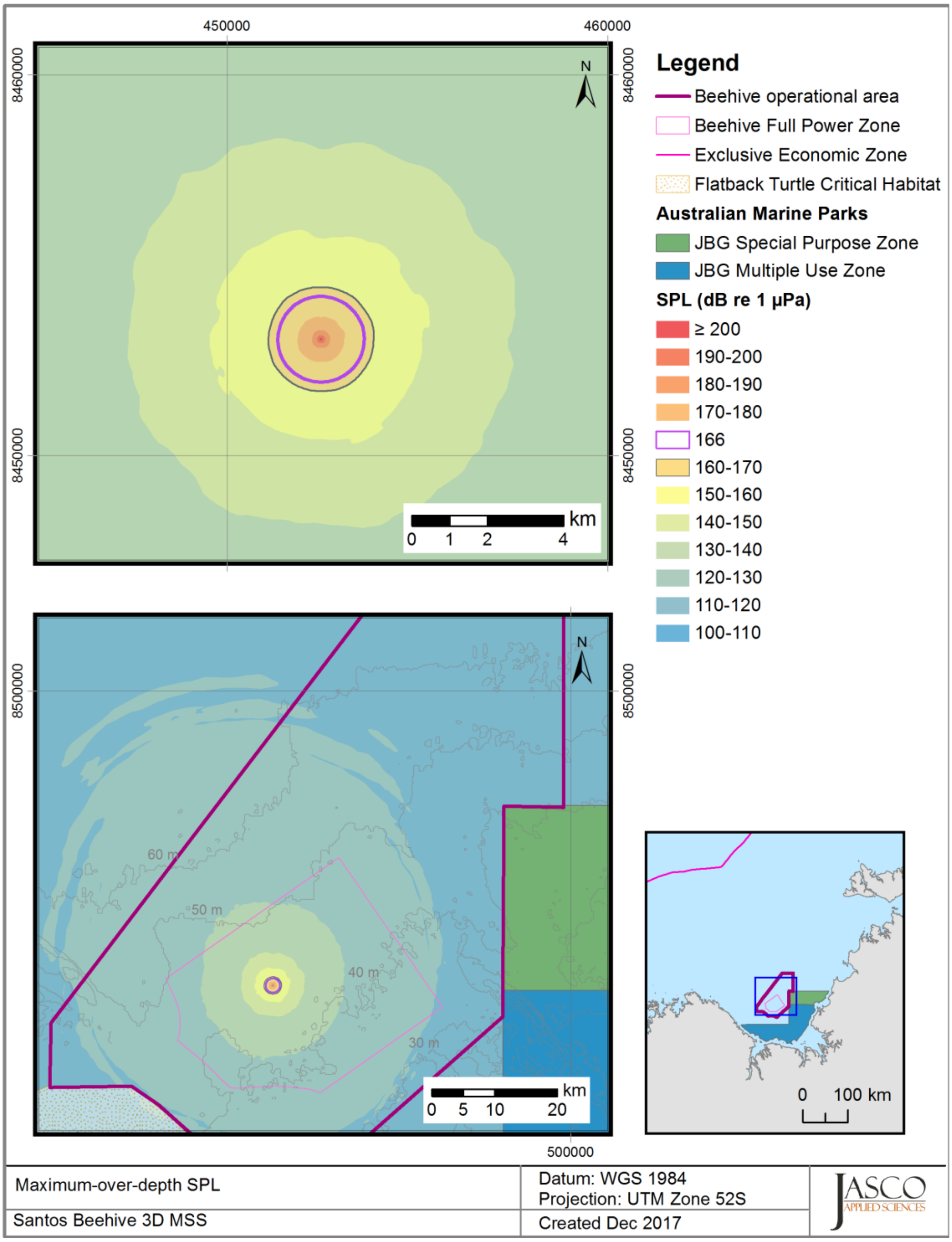

Figure 4. Sound level contour map showing unweighted maximum-over-depth SPL results for the 2380 in^3 array. Isopleths for turtle (166 dB re 1 µPa) and marine mammal (160 dB re 1 µPa) behavioural criteria are shown.

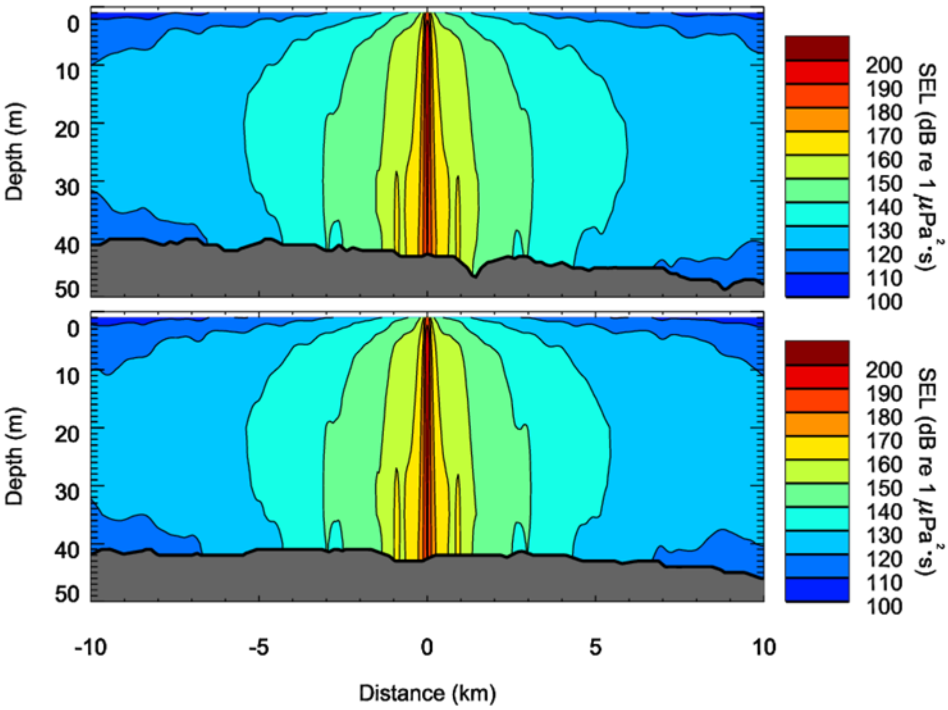

Figure 5. Site 1: Predicted unweighted per-pulse SEL for the 2380 in³ array as vertical slices. Levels are shown along a single transect from broadside (top) and endfire (bottom). The source depth is 6 m.

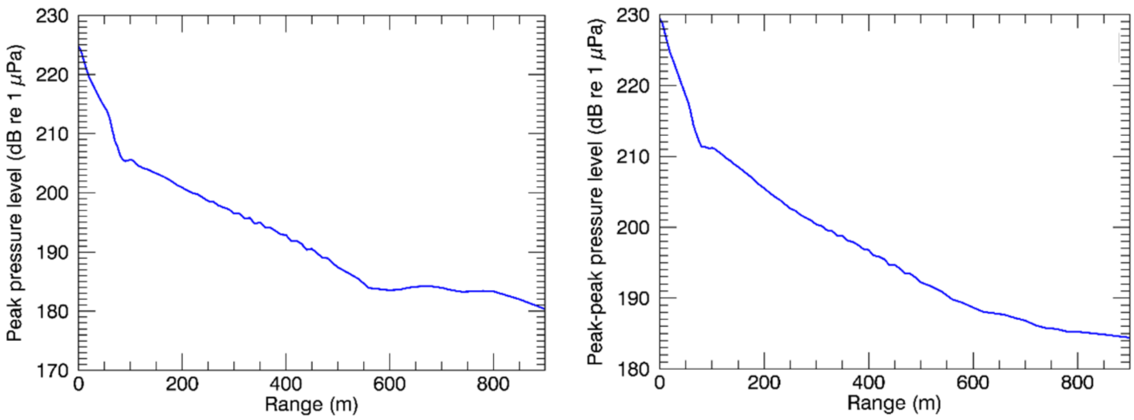

Figure 6. Peak pressure level (left) and peak-peak pressure level (right) as a function of range, for receivers at the seafloor. Maximum levels are shown for each of four transects, assessing broadside and endfire directions. The source depth is 6 m.

4.3. Multiple Pulse Sound Fields

The SEL_{24h} results for the proposed Beehive MSS are presented for one possible operational scenario, described in Section 3.4.2. Tables 13 and 14 show estimated ranges to the appropriate cumulative exposure criterion contour for the marine fauna groups considered. The radii in this section represent the perpendicular distance from to the closest survey line to the relevant isopleth.

Table 13. Maximum-over-depth distances to SEL_{24h} based marine mammal PTS and TTS thresholds NMFS (2016) for the considered scenario within the Beehive MSS acquisition area. A dash indicates the threshold is not reached.

Hearing group	PTS			TTS		
	Threshold for SEL_{24h} (dB re 1 µPa²·s)	R_{max} (km)	Area (km²)	Threshold for SEL_{24h} (dB re 1 µPa²·s)	R_{max} (km)	Area (km²)
Low-frequency cetaceans	183	0.30	53.00	168	2.28	273.00
Mid-frequency cetaceans	185	–	–	170	0.05	2.15
High-frequency cetaceans	155	0.07	11.00	140	0.09	15.90

Table 14. Distances (in km) to maximum-over-depth and seafloor SEL_{24h} based fish and turtle criteria for the considered scenario within the Beehive MSS acquisition area. Fish I–No swim bladder; Fish II–Swim bladder not involved with hearing; Fish III–Swim bladder involved with hearing. A dash indicates the threshold is not reached. The grid resolution was 40 m.

Marine animal group	Threshold for SEL_{24h} (dB re 1 µPa²·s)	Maximum-over-depth		Seafloor	
		R_{max} (km)	Area (km²)	R_{max} (km)	Area (km²)
Fish mortality and potential mortal injury					
I	219	0.07	11.00	–	–
II Fish eggs and larvae	210	0.07	11.00	–	–
III	207	0.07	11.00	–	–
Fish recoverable injury					
I	216	0.07	11.00	–	–
II, III	203	0.07	11.00	–	–
Fish TTS					
I, II, III	186	0.41	70.10	0.38	67.30
Turtle mortality and potential mortal injury					
Turtles	210	0.07	11.00	–	–

The sound level contour map is presented in Figure 7. The contours for marine mammal injury thresholds shown in the maps represent weighted metrics for low-frequency cetaceans and as such do not numerically match the SEL contour bands that are unweighted.

