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Taranaki West 3D Seismic Survey MMIA

Marine Mammal Impact Assessment

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Taranaki West 3D Seismic Survey MMIA

Marine Mammal Impact Assessment

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Executive Summary

PGS Australia Pty Ltd (PGS) is proposing to acquire a three dimensional (3D) marine seismic survey in the Taranaki Basin. The Operational Area lies to the northwest of Cape Farewell in water depths of over 200 m. The seismic survey is predicted to be a 45 day operational programme that is scheduled to be acquired between approximately December 2016 and January 2017.

The *PGS Apollo* will undertake the survey using an acoustic source volume of 3,660 in^3. The seismic vessel will tow 10 streamers that extend 8.1 km behind the vessel and will be accompanied by a support vessel (*Thor Alpha*).

This Marine Mammal Impact Assessment (MMIA) is a pre-requisite to seismic operations in New Zealand's Exclusive Economic Zone (EEZ) which, under the EEZ (Environmental Effects) Act 2012 and the associated Permitted Activities Regulations stipulate mandatory compliance with the Department of Conservation's 2013 *Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations* (the 'Code of Conduct'). As well as compliance with the Code of Conduct, PGS will operate in accordance with relevant NZ legislation, international conventions and their internal environmental standards.

This MMIA sets out to describe the seismic operations that PGS proposes to undertake, provide a description of the baseline environment, identify the actual and potential effects of the proposed operations on the environment and to specify the measures that PGS intends to take to avoid, remedy, or mitigate any potential adverse effects. An assessment of the significance of any potential effects is also provided through an Environmental Risk Assessment (ERA) process. The MMIA not only includes a discussion on the potential effects of seismic operations on the biological environment, but also on the social, cultural and commercial environments of the Operational Area.

A significant part of the development of this MMIA was engagement with stakeholders through the provision of information sheets, letters and face-to-face meetings. Information collected during this engagement process was used to populate the MMIA and to refine survey design where possible.

In assessing the baseline environment it was noted that the marine mammal species most likely to be present in the Operational Area are pygmy blue whales, humpback whales, sperm whales, common dolphin, long-finned pilot whales and killer whales. Of these species only the killer whale is considered to be threatened under the New Zealand Threat Classification System, and the Operational Area is not considered to be of particular ecological importance for killer whales which travel readily on a regional basis.

The recent observation of feeding and breeding behaviour by pygmy blue whales in the South Taranaki Bight Region has been carefully considered in the development of this impact assessment.

Acoustic disturbance from seismic surveys is considered to be the most significant potential effect from the Taranaki West 3D Seismic Survey. Hence compliance with the Code of Conduct is the primary mitigation measure that will be employed during the Taranaki West 3D Seismic Survey. Of primary importance is 1) the presence of marine mammal observers (MMOs) who visually and acoustically detect marine mammals, 2) delayed starts if marine mammals are detected in close proximity to the acoustic source before operations commence, 3) the use of 'soft starts' to ensure that any undetected marine mammals have an opportunity to leave the vicinity before full operational power is reached, and 4) shut downs of the acoustic source if marine mammals enter the defined mitigation zones.

Executive Summary

Although sound transmission loss modelling (STLM) is not required when a seismic survey is conducted outside an Area of Ecological Importance (defined by the Department of Conservation), PGS has elected to undertake this modelling as an additional component for the development of this MMIA. This modelling is used to predict how far sound from the seismic survey is predicted to travel underwater, and to assess the validity of the mitigation zones specified in the Code of Conduct (which are designed to protect marine mammals from behavioural and physiological effects associated with underwater noise). The results of the STLM indicate that the standard mitigation zones in the Code of Conduct will sufficiently protect marine mammals from both behavioural and physiological effects during the Taranaki West 3D Seismic Survey.

In addition to compliance with the Code of Conduct PGS has committed to the following actions to avoid, remedy or mitigate potential adverse effects of the Taranaki West 3D Seismic Survey on the biological, social, cultural and commercial environment of the Operational Area:

- Seismic operations will continue around the clock (as possible) to reduce the overall duration of the survey;
- PGS has undertaken source modelling to ensure that their survey is using the lowest possible acoustic source volume while still ensuring the geological objectives of the survey can be fulfilled;
- PGS has undertaken STLM to confirm that the mitigation zones in the Code of Conduct are appropriate for this survey;
- Marine mammal sightings will be collected whilst in transit between the Operational Area and Port Taranaki;
- MMOs will be vigilant for entanglement incidents and will report any dead marine mammals observed at sea;
- MMOs will notify DOC immediately of any Hector's/Maui's dolphin sightings;
- Weekly MMO reports to be provided to the regulators;
- PGS will consider covering the cost of necropsies on a case-by-case basis in the event of marine mammal strandings;
- PGS will provide an opportunity for the participation of a trainee iwi MMO(s);
- Post-survey meetings with iwi groups will be convened to discuss any issues that may have arisen during the survey;
- PGS will provide a seafloor bathymetry image to fishing groups after data processing is complete; and
- Web-based near real-time vessel positioning updates will be provided to commercial fishers.