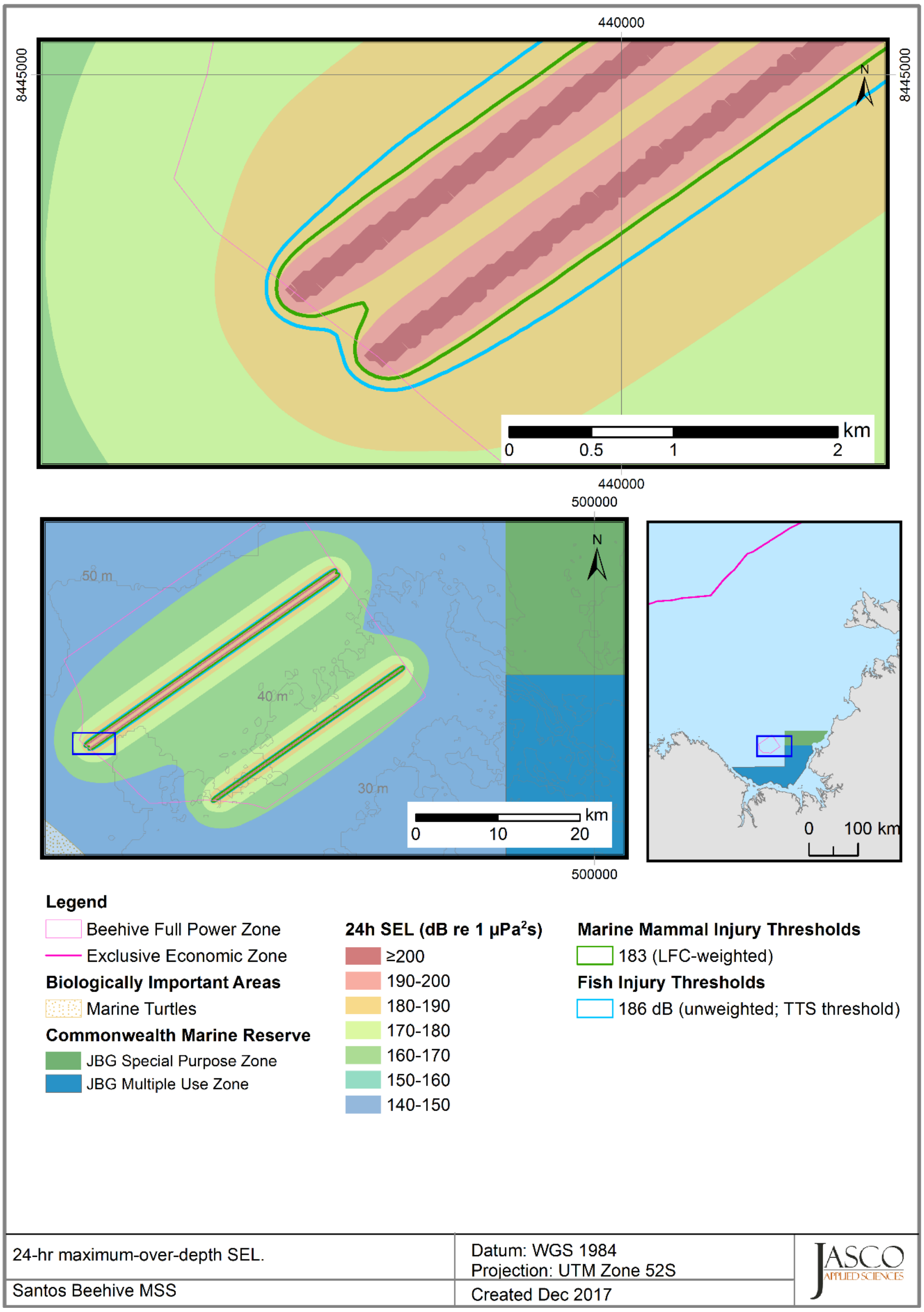

Figure 7. Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results for the 2380 in^3 array.

5. Discussion

5.1. Overview and sound source levels

This modelling study predicted underwater sound levels associated with the Santos proposed Beehive MSS. The underwater sound field was modelled for operating a 2380 in^3 airgun array as the maximum source (Appendix D.4) with water column sound speed profiles for July. Analysed sound speed profiles (Appendix D.3.2) indicated that this month had the greatest noise transmission, making it the most conducive month for sound propagation, and as such it was selected for modelling to ensure distances to received sound level thresholds were not underestimated over the entire survey period. The modelling also accounted for site-specific bathymetric variations (Appendix D.3.1) and local geoacoustic properties (Appendix D.3.3).

This report focuses on PK levels at the seafloor that are relevant to fish. These levels are highly dependent upon the depth of the water at close range. The first reflection is the sound from the sea surface, followed by a reflection from the seafloor, these two reflections then interact with each other prior to subsequent reflections. As the distance from the source increases beyond approximately three water depths, a complex pattern of destructive surface reflection and constructive critical angle bottom reflections dominate over sounds due to any direct path transmission. Therefore, in different water depths, the seafloor sound levels will not follow a consistent simple relationship with water depth. However, as the water depth is consistent throughout the survey area, the seafloor sound levels are expected to be consistent with the modelled levels (see results in Table 10).

While the modelled results of seafloor sound levels are presented in terms of horizontal distances to the sound level at the seafloor, given the distribution of sound within the water column for the locations assessed, these distances will also predominantly represent the maximum-over-depth distance. This relationship is the case for distances associated with sound levels greater than 170 dB re 1 µPa^2·s, with the distances for all metrics within approximately 600 m being determined by seafloor sound levels.

Most acoustic energy from the airgun array is output at lower frequencies, in the tens to hundreds of hertz. Although there was little difference in the broadband source levels in the endfire and broadside directions, some directivity below a few hundred hertz led to slightly higher emissions in the broadside direction at those frequencies. Because the survey will be in shallow water, the low-frequency components associated with the highest spectral levels for the source attenuated rapidly compared to those at higher frequencies. The overall broadband (10–2000 Hz) unweighted per-pulse SEL source level of the 2380 in^3 airgun array operating at 6 m were 223.2 dB re 1 µPa^2·s @ 1 m in the broadside direction and 223.1 dB re 1 µPa^2·s @ 1 m in the endfire direction. The peak pressure levels in the same directions were 248.0 and 245.9 dB re 1 µPa, respectively. Table 5 presents these results.

5.2. Per-pulse sound fields

The 2380 in^3 airgun array is does not exhibit strong directionality (Appendix B.2), which combined with the shallow water depth, resulted in footprints with directionality determined more by bathymetry than by the airgun array itself. The footprint (Figure 3) is almost omni-directional out to the distance associated with the 130 dB re 1 µPa^2·s isopleth, beyond this the increasing depth to the north, and the decreasing depth to the south, start influencing the footprint shape.

Marine mammals could experience a permanent auditory threshold shift (PTS) based on the criteria applied (NMFS 2016). This is a dual metric criterion, requiring consideration of both PK and accumulated SEL, with the maximum distance from either metric being the one required to be applied. The peak pressure criteria were exceeded at a maximum horizontal distance of 24 m for low-frequency cetaceans, and 172 m for high-frequency cetaceans (Table 9), and are not reached for mid-frequency cetaceans. Distances are from the centre of the array, but as the array is not a point source (11.2 × 15 m), and the actual ranges from the edge of the airgun array are negligible for all but high-frequency cetaceans. TTS is predicted to occur in the three cetacean hearing groups, with the maximum distances being 54, < 20, and 280 m for low, mid and high-frequency cetaceans, respectively.

The distance to PK levels relevant to fish at the seafloor follows a relatively consistent decay rate (Table 10, Figure 6).

5.3. Multiple Pulse Sound Fields

The accumulated SEL scenario considers 24 h of seismic operation along two specified acquisition lines. The model measured the accumulated effects of noise, accounting for the change in location and the azimuth of the source at each impulse point. These accumulated SEL results which were used to assess possible PTS and TTS in marine mammals, along with SEL_{24h}-based fish and turtle criteria.

The SEL_{24h} is a cumulative metric that reflects the dosimetric impact of noise levels within 24 h, based on the assumption that an animal is consistently exposed to such noise levels at a fixed position. The radii that correspond to SEL_{24h} typically represent an unlikely worst case scenario for SEL-based exposure since, more realistically, marine fauna (mammals or fish) would not stay in the same location or at the same range for 24 h. Therefore, a reported radius of SEL_{24h} criteria does not mean that any animal travelling within this radius of the source will be injured, but rather that it could be injured if it remained in that range for 24 h. The reported radii represent the perpendicular distance from to the closest survey line to the relevant isopleth.

The assessed survey lines are 13.8 km apart in sequence, and in total comprise 8204 single impulses. At receiver locations close to the survey lines, the modelled noise level was dominated by those shots nearest to them with little to no influence from the other line where the nearest shot was within a few kilometres of the receiver. The greater propagation in the offshore direction seen in the single shot results was reflected here, as again the ranges to isopleths at lower levels were greater in this direction, which is because propagation towards the north encountered the gradual increase in depth. This was apparent in the 160 dB re 1 $\mu Pa^2 \cdot s$ isopleth. For levels above 160 dB re 1 $\mu Pa^2 \cdot s$, the isopleths were relatively evenly distributed around the track lines, with only a slight extension of ranges in the broadside direction (Figure 7).

The SEL_{24h} PTS criteria for marine mammals (NMFS 2016) was not exceeded for mid-frequency cetaceans, but it was exceeded for low- and high-frequency cetaceans, which could be effected at distances of up to 300 or 70 m (Table 13). The distance for low-frequency cetaceans was greater for the SEL_{24h} metric than the PK metric, but the opposite was the case for high-frequency cetaceans.