In summary, the potential effects of the proposed seismic operations are considered to be appropriately managed by the mitigation measures noted above. On this basis it is considered that behavioural or physiological effects on marine mammals are unlikely, and that potential social, cultural and commercial impacts are also unlikely given the distance from shore and the limited number of regular users of this offshore area.

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ABBREVIATIONS AND DEFINITIONS

AIS	Automatic Identification System
CMA	Coastal Marine Area
Code of Conduct	2013 Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations
COLREGS	International Regulations for the Prevention of Collisions at Sea 1972
CRMS	Craft Risk Management Standard for Vessel Biofouling
DOC	Department of Conservation
EEZ	Exclusive Economic Zone
EEZ Act	Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012
EMP	Environmental Management Plan
EPA	Environmental Protection Authority
ERA	Environmental Risk Assessment
FMA	Fisheries Management Area
IAPPC	International Air Pollution Prevention Certificate
IHS	Import Health Standard for Ships Ballast Water
IOPPC	International Oil Pollution Prevention Certificate
ISPPC	International Sewage Pollution Prevention Certificate
IUCN	International Union for Conservation of Nature
JHA	Job Hazard Analysis
MARPOL	International Convention for the Prevention of Pollution from Ships 1973
MMIA	Marine Mammal Impact Assessment
MMMP	Marine Mammal Mitigation Plan
MMO	Marine Mammal Observer
NABIS	National Aquatic Biodiversity Information System
NIWA	National Institute of Water and Atmospheric Research
PAM	Passive Acoustic Monitoring
PGS	Petroleum Geo-services Limited
PPP	Petroleum Prospecting Permit
SEL	Sound Exposure Level
SLR	SLR Consulting NZ Limited
SOPEP	Ship Oil Pollution Emergency Plan
STLM	Sound Transmission Loss Modelling

1 INTRODUCTION

1.1 Background

PGS Australia Pty Ltd (PGS) is proposing to acquire a three dimensional (3D) marine seismic survey in the Taranaki Basin. The Operational Area, within which all seismic operations will occur is illustrated in **Figure 1**, and lies to the northwest of Cape Farewell. This survey is referred to as the 'Taranaki West 3D Seismic Survey'.