The criteria for either possible mortality and potential mortal injury in fish, turtles, fish eggs, and fish larvae was not reached at the seafloor using the SEL_{24h} metric based on Popper et al. (2014) (Table 14). Recoverable injury in fish, turtles, fish eggs, and fish larvae could occur within 70 m; however, this distance was less than that predicted considering the PK metric. Temporary impairment of fish auditory systems (TTS) could occur within 410 m of the airgun array for fish in the water column, or within 380 m for seafloor fish, based on the estimated R_{max} radii (Table 14).

5.4. Summary

5.4.1. Marine mammal injury

For comparison to the EPBC Act Policy Statement 2.1 (DEWHA 2008), the $R_{95\%}$ 160 dB re 1 $\mu Pa^2 \cdot s$ single-impulse SEL distances for the survey were less than 1 km, being 0.9 km.

The results for the NMFS (2016) criteria applied for marine mammal PTS consider both metrics within the criteria (PK and SEL_{24h}). The farthest distance associated with either metric is required to be applied. The maximum distances along with the relevant metric and the location of the results are summarised in Table 15.

Table 15. Summary of marine mammal PTS onset distances.

Relevant hearing group	Metric associated with greatest distance to PTS onset	Distance R_{max} (km)	Result location
Low-frequency cetaceans	SEL_{24h}	0.30	Table 13
Mid-frequency cetaceans	PK	–	Table 9
High-frequency cetaceans	PK	0.16	Table 9

5.4.2. Marine mammal behaviour

The maximum distance at which the NMFS (2013) marine mammal behavioural response criterion of 160 dB re 1 µPa could be exceeded was 1.4 km (Table 6).

5.4.3. Fish, turtles, fish eggs, and fish larvae

In addition to presenting detailed results for seafloor PK, PK-PK, and per-pulse SEL for comparison to literature, the modelling study assessed the ranges for quantitative criteria from Popper et al. (2014) associated with mortality and potential mortal injury and impairment in:

- Fish without a swim bladder (also appropriate for sharks in the absence of other information)
- Fish with a swim bladder not used for hearing
- Fish that use their swim bladders for hearing
- Turtles
- Fish eggs, and fish larvae

The distance to PK levels relevant to fish at the seafloor is site specific, with no consistent pattern between site depth and distance to isopleth.

Sound levels associated with either mortality and potential mortal injury or recoverable injury to fish, based on Popper et al. (2014), using the SEL_{24h} metric, are predicted to occur at ranges shorter than those predicted using the PK metric. In line with the conditions of the criteria, the PK metric therefore should be used to assess these impacts. A similar scenario exists for sound levels associated with either mortality and potential mortal injury to turtles, fish eggs, and fish larvae.

Therefore, applying the Popper et al. (2014) criteria:

- For mortality and potential mortal injury or recoverable injury, the relevant sound level for the most sensitive fish groups is 207 dB re 1 µPa PK, and the associated maximum distance is 78 m.
    - This sound level and distance are also associated in the criteria with mortality and potential mortal injury to turtles, fish eggs, and fish larvae.
- The relevant sound level for the least sensitive fish group (fishes without a swim bladder, sharks), is 213 dB re 1 µPa PK, and the associated maximum distance is 58 m.

Considering the defined 24h period of exposure, fish (including sharks) could experience TTS within 410 m of the airgun array anywhere in the water column, or within 380 m of the array on the seafloor.

Behavioural effects in turtles were also considered. The maximum distance to the isopleth associated with the U.S. NMFS criterion for behavioural effects in turtles (166 dB re 1 µPa) was 1.1 km (R_{max} distance, Site 3).

5.4.4. Plankton

For comparison to the level reported in McCauley et al. (2017) for potential effects on plankton, the distance to 178 dB re 1 µPa PK-PK in the water column was assessed. The range to this sound level is predicted to be 1.95 km.

Glossary

1/3-octave-band
Non-overlapping passbands that are one-third of an octave wide (where an octave is a doubling of frequency). Three adjacent 1/3-octave-bands comprise a one octave-band. One-third-octave-bands become wider with increasing frequency. Also see octave.

90% time window
The time interval over which the cumulative energy rises from 5% to 95% of the total pulse energy. This interval contains 90% of the total pulse energy. Symbol: T_{90}.

90% sound pressure level (SPL(T_{90}))
The root-mean-square sound pressure levels calculated over the 90%-energy time window of a pulse. Used only for pulsed sounds.

attenuation
The gradual loss of acoustic energy from absorption and scattering as sound propagates through a medium.

audiogram
A graph of hearing threshold level (sound pressure levels) as a function of frequency, which describes the hearing sensitivity of an animal over its hearing range.

auditory weighting function (frequency-weighting function)
Auditory weighting functions account for marine mammal hearing sensitivity. They are applied to sound measurements to emphasise frequencies that an animal hears well and de-emphasise frequencies they hear less well or not at all (Southall et al. 2007, Finneran and Jenkins 2012, NOAA 2013).

azimuth
A horizontal angle relative to a reference direction, which is often magnetic north or the direction of travel. In navigation it is also called bearing.

bandwidth
The range of frequencies over which a sound occurs. Broadband refers to a source that produces sound over a broad range of frequencies (e.g., seismic airguns, vessels) whereas narrowband sources produce sounds over a narrow frequency range (e.g., sonar) (ANSI/ASA S1.13-2005 R2010).

bar
Unit of pressure equal to 100 kPa, which is approximately equal to the atmospheric pressure on Earth at sea level. 1 bar is equal to $10^{6\ \mathrm{Pa}}$ or $10^{11\ \mu\mathrm{Pa}}$.

broadside direction
Perpendicular to the travel direction of a source. Compare to endfire direction.

cetacean
Any animal in the order Cetacea. These are aquatic, mostly marine mammals and include whales, dolphins, and porpoises.

compressional wave
A mechanical vibration wave in which the direction of particle motion is parallel to the direction of propagation. Also called primary wave or P-wave.

decibel (dB)
One-tenth of a bel. Unit of level when the base of the logarithm is the tenth root of ten, and the quantities concerned are proportional to power (ANSI S1.1-1994 R2004).

endfire direction
Parallel to the travel direction of a source. Also see broadside direction.

frequency
The rate of oscillation of a periodic function measured in cycles-per-unit-time. The reciprocal of the period. Unit: hertz (Hz). Symbol: *f*. 1 Hz is equal to 1 cycle per second.

functional hearing group
Grouping of marine mammal species with similar estimated hearing ranges. Southall et al. (2007) proposed the following functional hearing groups: low-, mid-, and high-frequency cetaceans, pinnipeds in water, and pinnipeds in air.

geoacoustic
Relating to the acoustic properties of the seafloor.

hearing threshold
The sound pressure level that is barely audible for a given individual in the absence of significant background noise during a specific percentage of experimental trials.

hertz (Hz)
A unit of frequency defined as one cycle per second.

high-frequency cetacean
The functional hearing group that represents odontocetes specialised for using high frequencies.

impulsive sound
Sound that is typically brief and intermittent with rapid (within a few seconds) rise time and decay back to ambient levels (NOAA 2013, ANSI S12.7-1986 R2006). For example, seismic airguns and impact pile driving.

low-frequency cetacean
The functional hearing group that represents mysticetes (baleen whales).

maximum-over-depth (MOD)
The maximum value over all modelled depths above the seafloor.

mid-frequency cetacean
The functional hearing group that represents some odontocetes (dolphins, toothed whales, beaked whales, and bottlenose whales).

M-weighting
The process of band-pass filtering loud sounds to reduce the importance of inaudible or less-audible frequencies for broad classes of marine mammals. “Generalized frequency weightings for various functional hearing groups of marine mammals, allowing for their functional bandwidths and appropriate in characterizing auditory effects of strong sounds” (Southall et al. 2007).

mysticete
Mysticeti, a suborder of cetaceans, use their baleen plates, rather than teeth, to filter food from water. They are not known to echolocate, but use sound for communication. Members of this group include rorquals (Balaenopteridae), right whales (Balaenidae), and the grey whale (*Eschrichtius robustus*).

non-impulsive sound
Sound that is broadband, narrowband or tonal, brief or prolonged, continuous or intermittent, and typically does not have a high peak pressure with rapid rise time (typically only small fluctuations in decibel level) that impulsive signals have (ANSI/ASA S3.20-1995 R2008). Marine vessels, aircraft, machinery, construction, and vibratory pile driving are examples.

octave
The interval between a sound and another sound with double or half the frequency. For example, one octave above 200 Hz is 400 Hz, and one octave below 200 Hz is 100 Hz.

odontocete
The presence of teeth, rather than baleen, characterises these whales. Members of the Odontoceti are a suborder of cetaceans, a group comprised of whales, dolphins, and porpoises. The toothed whales' skulls are mostly asymmetric, an adaptation for their echolocation. This group includes sperm whales, killer whales, belugas, narwhals, dolphins, and porpoises.

parabolic equation method
A computationally-efficient solution to the acoustic wave equation that is used to model transmission loss. The parabolic equation approximation omits effects of back-scattered sound, simplifying the computation of transmission loss. The effect of back-scattered sound is negligible for most ocean-acoustic propagation problems.

peak sound pressure level (PK)
The maximum instantaneous sound pressure level, in a stated frequency band, within a stated period. Also called zero-to-peak sound pressure level. Unit: dB re 1 µPa

permanent threshold shift (PTS)
A permanent loss of hearing sensitivity caused by excessive noise exposure. PTS is considered auditory injury.

point source
A source that radiates sound as if from a single point (ANSI S1.1-1994 R2004).

power spectrum density
The acoustic signal power per unit frequency as measured at a single frequency. Unit: μPa^2/Hz, or $\mu Pa^2 \cdot s$.

power spectrum density level
The decibel level ($10\log_{10}$) of the power spectrum density, usually presented in 1 Hz bins. Unit: dB re 1 μPa^2/Hz.

pressure, acoustic
The deviation from the ambient hydrostatic pressure caused by a sound wave. Also called overpressure. Unit: pascal (Pa). Symbol: *p*.

pulsed sound
Discrete sounds with durations less than a few seconds. Sounds with longer durations are called continuous sounds.

received level
The sound level measured at a receiver.

signature
Pressure signal generated by a source.

sound
A time-varying pressure disturbance generated by mechanical vibration waves travelling through a fluid medium such as air or water.

sound exposure
Time integral of squared, instantaneous frequency-weighted sound pressure over a stated time interval or event. Unit: pascal-squared second ($Pa^2 \cdot s$) (ANSI S1.1-1994 R2004).

sound exposure level (SEL)
A measure related to the sound energy in one or more pulses. Unit: dB re 1 µPa²·s.

sound field
Region containing sound waves (ANSI S1.1-1994 R2004).

sound pressure level (SPL)
The decibel ratio of the time-mean-square sound pressure, in a stated frequency band, to the square of the reference sound pressure (ANSI S1.1-1994 R2004).

For sound in water, the reference sound pressure is one micropascal (p_0 = 1 µPa) and the unit for SPL is dB re 1 µPa:

$$\mathrm{SPL} = 10\log_{10}\left(p^2 / p_0^2\right) = 20\log_{10}\left(p / p_0\right)$$

Unless otherwise stated, SPL refers to the root-mean-square sound pressure level Unit: dB re 1 µPa.

sound speed profile
The speed of sound in the water column as a function of depth below the water surface.

source level (SL)
The sound pressure level or sound exposure level measured 1 metre from a theoretical point source that radiates the same total sound power as the actual source. Unit: dB re 1 µPa @ 1 m or dB re 1 µPa²·s.

spectrum
An acoustic signal represented in terms of its power (or energy) distribution versus frequency.

temporary threshold shift (TTS)
Temporary loss of hearing sensitivity caused by excessive noise exposure.

transmission loss (TL)
Also called propagation loss, this refers to the decibel reduction in sound level between two stated points that results from sound spreading away from an acoustic source subject to the influence of the surrounding environment.

wavelength
Distance over which a wave completes one oscillation cycle. Unit: meter (m). Symbol: λ.

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Appendix A. Acoustic Metrics

A.1. Pressure Related Acoustic Metrics

Underwater sound pressure amplitude is measured in decibels (dB) relative to a fixed reference pressure of p_0 = 1 µPa. Because the perceived loudness of sound, especially impulsive noise such as from seismic airguns, pile driving, and sonar, is not generally proportional to the instantaneous acoustic pressure, several sound level metrics are commonly used to evaluate noise and its effects on marine life. We provide specific definitions of relevant metrics used in the accompanying report. Where possible we follow the ANSI and ISO standard definitions and symbols for sound metrics, but these standards are not always consistent.

The zero-to-peak sound pressure level (PK; dB re 1 µPa), is the maximum instantaneous sound pressure level in a stated frequency band attained by an acoustic pressure signal, $p(t)$:

$$L_{p,pk} = 20\log_{10}\left[\frac{\max\left(|p(t)|\right)}{p_0}\right] \quad \text{(A-1)}$$

$L_{p,pk}$ is often included as a criterion for assessing whether a sound is potentially injurious; however, because it does not account for the duration of a noise event, it is generally a poor indicator of perceived loudness.

The peak-to-peak sound pressure level (dB re 1 µPa) is the difference between the maximum and minimum instantaneous sound pressure levels in a stated frequency band attained by an impulsive sound, $p(t)$:

$$L_{p,pk-pk} = 10\log_{10}\left\{\frac{\left[\max\left(p(t)\right) - \min\left(p(t)\right)\right]^2}{p_0^2}\right\} \quad \text{(A-2)}$$

The sound pressure level (SPL; dB re 1 µPa) is the root-mean-square (rms) pressure level in a stated frequency band over a specified time window (T, s) containing the acoustic event of interest. It is important to note that SPL always refers to an rms pressure level and therefore not instantaneous pressure:

$$L_p = 10\log_{10}\left(\frac{1}{T}\int_T g(t)\,p^2(t)\,dt \Big/ p_0^2\right), \quad \text{(A-3)}$$

where $g(t)$ is an optional time weighting function. The SPL represents a nominal effective continuous sound over the duration of an acoustic event, such as the emission of one acoustic pulse, a marine mammal vocalization, the passage of a vessel, or over a fixed duration. Because the window length, T, is the divisor, events with similar sound exposure level (SEL) but more spread out in time have a lower SPL.

In studies of impulsive noise, the time window function $g(t)$ is often a decaying exponential that emphasises more recent pressure signals to mimic the leaky integration of the mammalian hearing system. For example, human-based fast time weighting applies an exponential function with time constant 125 ms. Other approaches for evaluating L_p of impulsive signals include setting g(t) to 1 and T to the “90% time window” (T_{90}; the period over which cumulative square pressure function passes between 5% and 95% of its full per-pulse value) or to a constant value (e.g., T_{fix} = 125 ms).

The sound exposure level (SEL, dB re 1 µPa²·s) is a measure related to the acoustic energy contained in one or more acoustic events (N). The SEL for a single event is computed from the time-integral of the squared pressure over the full event duration (T):

$$L_E = 10\log_{10}\left(\int_T p^2(t)dt \Big/ T_0 p_0^2 \right) \tag{A-4}$$

where T_0 is a reference time interval of 1 s. The SEL continues to increase with time when non-zero pressure signals are present. It therefore can be construed as a dose-type measurement, so the integration time used must be carefully considered in terms of relevance for impact to the exposed recipients.

SEL can be calculated over periods with multiple acoustic events or over a fixed duration. For a fixed duration, the square pressure is integrated over the duration of interest. For multiple events, the SEL can be computed by summing (in linear units) the SEL of the N individual events:

$$L_{E,N} = 10\log_{10}\left(\sum_{i=1}^{N} 10^{\frac{L_{E,i}}{10}} \right) . \tag{A-5}$$

Because the SPL(T_{90}) and SEL are both computed from the integral of square pressure, these metrics are related by the following expression, which depends only on the duration of the time window T:

$$L_p = L_E - 10\log_{10}(T) , \tag{A-6}$$

$$L_{p90} = L_E - 10\log_{10}(T_{90}) - 0.458 , \tag{A-7}$$

where the 0.458 dB factor accounts for the 10% of SEL missing from the SPL(T_{90}) integration time window.

If applied, the frequency weighting of an acoustic event should be specified, as in the case of weighted SEL (e.g., $L_{E,LFC,24h}$; Appendix A.3). The use of fast, slow, or impulse exponential-time-averaging or other time-related characteristics should else be specified.

A.2. Marine Mammal Impact Criteria

It has been long recognised that marine mammals can be adversely affected by underwater anthropogenic noise. For example, Payne and Webb (1971) suggested that communication distances of fin whales are reduced by shipping sounds. Subsequently, similar concerns arose regarding effects of other underwater noise sources and the possibility that impulsive sources—primarily airguns used in seismic surveys—could cause auditory injury. This led to a series of workshops held in the late 1990s, conducted to address acoustic mitigation requirements for seismic surveys and other underwater noise sources (NMFS 1998, ONR 1998, Nedwell and Turnpenny 1998, HESS 1999, Ellison and Stein 1999). In the years since these early workshops, a variety of thresholds have been proposed for both injury) and disturbance (Section 2.1.1). The following sections summarize the recent development of thresholds; however, this field remains an active research topic.

A.2.1. Injury

In recognition of shortcomings of the SPL-only based injury criteria, in 2005 NMFS sponsored the Noise Criteria Group to review literature on marine mammal hearing to propose new noise exposure criteria. Some members of this expert group published a landmark paper (Southall et al. 2007) that suggested assessment methods similar to those applied for humans. The resulting recommendations introduced dual acoustic injury criteria for impulsive sounds that included peak pressure level thresholds and SEL_{24h} thresholds, where the subscripted 24h refers to the accumulation period for calculating SEL. The peak pressure level criterion is not frequency weighted whereas the SEL_{24h} is frequency weighted according to one of four marine mammal species hearing groups: Low-, Mid- and

High-Frequency Cetaceans (LFC, MFC, and HFC respectively) and Pinnipeds in Water (PINN). These weighting functions are referred to as M-weighting filters (analogous to the A-weighting filter for human; Appendix A.3). The SEL_{24h} thresholds were obtained by extrapolating measurements of onset levels of Temporary Threshold Shift (TTS) in belugas by the amount of TTS required to produce Permanent Threshold Shift (PTS) in chinchillas. The Southall et al. (2007) recommendations do not specify an exchange rate, which suggests that the thresholds are the same regardless of the duration of exposure (i.e., it implies a 3 dB exchange rate).

Wood et al. (2012) refined Southall et al.'s (2007) thresholds, suggesting lower injury values for LFC and HFC while retaining the filter shapes. Their revised thresholds were based on TTS-onset levels in harbour porpoises from Lucke et al. (2009), which led to a revised impulsive sound PTS threshold for HFC of 179 dB re 1 $\mu Pa^2 \cdot s$. Because there were no data available for baleen whales, Wood et al. (2012) based their recommendations for LFC on results obtained from MFC studies. In particular they referenced Finneran and Schlundt (2010) research, which found mid-frequency cetaceans are more sensitive to non-impulsive sound exposure than Southall et al. (2007) assumed. Wood et al. (2012) thus recommended a more conservative TTS-onset level for LFC of 192 dB re 1 $\mu Pa^2 \cdot s$.

As of 2017, an optimal approach is not apparent. There is consensus in the research community that an SEL-based method is preferable either separately or in addition to an SPL-based approach to assess the potential for injuries. In August 2016, after substantial public and expert input into three draft versions and based largely on the above-mentioned literature (NOAA 2013, 2015, 2016), NMFS finalised technical guidance for assessing the effect of anthropogenic sound on marine mammal hearing (NMFS 2016). The guidance describes injury criteria with new thresholds and frequency weighting functions for the five hearing groups described by Finneran and Jenkins (2012). The recommended thresholds are provided in the table below. The criteria defined in NMFS (2016) are applied in this report.

Table A-1. Marine mammal injury (PTS onset) thresholds based on NMFS (2016).

Hearing group	Impulsive source		Non-impulsive source
	PK	Weighted SEL (24 h)	Weighted SEL (24 h)
Low-frequency cetaceans	219	183	199
Mid-frequency cetaceans	230	185	198
High-frequency cetaceans	202	155	173
Phocid pinnipeds in water	218	185	201
Otariid pinnipeds in water	232	203	219

A.3. Marine Mammal Frequency Weighting

The potential for noise to affect animals depends on how well the animals can hear it. Noises are less likely to disturb or injure an animal if they are at frequencies that the animal cannot hear well. An exception occurs when the sound pressure is so high that it can physically injure an animal by non-auditory means (i.e., barotrauma). For sound levels below such extremes, the importance of sound components at particular frequencies can be scaled by frequency weighting relevant to an animal's sensitivity to those frequencies (Nedwell and Turnpenny 1998, Nedwell et al. 2007).