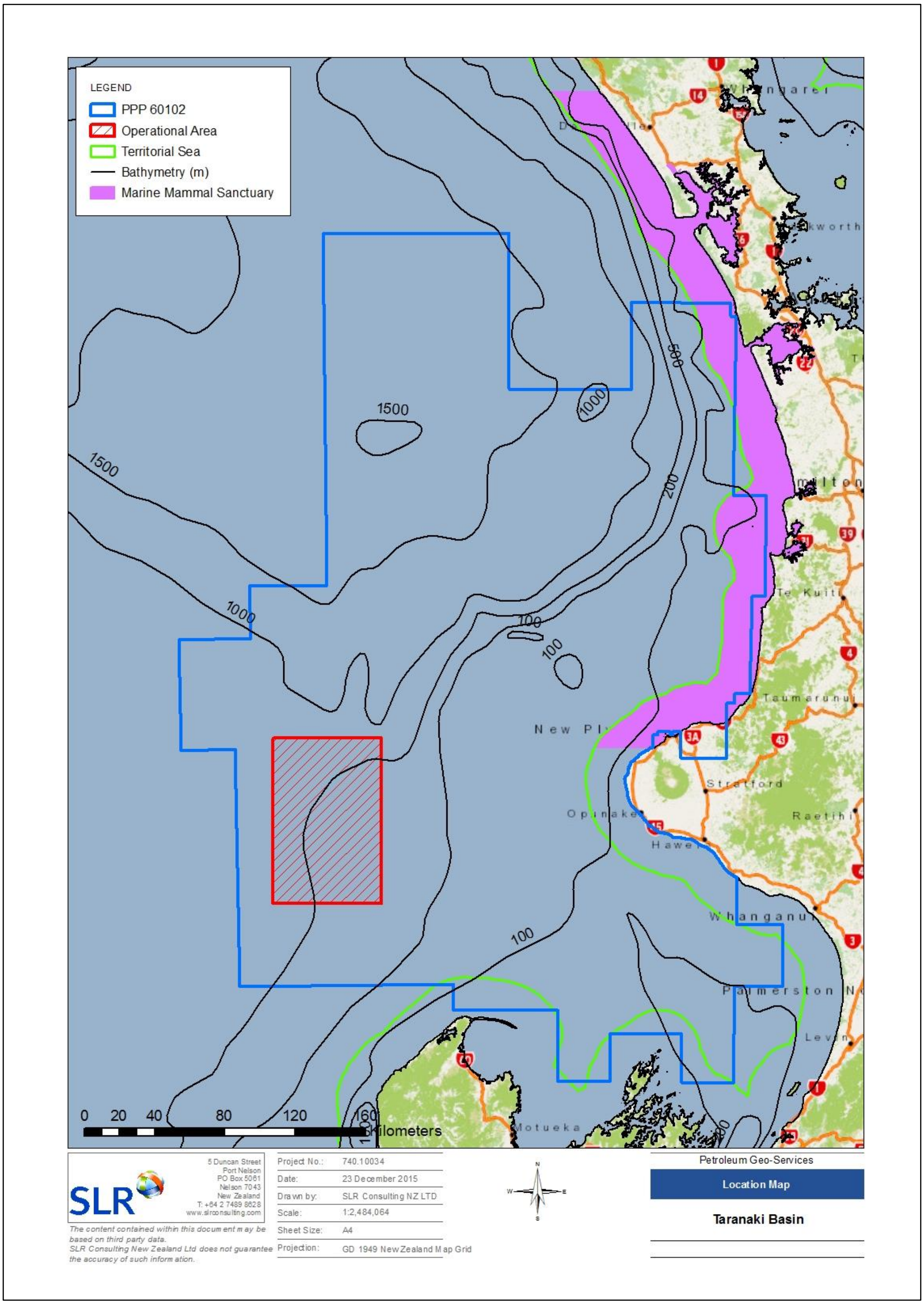
A Petroleum Prospecting Permit (PPP) (no. 60102) has been granted by NZ Petroleum and Minerals. This PPP will facilitate the proposed prospecting activities. Under Section 23 of the Crown Minerals Act 1991, the purpose of a PPP is to authorise the holder to undertake activities for the purpose of identifying petroleum deposits through geological or geophysical surveying. Further details in regard to the Crown Minerals Act are provided in **Section 3.1**.

The 'Exclusive Economic Zone (EEZ) and Continental Shelf (Environmental Effects – Permitted Activities) Act' 2012 (EEZ Act) was promulgated, and came into effect, on 28 June 2013. The EEZ Act managed the previously unregulated potential for adverse environmental effects of activities within the EEZ and continental shelf. Under the EEZ Act, a marine seismic survey is classified as a permitted activity, providing the operator undertaking the survey complies with the '2013 Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations' (Code of Conduct) (DOC, 2013). The Code of Conduct is summarised in **Section 3.4**.

SLR Consulting NZ Limited (SLR) has been engaged to prepare a Marine Mammal Impact Assessment (MMIA) in accordance with the Code of Conduct in order to assess the potential environmental effects from the Taranaki West 3D Seismic Survey on the sensitive environments and marine species in the surrounding area. The MMIA also sets out the mitigation measures that will be implemented to avoid or minimise any potential environmental effects.

PGS are planning to undertake this seismic survey between approximately December 2016 and January 2017. The exact survey duration will be dependent on down-time for weather and marine mammal encounters. The *PGS Apollo,* is the seismic vessel that will undertake the surveys.

Figure 1: Location Map of the Taranaki West 3D Seismic Survey Operational Area



1.2 General Approach

This MMIA is a pre-requisite to ensure that PGS undertake seismic operations in adherence to the EEZ Act (Permitted Activities Regulations) and the Department of Conservation (DOC) Code of Conduct. As well as the Code of Conduct, PGS will operate in accordance with relevant NZ legislation, international conventions and their relevant internal environmental standards.

The Taranaki West 3D Seismic Survey is classified as a ‘Level 1 Survey’ by the Code of Conduct and PGS will comply with the relevant requirements while conducting their survey. The Code of Conduct requirements of a Level 1 marine seismic survey are outlined in **Section 3.4**, and **Section 6** summarises all the measures that PGS proposes to minimise their environmental effects.

During the preparation of this MMIA, an extensive review of literature and existing data on the environment surrounding the Operational Area has been undertaken (see **Section 4**). A full list of references is presented in **Section 8**.