A.3.1. Marine mammal frequency weighting functions

In 2015, a U.S. Navy technical report by Finneran (2015) recommended new auditory weighting functions. The overall shape of the auditory weighting functions is similar to human A-weighting functions, which follows the sensitivity of the human ear at low sound levels. The new frequency-weighting function is expressed as:

$$G(f) = K + 10\log_{10}\left[\left(\frac{(f/f_{lo})^{2a}}{\left[1+(f/f_{lo})^2\right]^a\left[1+(f/f_{hi})^2\right]^b}\right)\right] \quad \text{(A-8)}$$

Finneran (2015) proposed five functional hearing groups for marine mammals in water: low-, mid-, and high-frequency cetaceans, phocid pinnipeds, and otariid pinnipeds. The parameters for these frequency-weighting functions were further modified the following year (Finneran 2016) and were adopted in NOAA's technical guidance that assesses noise impacts on marine mammals (NMFS 2016). Table A-2 lists the frequency-weighting parameters for each hearing group; Figure A-1 shows the resulting frequency-weighting curves.

Table A-2. Parameters for the auditory weighting functions recommended by NMFS (2016).

Hearing group	*a*	*b*	f_{lo} (Hz)	f_{hi} (Hz)	*K* (dB)
Low-frequency cetaceans	1.0	2	200	19,000	0.13
Mid-frequency cetaceans	1.6	2	8,800	110,000	1.20
High-frequency cetaceans	1.8	2	12,000	140,000	1.36
Phocid pinnipeds in water	1.0	2	1,900	30,000	0.75
Otariid pinnipeds in water	2.0	2	940	25,000	0.64

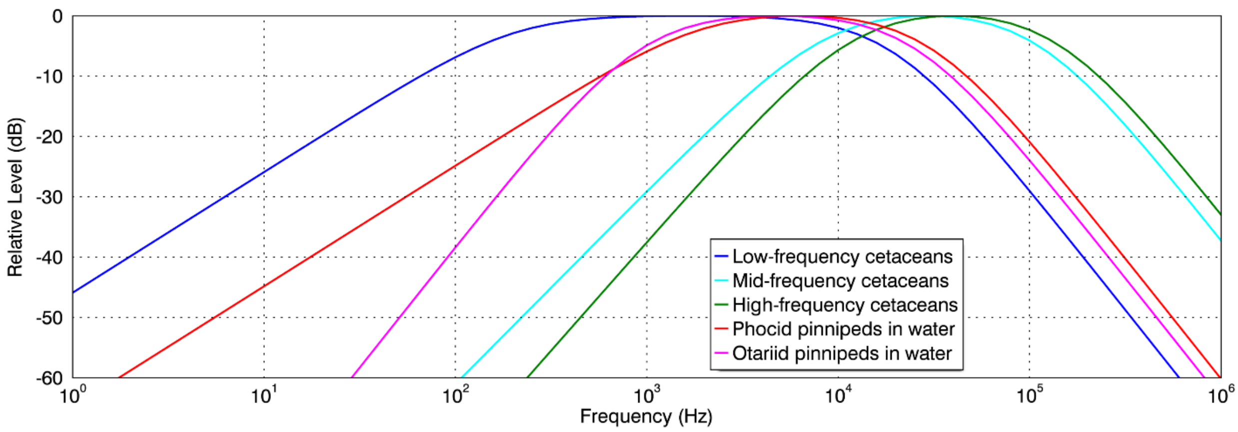

Figure A-1. Auditory weighting functions for functional marine mammal hearing groups as recommended by NMFS (2016).

Appendix B. Acoustic Source Model

B.1. Airgun Array Source Model (AASM)

The source levels and directivity of the airgun array were predicted with JASCO's Airgun Array Source Model (AASM). AASM includes low- and high-frequency modules for predicting different components of the airgun array spectrum. The low-frequency module is based on the physics of oscillation and radiation of airgun bubbles, as originally described by Ziolkowski (1970), that solves the set of parallel differential equations that govern bubble oscillations. Physical effects accounted for in the simulation include pressure interactions between airguns, port throttling, bubble damping, and generator-injector (GI) gun behaviour discussed by Dragoset (1984), Laws et al. (1990), and Landro (1992). A global optimisation algorithm tunes free parameters in the model to a large library of airgun source signatures.

While airgun signatures are highly repeatable at the low frequencies, which are used for seismic imaging, their sound emissions have a large random component at higher frequencies that cannot be predicted using a deterministic model. Therefore, AASM uses a stochastic simulation to predict the high-frequency (800−25,000 Hz) sound emissions of individual airguns, using a data-driven multiple-regression model. The multiple-regression model is based on a statistical analysis of a large collection of high quality seismic source signature data recently obtained from the Joint Industry Program (JIP) on Sound and Marine Life (Mattsson and Jenkerson 2008). The stochastic model uses a Monte-Carlo method to simulate the random component of the high-frequency spectrum of each airgun in an array. The mean high-frequency spectra from the stochastic model augment the low-frequency signatures from the physical model, allowing AASM to predict airgun source levels at frequencies up to 25,000 Hz.

AASM produces a set of "notional" signatures for each array element based on:

- Array layout
- Volume, tow depth, and firing pressure of each airgun
- Interactions between different airguns in the array

These notional signatures are the pressure waveforms of the individual airguns at a standard reference distance of 1 m; they account for the interactions with the other airguns in the array. The signatures are summed with the appropriate phase delays to obtain the far-field source signature of the entire array in all directions. This far-field array signature is filtered into 1/3-octave-bands to compute the source levels of the array as a function of frequency band and azimuthal angle in the horizontal plane (at the source depth), after which it is considered a directional point source in the far field.

A seismic array consists of many sources and the point source assumption is invalid in the near field where the array elements add incoherently. The maximum extent of the near field of an array (R_{nf}) is:

$$R_{\mathrm{nf}} < \frac{l^2}{4\lambda}\,, \tag{B-1}$$

where λ is the sound wavelength and l is the longest dimension of the array (Lurton 2002, §5.2.4). For example, an airgun array length of l = 21 m yields a near-field range of 147 m at 2 kHz and 7 m at 100 Hz. Beyond this R_{nf} range, the array is assumed to radiate like a directional point source and is treated as such for propagation modelling.

The interactions between individual elements of the array create directionality in the overall acoustic emission. Generally, this directionality is prominent mainly at frequencies in the mid-range between tens of hertz to several hundred hertz. At lower frequencies, with acoustic wavelengths much larger than the inter-airgun separation distances, the directionality is small. At higher frequencies, the pattern of lobes is too finely spaced to be resolved and the effective directivity is less.

B.2. Array Source Levels and Directivity

Figure B-1 shows the broadside (perpendicular to the tow direction), endfire (parallel to the tow direction), and vertical overpressure signature and corresponding power spectrum levels for the 2380 in^3 array. The signatures consist of a strong primary peak, related to the initial release of high-pressure air, followed by a series of pulses associated with bubble oscillations. Most energy is produced at frequencies below 500 Hz. Frequency-dependent peaks and nulls in the spectrum result from interference among airguns in the array, and correspond with the volumes and relative locations of the airguns to each other.

Horizontal 1/3-octave-band source levels are shown as a function of band centre frequency and azimuth (Figure B-2); directivity in the sound field is most noticeable at mid-frequencies as described in the model detail in Appendix B.1.

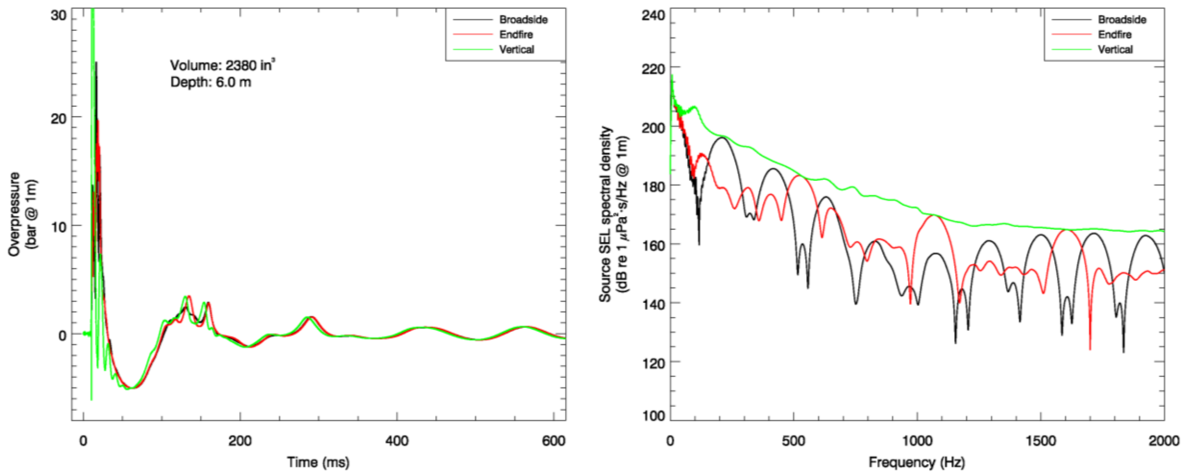

Figure B-1. Predicted source level details for the 2380 in^3 array towed at a depth of 6 m. (Left) the overpressure signature and (right) the power spectrum for broadside (perpendicular to tow direction) and endfire (directly aft of the array) directions, and for vertically down.