1.3 Consultation

PGS has undertaken consultation with existing interests, stakeholders, and tangata whenua in relation to the Taranaki West 3D Seismic Survey. Groups with which to engage were identified based on 1) the geographical extent of both Operational Areas, 2) existing PGS protocol for community engagement and 3) following discussions with DOC and New Zealand Petroleum and Minerals.

The consultation process involved groups being consulted either in person or by email. All consulted groups are listed in **Table 1.**

In relation to iwi consultation and because the scope of the PPP application area was much broader than the scope of the Operational Area (to cater for the re-processing of old seismic data), two approaches were used.

- Those iwi groups whose rohe are associated with the broader PPP area for which no new acquisition was planned were notified by way of letter (see **Appendix A** and **Table 1**); and
- Those iwi groups whose rohe would potentially be subject to new acquisition were engaged in face-to-face meetings and/or the provision of an information sheet (**Appendix B** and **Appendix C**).

Table 1: Groups with which consultation has occurred

Iwi (engagement by letter)	
Te Atiawa ki Whakarongotai	Tainui
Taranaki Whānui ki te Upoko o te Ika	Ngati Maru (Hauraki)
Te Atiawa (Wellington)	Ngati Paoa
Ngāti Toa Rangatira	Ngati Tamatera
Te Atiawa o Te Waka-a-Māui	Ngati Hako
Ngāti Apa ki te Rā Tō	Ngāti Whātua o Ōrākei
Rangitāne o Wairau	Te Kawerau a Maki
Ngāti Kuia	Ngāti Tamaoho
Ngāti Rarua	Te Ākitai Waiohua
Ngāti Kōata	Ngāti Whanaunga
Ngāti Tama ki Te Tau Ihu	Ngāti Whātua o Kaipara
Te Atiawa – Top of the South	Ngāti Te Ata
Iwi (information sheet and/or meeting)	
Ngati Maniapoto	Nga Ruahine *
Ngati Tama *	Ngati Ruanui *
Ngati Mutunga *	Nga Rauru Kitahi
Te Atiawa (Taranaki) *	Whanganui iwi *
Taranaki iwi	Ngati Apa *
Manawhenua ki Mohua (the umbrella entity for the three iwi of Golden Bay, Ngati Tama, Te Atiawa and Ngati Rarua)*	
Other (information sheet and/or meeting)	
Department of Conservation – Wellington *	Egmont Seafoods *
Department of Conservation – Taranaki *	Whanganui Iwi Fisheries *
Department of Conservation – Takaka *	New Plymouth Sport Fishing Club *
Environmental Protection Authority *	Port Taranaki *
Taranaki Regional Council *	Project Jonah
Deepwater Group *	NIWA
Massey University	Oregon State University
Auckland University	Rock Lobster Industry Council
Compass Rose Fishing	Sealord & Talley's Fisheries*
* indicates groups with which a face-to-face meeting was had	

A full consultation register that captures the key points of the face-to-face engagement is included as **Appendix C**.

The primary commitments of relevance to the Taranaki West 3D Seismic Survey that were made during the consultation period are summarised here:

- The employment of one trainee iwi MMO per swing;
- A return trip for close-out project and to discuss any issues that may have arisen;
- The involvement of the trainee iwi MMOs in close-out meetings;
- Immediate notification to DOC Taranaki of 1) Maui's or Hector's dolphins throughout the Operational Area, or 2) humpback whales and southern right whales within the territorial sea;
- The provision of the final MMO report to those stakeholders that request it;
- The provision of a seafloor bathymetry image to fishing groups after final processing; and
- The provision of web-based near real-time vessel positioning updates for commercial fishers.

1.4 Research

The Code of Conduct states that during marine seismic surveys, research opportunities relevant to the local species, habitats and conditions should be undertaken where possible in order to increase the understanding of the effects of seismic surveys on the marine environment (DOC, 2013).

In accordance with the Code of Conduct, and within 60 days following the completion of the Taranaki West 3D Seismic Survey, a Marine Mammal Observer (MMO) report is to be submitted to DOC. This report includes all marine mammal observation data collected, including where shut downs occurred on account of marine mammal presence. In addition to this, raw datasheets must also be provided to DOC within 14 days of completion of each swing. The provision of this information to DOC is the primary way in which PGS will contribute to research, whereby the resulting data is incorporated into the national marine mammal sighting database and is then accessible to third parties for research purposes on request. In essence, records collected during the proposed seismic operations will increase knowledge of marine mammal distributions in the Operational Area.