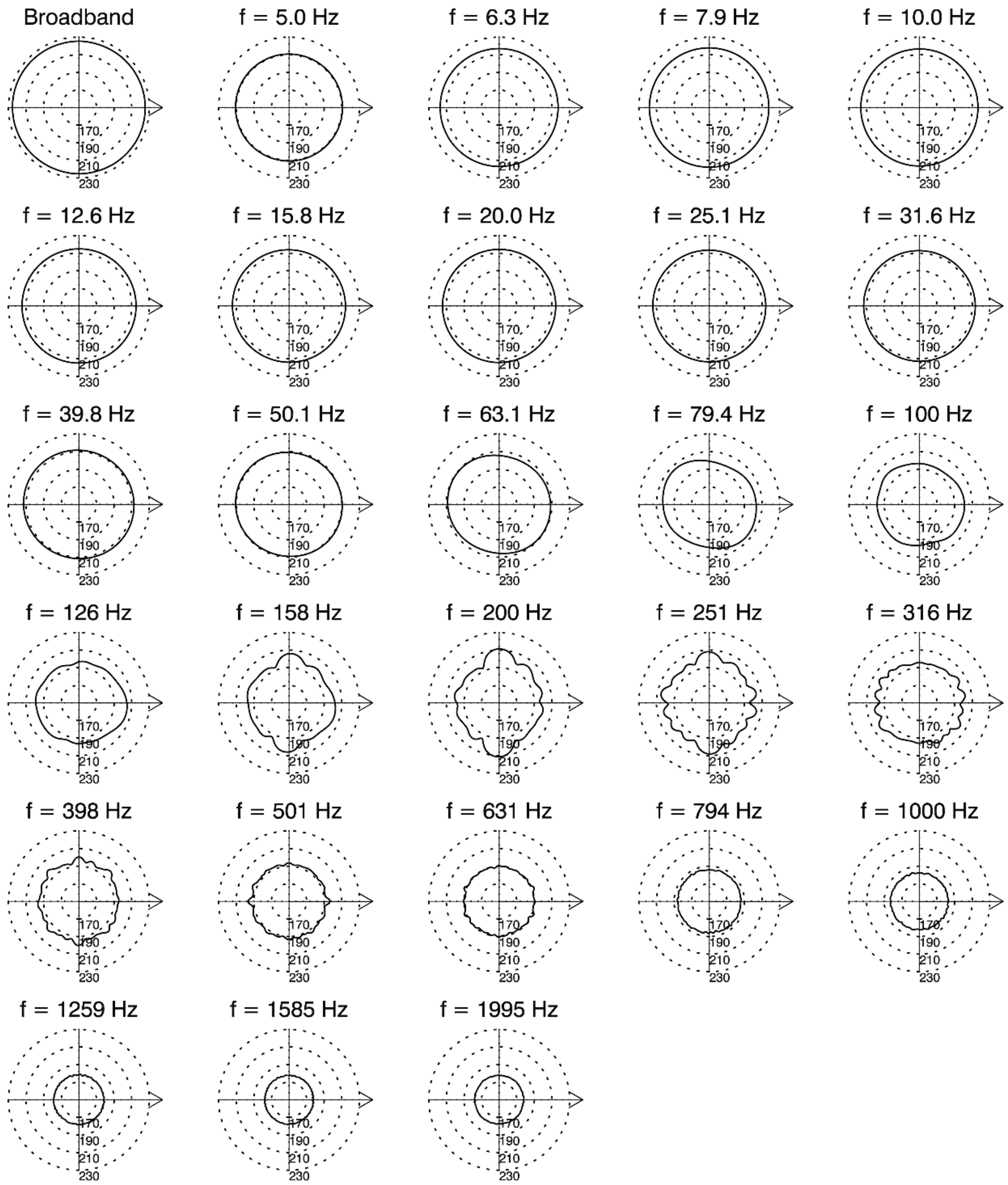

Figure B-2. Directionality of the predicted horizontal source levels for the 2380 in^3 array, 5 Hz to 2 kHz. Source levels (in dB re 1 µPa^2·s) are shown as a function of azimuth for the centre frequencies of the 1/3-octave-bands modelled; frequencies are shown above the plots. Tow direction is to the right. Tow depth is 6 m (see Figure B-1).

Appendix C. Sound Propagation Models

C.1. MONM-BELLHOP

Long-range sound fields were computed using JASCO's Marine Operations Noise Model (MONM). Compared to VSTACK, MONM less accurately predicts steep-angle propagation for environments with higher shear speed, but is well suited for effective longer range estimation. This model computes sound propagation at frequencies of 5 Hz to 1.25 kHz via a wide-angle parabolic equation solution to the acoustic wave equation (Collins 1993) based on a version of the U.S. Naval Research Laboratory's Range-dependent Acoustic Model (RAM), which has been modified to account for a solid seabed (Zhang and Tindle 1995). MONM computes sound propagation at frequencies >1.25 kHz via the BELLHOP Gaussian beam acoustic ray-trace model (Porter and Liu 1994).

The parabolic equation method has been extensively benchmarked and is widely employed in the underwater acoustics community (Collins et al. 1996). MONM accounts for the additional reflection loss at the seabed, which results from partial conversion of incident compressional waves to shear waves at the seabed and sub-bottom interfaces, and it includes wave attenuations in all layers. MONM incorporates the following site-specific environmental properties: a bathymetric grid of the modelled area, underwater sound speed as a function of depth, and a geoacoustic profile based on the overall stratified composition of the seafloor.

This version of MONM accounts for sound attenuation due to energy absorption through ion relaxation and viscosity of water in addition to acoustic attenuation due to reflection at the medium boundaries and internal layers (Fisher and Simmons 1977). The former type of sound attenuation is significant for frequencies higher than 5 kHz and cannot be neglected without noticeably affecting the model results.

MONM computes acoustic fields in three dimensions by modelling transmission loss within two-dimensional (2-D) vertical planes aligned along radials covering a 360° swath from the source, an approach commonly referred to as N×2-D. These vertical radial planes are separated by an angular step size of $\Delta\theta$, yielding N = 360°/$\Delta\theta$ number of planes (Figure C-1).

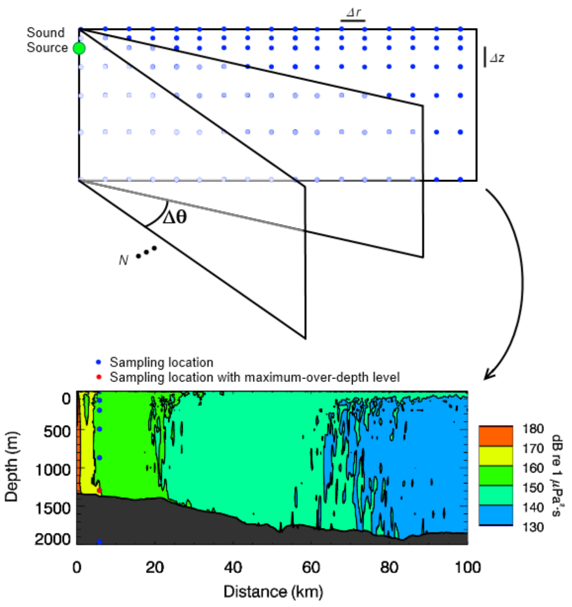

Figure C-1. The N×2-D and maximum-over-depth modelling approach used by MONM.

MONM treats frequency dependence by computing acoustic transmission loss at the centre frequencies of 1/3-octave-bands. Sufficiently many 1/3-octave-bands, starting at 10 Hz, are modelled to include most of the acoustic energy emitted by the source. At each centre frequency, the transmission loss is modelled within each of the N vertical planes as a function of depth and range from the source. The 1/3-octave-band received per-pulse SEL are computed by subtracting the band transmission loss values from the directional source level in that frequency band. Composite broadband received per-pulse SEL are then computed by summing the received 1/3-octave-band levels.

The received per-pulse SEL sound field within each vertical radial plane is sampled at various ranges from the source, generally with a fixed radial step size. At each sampling range along the surface, the sound field is sampled at various depths, with the step size between samples increasing with depth below the surface. The step sizes are chosen to provide increased coverage near the depth of the source and at depths of interest in terms of the sound speed profile. For areas with deep water, sampling is not performed at depths beyond those reachable by marine mammals. The received per-pulse SEL at a surface sampling location is taken as the maximum value that occurs over all samples within the water column, i.e., the maximum-over-depth received per-pulse SEL. These maximum-over-depth per-pulse SELs are presented as colour contours around the source.

An inherent variability in measured sound levels is caused by temporal variability in the environment and the variability in the signature of repeated acoustic impulses (sample sound source verification results is presented in Figure C-2). While MONM's predictions correspond to the averaged received levels, cautionary estimates of the threshold radii are obtained by shifting the best fit line (solid line, Figure C-2) upward so that the trend line encompasses 90% of all the data (dashed line, Figure C-2).

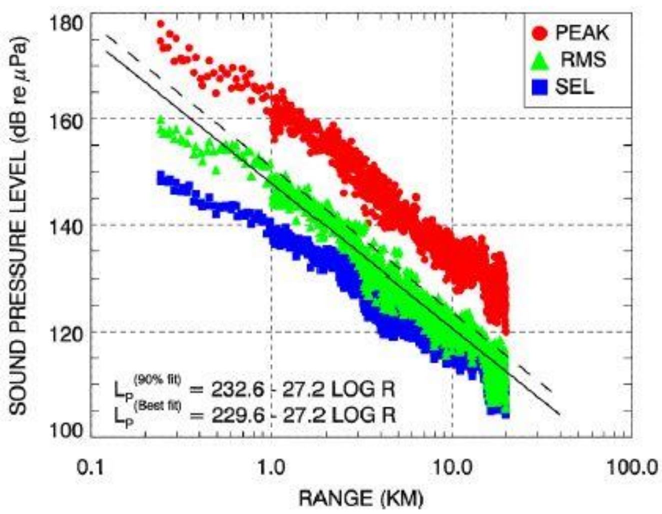

Figure C-2. Peak and SPL and per-pulse SEL versus range from a 20 in^3 airgun array. Solid line is the least squares best fit to SPL. Dashed line is the best fit line increased by 3.0 dB to exceed 90% of all SPL values (90th percentile fit) (Ireland et al. 2009, Figure 10).

C.2. Full Waveform Range-dependent Acoustic Model: FWRAM

For impulsive sounds from the seismic array, time-domain representations of the pressure waves generated in the water are required to calculate SPL and peak pressure level. Furthermore, the airgun array must be represented as a distributed source to accurately characterise vertical directivity effects in the near-field zone. For this study, synthetic pressure waveforms were computed using FWRAM, which is a time-domain acoustic model based on the same wide-angle parabolic equation (PE) algorithm as MONM. FWRAM computes synthetic pressure waveforms versus range and depth for range-varying marine acoustic environments, and it takes the same environmental inputs as MONM (bathymetry, water sound speed profile, and seafloor geoacoustic profile). Unlike MONM, FWRAM computes pressure waveforms via Fourier synthesis of the modelled acoustic transfer function in closely spaced frequency bands. FWRAM employs the array starter method to accurately model sound propagation from a spatially distributed source (MacGillivray and Chapman 2012).

Besides providing direct calculations of the peak pressure level and SPL, the synthetic waveforms from FWRAM can also be used to convert the SEL values from MONM to SPL.

C.3. Wavenumber Integration Model

Sound pressure levels near the airgun array were modelled using JASCO's VSTACK wavenumber integration model. VSTACK computes synthetic pressure waveforms versus depth and range for arbitrarily layered, range-independent acoustic environments using the wavenumber integration approach to solving the exact (range-independent) acoustic wave equation. This model is valid over the full angular range of the wave equation and can fully account for the elasto-acoustic properties of the sub-bottom. Wavenumber integration methods are extensively used in the field of underwater acoustics and seismology where they are often referred to as reflectivity methods or discrete wavenumber methods. VSTACK computes sound propagation in arbitrarily stratified water and seabed layers by decomposing the outgoing field into a continuum of outward-propagating plane cylindrical waves. Seabed reflectivity in the model is dependent on the seabed layer properties: compressional and shear wave speeds, attenuation coefficients, and layer densities. The output of the model can be post-processed to yield estimates of the SEL, SPL, and PK.

VSTACK accurately predicts steep-angle propagation in the proximity of the source, but is computationally slow at predicting sound pressures at large distances due to the need for smaller wavenumber steps with increasing distance. Additionally, VSTACK assumes range-invariant bathymetry with a horizontally stratified medium (i.e., a range-independent environment) which is azimuthally symmetric about the source. VSTACK is thus best suited to modelling the sound field near the source.

Appendix D. Methods and Parameters

This section describes the specifications of the airgun array source that was used at all sites and the environmental parameters used in the propagation models.

D.1. Estimating Range to Thresholds Levels

Sound level contours were calculated based on the underwater sound fields predicted by the propagation models, sampled by taking the maximum value over all modelled depths above the seafloor for each location in the modelled region. The predicted distances to specific levels were computed from these contours. Two distances relative to the source are reported for each sound level: 1) R_{max}, the maximum range to the given sound level over all azimuths, and 2) $R_{95\%}$, the range to the given sound level after the 5% farthest points were excluded (see examples in Figure D-1).

The $R_{95\%}$ is used because sound field footprints are often irregular in shape. In some cases, a sound level contour might have small protrusions or anomalous isolated fringes. This is demonstrated in the image in Figure D-1(a). In cases such as this, where relatively few points are excluded in any given direction, R_{max} can misrepresent the area of the region exposed to such effects, and $R_{95\%}$ is considered more representative. In strongly asymmetric cases such as shown in Figure D-1(b), on the other hand, $R_{95\%}$ neglects to account for significant protrusions in the footprint. In such cases R_{max} might better represent the region of effect in specific directions. Cases such as this are usually associated with bathymetric features affecting propagation. The difference between R_{max} and $R_{95\%}$ depends on the source directivity and the non-uniformity of the acoustic environment.

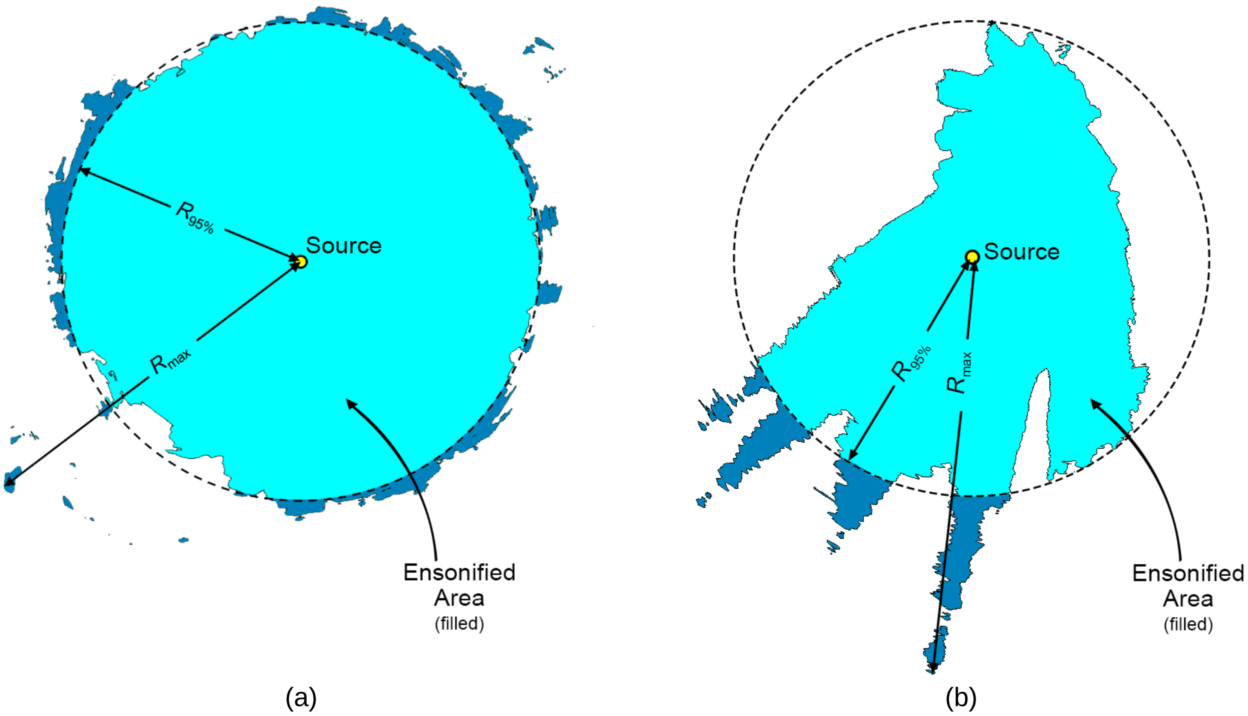

Figure D-1. Sample areas ensonified to an arbitrary sound level with R_{max} and $R_{95\%}$ ranges shown for two different scenarios. (a) Largely symmetric sound level contour with small protrusions. (b) Strongly asymmetric sound level contour with long protrusions. Light blue indicates the ensonified areas bounded by $R_{95\%}$; darker blue indicates the areas outside this boundary which determine R_{max}.

D.2. Estimating SPL from Modelled SEL Results

The per-pulse SEL of sound pulses is an energy-like metric related to the dose of sound received over the pulse's entire duration. The pulse SPL on the other hand is related to its intensity over a specified time interval. Seismic pulses typically lengthen in duration as they propagate away from their source, due to seafloor and surface reflections, and other waveguide dispersion effects. The changes in pulse length, and therefore the time window considered, affect the numeric relationship between SPL and SEL. This study has applied a fixed window duration to calculate SPL (T_{fix} = 125 ms) (Appendix A), as implemented in Martin et al. (2017). Full-waveform modelling was used to estimate SPL, but this type of modelling is computationally intensive, and can be prohibitively time consuming when run at high spatial resolution over large areas.

For the current study, FWRAM (Appendix C.2) was used to model synthetic seismic pulses over the frequency range 5–2000 Hz. This was performed along both broadside and endfire (two directions), endfire, and frontfire radials. FWRAM uses Fourier synthesis to recreate the signal in the time domain so that both the SEL and SPL from the source can be calculated. The differences between the SEL and SPL (Figure D-2) were extracted for all ranges and depths that corresponded to those generated from the high spatial-resolution results from MONM. A 125 ms fixed time window positioned to maximize the SPL over the pulse duration was applied. The resulting SEL -to-SPL offsets were averaged in 1 km range bins along each modelled radial and depth, and the 90th percentile was selected at each range to generate a generalised range-dependent conversion function. The range-dependent conversion function was applied to predicted per-pulse SEL results from MONM to model SPL values.

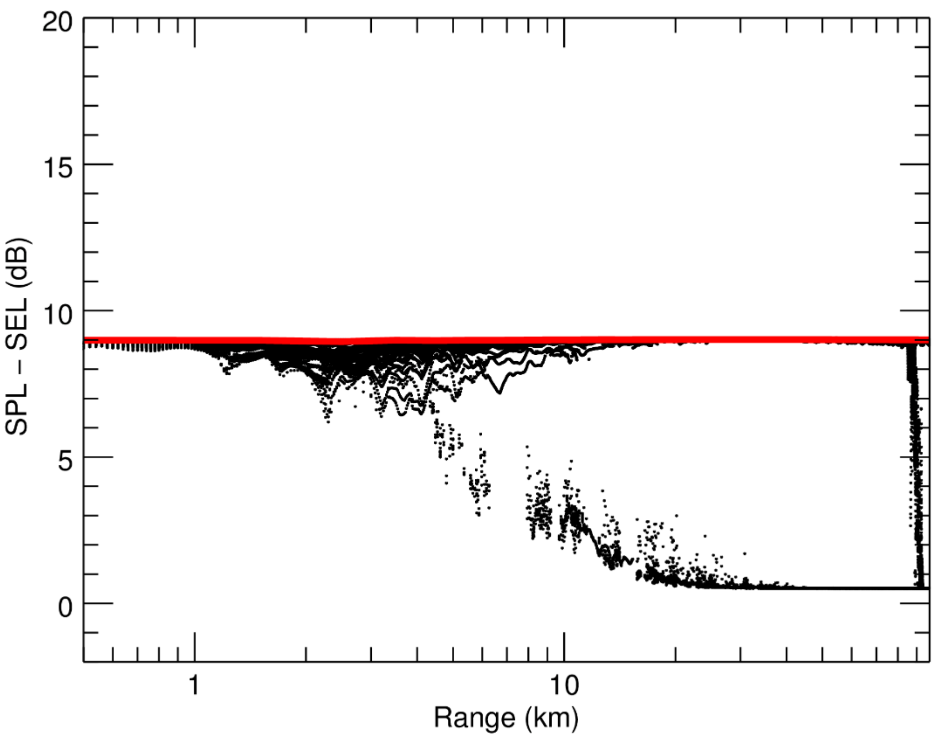

Figure D-2. Range-and-depth-dependent conversion offset for converting SEL to SPL for seismic pulses along the transects in the broadside and endfire directions toward deeper water. Slices are shown for the 2380 in^3 array described in Appendix B.2. Black lines are the modelled differences between SEL and SPL across different radials and receiver depths; the solid red line is the 90th percentile of the modelled differences at each range.