New Zealand is a hotspot for marine mammal strandings. Since 1840, more than 5,000 strandings of whales and dolphins have been recorded around the New Zealand coast. During any stranding event, DOC is responsible for all aspects of stranding management, including whether or not a necropsy will be undertaken to investigate the cause of death. Despite no scientific evidence that whale strandings are linked to seismic surveys, marine mammal strandings in the vicinity of a seismic survey are often targeted for necropsy to investigate potential acoustic injury. PGS will consider covering the costs associated with a necropsy if a dead marine mammal is found in close proximity to the Operational Area during acquisition and within two weeks of the completion of the Taranaki West 3D Seismic Survey. Any resultant necropsy data would also be of research benefit to the scientific community.

In recent years surveys for blue whales have occurred in the South Taranaki Bight by Oregon State University, DOC and NIWA. These surveys typically involve photo-identification, biopsy sampling, water column sampling and/or hydrophone deployments. Engagement with researchers has occurred during the planning phase for the Taranaki West 3D Seismic Survey and will continue. In the event that a temporal overlap will occur between seismic operations and research activities, PGS has committed to maintain communications with the research vessel and to advise it of any blue whale sightings that are made during the Taranaki West 3D Seismic Survey.

2 PROJECT DESCRIPTION

2.1 Marine Seismic Surveys - overview

The basic principle behind a marine seismic survey is that an acoustic source instantaneously releases compressed air in a directionally focused acoustic wave at low frequency that travels several kilometres down through the earth. As the acoustic wave travels through the earth, portions are reflected by the underlying rock layers and the reflected acoustic energy is recorded by receivers (hydrophones) in the streamers. Depths and spatial extent of the strata can be calculated and mapped, based on the time difference of the generated wave and received wave.

2.1.1 2D and 3D surveys

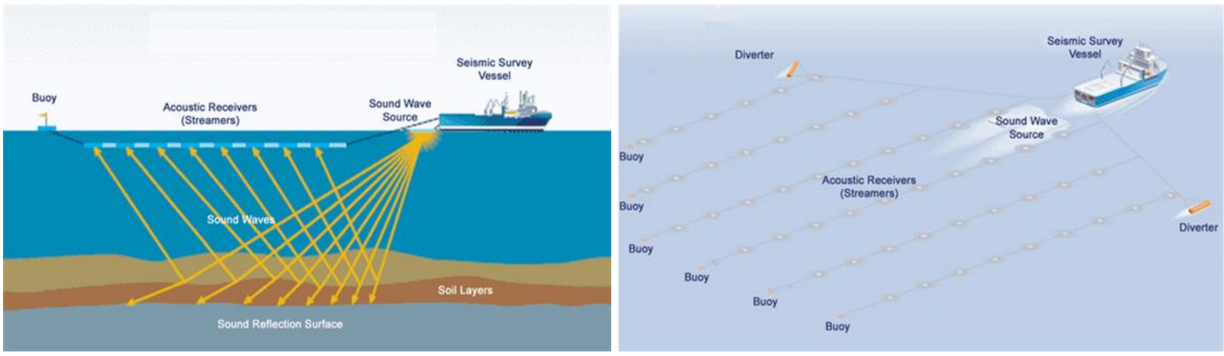
Marine seismic surveys fall into two main categories of varying complexity: 2-Dimensional (2D) and 3-Dimensional (3D) surveys. A 2D survey can be described as a fairly basic survey method which involves an acoustic source with a single streamer towed behind the seismic vessel (**Figure 2**). In contrast, a 3D survey is a more complex method which involves a greater span of more sophisticated equipment.

2D surveys are commonly used for frontier exploration areas in order to acquire a general understanding of the regional geological structure and to identify prospective survey areas, which are then comprehensively examined through a 3D survey at a later date.

3D seismic surveys focus on a specific area over known geological targets that are considered likely to contain hydrocarbons. Extensive planning is undertaken to ensure the survey area is precisely defined and the acoustic parameters are selected in order to achieve the best geological results. 3D surveys produce a three-dimensional image of the subsurface.

For 3D surveys such as the Taranaki West 3D Seismic Survey, sail lines are typically separated by 500 m. The seismic vessel tows the acoustic array and up to 12 streamers of hydrophones (typically at separations of 100 m) (**Figure 2**).

Figure 2: Schematic of 2D (left) and 3D (right) Marine Seismic Survey



(Source: www.fishsafe.eu)

2.1.2 Underwater sound

Underwater sound has two primary measures:

- The amplitude (or relative loudness) is expressed by the decibel system which is a logarithmic scale that represents a ratio that must be expressed in relation to a reference value; and
- The frequency is the number of pressure waves that pass by a reference point per unit of time and is measured in Hertz (Hz), or cycles per second.

Sound levels in water are not the same as sound levels in the air and confusion often arises when trying to compare the two. The reference level of the amplitude of a sound must always be specified. For sounds in water the reference level is expressed as 'dB re 1µPa' – the amplitude of a sound wave's loudness with a pressure of 1 microPascal (µPa). In comparison, the reference level for sound in air is dB re 20 µPa. The amplitude of a sound wave depends on the pressure of the wave as well as the density and sound speed of the medium (e.g. air, water, etc.) through which the sound is travelling. As a result of environmental differences, 62 dB must be subtracted from any sound measurement underwater to make it equivalent to the same sound level in the air.

Although sound travels further in water than it does in air (due to water being denser), in both air and water, the loudness of a sound diminishes as the sound wave radiates away from its source. In air, the sound level reduces by 10 dB as the distance doubles, while in water sound level reduces by 6 dB for each doubling of distance. Underwater sounds are also subject to additional attenuation as they interact with obstacles and barriers (e.g. water temperature differences, currents, etc.). Given the sound level in water reduces by 6 dB as the distance doubles, high levels of sound are only experienced very close to the source. Furthermore, the loudness of a sound in water diminishes very quickly close to the source and more slowly away from the source.

The ocean is a naturally noisy environment. Natural sound inputs include wind, waves, marine life, underwater volcanoes and earthquakes. Man-made sounds such as shipping, commercial and recreational fishing vessels, pile-driving for marine construction, dredging, military activities etc. further add to natural background noises.

The sound produced during seismic surveys is comparable in loudness to a number of naturally occurring and man-made sources such as those provided in **Table 2**.

Table 2: Sound Comparisons in Air and Water

Type of Sound	In Air (dB re 20µPa @ 1m)	In Water (dB re 1µPa @ 1m)
Threshold of Hearing	0 dB	62 dB
Whisper at 1 metre	20 dB	82 dB
Normal conversation in restaurant	60 dB	122 dB
Ambient sea noise	-	100 dB
Blue whale	-	190 dB
Live rock music	110 dB	172 dB
Thunderclap or chainsaw	120 dB	182 dB
Large ship	-	200 dB
Earthquake	-	210 dB
Seismic array at 1 metre	158 – 178 dB	220 – 240 dB
Colliding iceberg	-	220 dB
Bottlenose dolphin	-	225 dB
Sperm whale click	-	236 dB
Jet engine take-off at 1 metre	180 dB	242 dB
Volcanic eruption	-	255 dB

2.1.3 The acoustic source

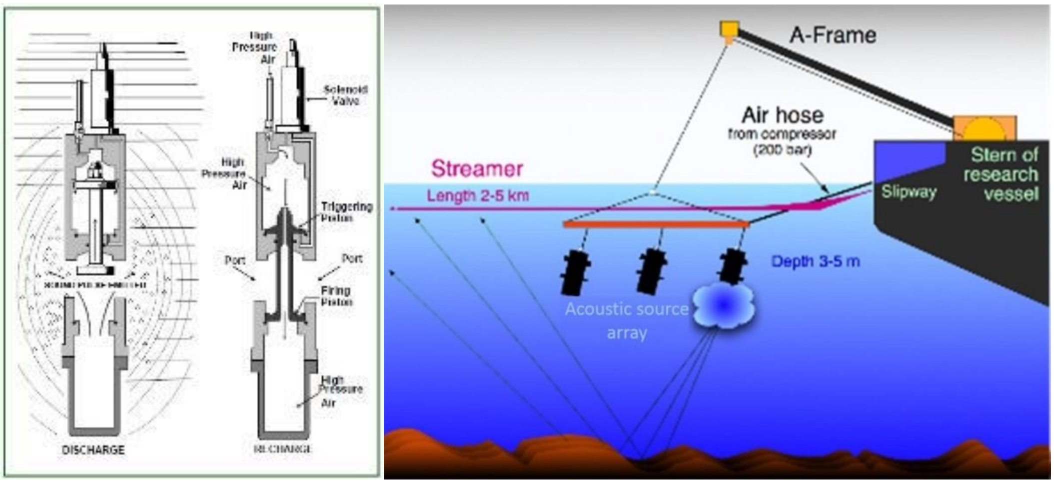
One or more acoustic sources are towed behind the seismic vessel to form an 'array'. Each source is comprised of two high pressure chambers; an upper control chamber and a discharge chamber. High pressure air (~2,000 psi) from compressors on-board the seismic vessel is continuously fed to each source, forcing a piston downwards. The chambers then fill with high-pressure air while the piston remains in the closed position (**Figure 3**).