D.3. Environmental Parameters

D.3.1. Bathymetry

Water depths throughout the modelled area were extracted from the Australian Bathymetry and Topography Grid, a 9 arc-second grid (~280 × 280 m at the studied latitude) rendered for Australian waters (Whiteway 2009) (Figure 1). Bathymetry data were extracted and re-gridded onto a Universal Transverse Mercator (UTM) coordinate projection (Zone 52 S) with a regular grid spacing of 100 × 100 m.

D.3.2. Sound speed profiles

The sound speed profile (SSP) for the modelled site was derived from temperature and salinity profiles from the U.S. Naval Oceanographic Office's *Generalized Digital Environmental Model V 3.0* (GDEM; Teague et al. 1990, Carnes 2009) for July. GDEM provides an ocean climatology of temperature and salinity for the world's oceans on a latitude-longitude grid with 0.25° resolution, with a temporal resolution of one month, based on global historical observations from the U.S. Navy's Master Oceanographic Observational Data Set (MOODS). The temperature-salinity profiles were converted to sound speed profiles according to the equations of Coppens (1981).

For this work, GDEM data at a location ~114 km north from the survey area provided an SSP up to 100 m depth. Since the modelling area included depths up to 117 m, the SSP was extended using GDEM data from a location ~456 km north from the survey area. The compound SSP is shown in

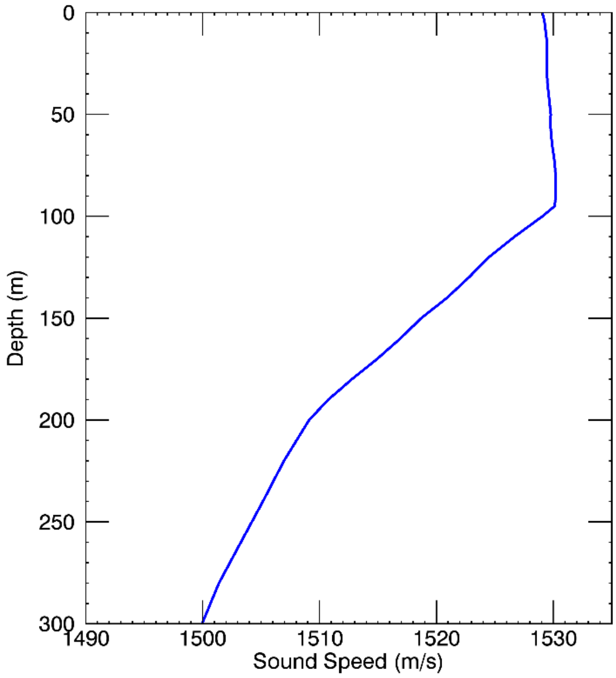

Figure D-3.

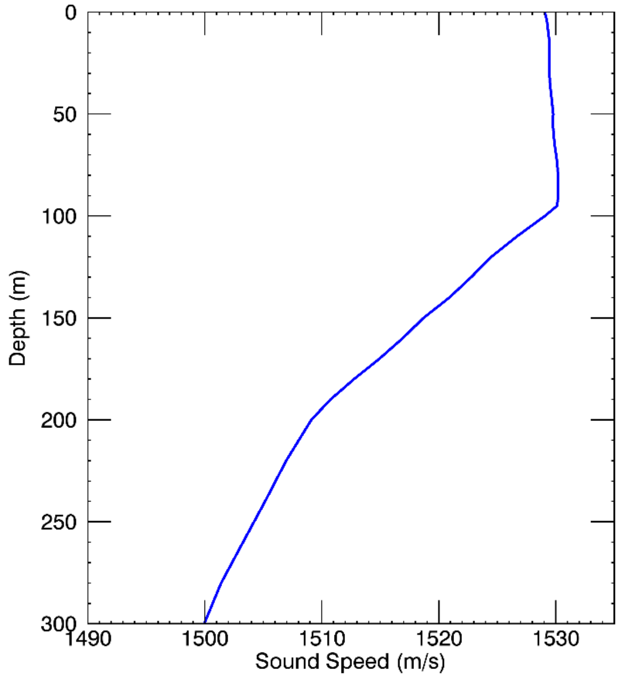

Figure D-3. July sound speed profile used for the modelling. Results are calculated from temperature and salinity profiles from GDEM V 3.0 (GDEM; Teague et al. 1990, Carnes 2009) at a locations ~114 km and ~456 km north of the survey area.

D.3.3. Geoacoustics

The modelling site is located in the North West Marine Region of Australia (Baker et al. 2008), more specifically the middle shelf region, which is dominated by calcareous sand. Grain size distributions are spatially variable in the area.

The modelling site is located in the North West Marine Region of Australia (Baker et al. 2008), more specifically the middle shelf region, which is dominated by calcareous sand; the sand content of the sites is 60–80% (Baker et al. 2008). Grain size distributions are spatially variable in the area around both sites, however, with higher sand contents in the southern and eastern portions of Bonaparte Gulf and higher mud content in the Bonaparte Depression to the west of the survey area (Baker et al. 2008). The Bonaparte also contains sedimentary rock at increased depths.

To provide precautionary estimates of underwater sound levels in the spatially heterogeneous environment, a simplified profile was constructed assuming increasingly consolidated sediment (Table D-1). Geoacoustic parameters were estimated from the sediment model of Buckingham (2005).

Table D-1. Geoacoustic profile used in the acoustic propagation models for Beehive survey area.

Depth below seafloor (m)	Material	Density (g/cm^3)	P-wave speed (m/s)	P-wave attenuation (dB/λ)	S-wave speed (m/s)	S-wave attenuation (dB/λ)
0–200	Unconsolidated sediment	1.562-1.880	1530–1947	1.0–1.0	306	0.45
200-400	Sedimentary rock	2.155-2.198	2475–2663	0.1–0.1		
400	Rock halfspace	2198	2663	0.1		

D.4. Acoustic Source

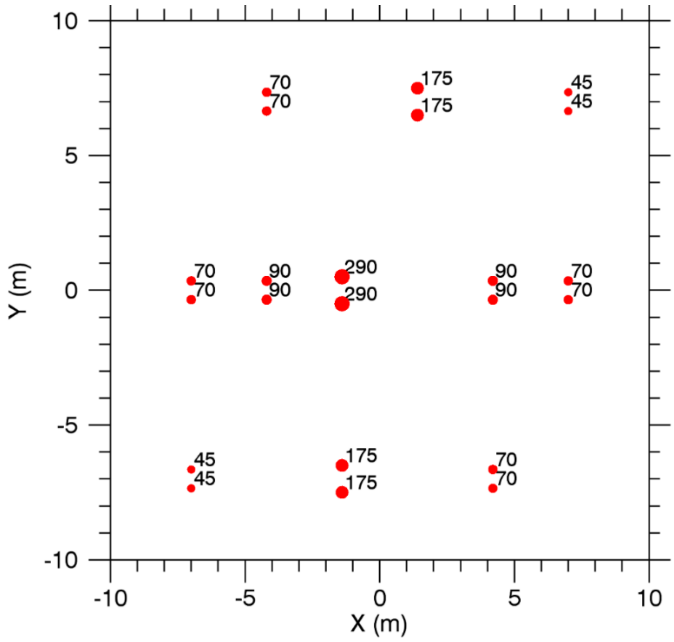

Figure D-4. Layout of the 2380 in³ modelled airgun array. Tow depth is 6 m and dimensions are 11.2 × 15 m. The labels indicate the firing volume (in cubic inches) for each airgun. The tow direction is assumed to be in the positive *x* direction. Also see Table D-2.

Table D-2. Layout of the modelled 2380 in³ airgun array. Tow depth is 6 m. Firing pressure for all guns is 2000 psi. The tow direction is assumed to be in the positive *x* direction. Also see Figure D-4.

Gun	*x* (m)	*y* (m)	Volume (in³)	Gun	*x* (m)	*y* (m)	Volume (in³)	Gun	*x* (m)	*y* (m)	Volume (in³)
1	−4.2	7.35	70	7	−7	0.35	70	17	−7	−6.65	45
2	−4.2	6.65	70	8	−7	−0.35	70	18	−7	−7.35	45
3	1.4	7.5	175	9	−4.2	0.35	90	19	−1.4	−6.5	175
4	1.4	6.5	175	10	−4.2	−0.35	90	20	−1.4	−7.5	175
5	7	7.35	45	11	−1.4	0.5	290	21	4.2	−6.65	70
6	7	6.65	45	12	−1.4	−0.5	290	22	4.2	−7.35	70
-	-	-	-	13	4.2	0.35	90	-	-	-	-
-	-	-	-	14	4.2	−0.35	90	-	-	-	-
-	-	-	-	15	7	0.35	70	-	-	-	-
-	-	-	-	16	7	−0.35	70	-	-	-	-

D.5. Model Validation

MONM's predictions have been validated against experimental data from several underwater acoustic measurement programs conducted by JASCO (Hannay and Racca 2005, Aerts et al. 2008, Funk et al. 2008, Ireland et al. 2009, O'Neill et al. 2010, Warner et al. 2010, Racca et al. 2012a, Racca et al. 2012b, Martin et al. 2015, Racca et al. 2015, Martin et al. 2017). In addition, JASCO has conducted many seismic surveys, which have been internally validated (including McCrodan et al. 2011, Austin and Warner 2012, McPherson and Warner 2012, Austin and Bailey 2013, Austin et al. 2013, Zykov and MacDonnell 2013, Austin 2014, Austin et al. 2015, Austin and Li 2016, Martin and Popper 2016).