The acoustic source is activated by sending an electrical pulse to the solenoid valve which opens, and the piston is forced upwards, allowing the high pressure air in the lower chamber to discharge to the surrounding water. The discharged air forms a bubble, which oscillates according to the operating pressure, the depth of operation, the temperature and the discharge volume. Following this discharge, the piston is forced back down to its original position by the high-pressure air in the control chamber, allowing the sequence to be repeated. The compressors are capable of recharging the acoustic source rapidly and continuously enabling the source arrays to be fired approximately every 10 seconds.

Acoustic source arrays are designed so that they direct most of the sound energy vertically downwards (**Figure 3**), although there is some residual energy which dissipates horizontally into the surrounding water. The amplitude of sound waves generally declines with lateral distance from the acoustic source, and the weakening of the signal with distance (attenuation) is frequency dependent, with stronger attenuation at higher frequencies. The decay of sound in the sea is dependent on the local conditions such as water temperature, water depth, seabed characteristics and depth at which the acoustic signal is generated.

The sound frequencies emitted from the acoustic source are broadband (10 – 1000 Hz). However, most of the energy is concentrated in the 10 – 250 Hz range. Typical source outputs will emit ~220 – 250 dB when measured relative to a reference pressure of one micropascal (re 1µPa/m) (IAGC, 2002). However, this does depend on how many acoustic sources are fired together; generally they are activated alternately.

Figure 3: Schematic of a typical acoustic source and acoustic array



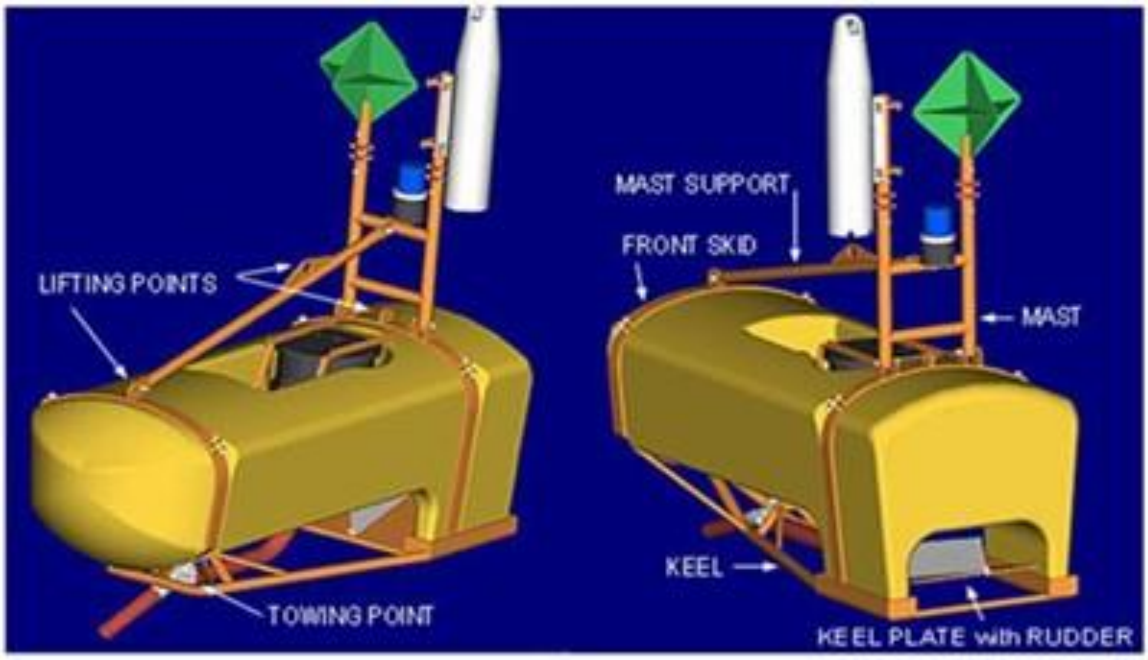
2.1.4 The streamers

When the acoustic source is discharged, the streamers detect the very low level of energy that is reflected back up from the geological structures below the seabed using hydrophones. The hydrophones convert the reflected pressure signals into electrical energy that is digitised and transmitted along the streamer to the recording system on-board the seismic vessel.

Towing a streamer underwater removes it from the sea surface weather and noise which limits the usability of the recorded data and other technical requirements. The deeper the tow depth, the quieter the streamer in regard to background weather and surface noises; however, this also results in a narrower bandwidth of received data. The operating depth typically ranges from 4 – 5 m for shallow high resolution surveys in relatively good weather, to 8 – 12 m for deeper penetration and lower frequency targets in more open waters. The streamers for the PGS seismic surveys will be towed at a depth of approximately 20 m, and streamers will extend 8.1 km behind the seismic vessel.

Tail buoys are attached to the end of each streamer to provide a hazard warning (lights and radar reflector) indicating the presence of the submerged streamer section, and to act as a platform for positional systems of the streamers (**Figure 4**).

Figure 4: Example of a Tail buoy with Light and Radar Reflector



2.2 Taranaki West 3D Seismic Survey

The Taranaki West 3D Seismic Survey is located off the west coast of central New Zealand (**Figure 1**); directly west of Cape Egmont and north-west of Farewell Spit. The Operational Area is located outside the12 Nm territorial sea. Water depths within the Operational Area are all in excess of 200 m.

PGS will use the *PGS Apollo* (**Figure 5**) to undertake the survey. Seismic survey parameters are summarised in **Table 3** and discussed below.

During the Taranaki West 3D Seismic Survey, 10 solid streamers of 8.1 km in length will be towed from the seismic vessel. Each streamer will be separated by 150 m. Solid streamers have a number of advantages over fluid filled streamers; they are more robust and resistant to damage (e.g. shark bites), they require less frequent repairs, and they are steerable, allowing greater control of the streamers, resulting in less infill lines and a reduction in the cumulative sound energy introduced into the marine environment. During the survey, the seismic vessel will be travelling at approximately 4.5 knots; therefore the streamer tail buoy will be approximately 40 - 45 minutes behind the vessel.

The acoustic source will be comprised of 2 sub-arrays, with a total effective volume of 3,660 in^3. The sub-arrays will be towed at a depth of 7 m below the sea surface. Sound Transmission Loss Modelling (STLM) was conducted on a larger acoustic source, prior to the confirmation that the 3,660 in^3 source would be used. On this basis, the mitigation zones are considered to be conservative as even with the larger acoustic source, the standard mitigation zones are sufficient. The STLM is further discussed in **Section 5.1.2.1** and the full STLM results are attached as **Appendix D**.

The acoustic source will have an operating pressure of 2,000 psi and will be activated at a source-point interval of 16.67 m. For a vessel speed of 4.5 knots, this equates to source activation approximately every 7 seconds.

PGS are planning to carry out the proposed Taranaki operations between approximately December 2016 and January 2017. Subject to weather conditions and marine mammal encounters within mitigation zones, the seismic operations will be conducted 24 hours per day, seven days per week. This survey is expected to take approximately 45 days to complete.

The technical specifications of the *PGS Apollo* are provided in (**Table 4**) and a chase vessel will be used to accompany the *PGS* Apollo during the survey. At least one of these vessels will be in close proximity to the seismic vessel at all times.

Survey operations can be divided into four main components:

- Mobilisation of seismic vessel to Operational Area;
- Deployment of acoustic equipment: Streamer and array deployment is expected to take up to four days depending on weather conditions etc. Once deployed the MMOs will begin the requisite pre-start observations as required under the Code of Conduct when arriving at a new location (**Section 3.4**), followed by a soft start;
- Data Acquisition: Once full acquisition is underway, a team of four observers (two MMOs and two PAM operators) will be used to fulfil the observer requirements of the Code of Conduct; and
- Demobilisation: Once acquisition is complete, the seismic array and streamers will be retrieved and the vessel will head to its next destination.

If the vessel has to 'wait on weather' during the acquisition period, the source array will typically be retrieved to minimise the likelihood of damage. The streamers, however, will only be retrieved on-board in extreme situations.

Table 3: Taranaki West 3D Seismic Survey Specifications

Parameter	Specifications
Total array volume	3,660 in^3
Maximum predicted output	< 212.8 dB re 1µPa/Hz @ 1m
Number of sub-arrays	2
Number of acoustic sources per sub-array	12 –12
Array length	14 m
Array width	10 m
Nominal operating pressure	2,000 psi
Source Frequency	16.67 m
Tow Depth	7 m
Number of streamers	10
Streamer length	8.1 km
Streamer manufacturer/model	PGS Geostreamer® Solid
Towing depth	20 m

Table 4: *PGS Apollo* Technical Specifications

General Specifications	
Vessel Name	*PGS Apollo*
Vessel Owner	OMP Apollo AS
Maritime Operator	PGS Geophysical AS
Engine Details	Twin CP propeller plant with nozzle and propeller shaft (Rolls Royce)
Fuel Capacity	1,452 m^3 HFO + 640 m^3 MGO
Dimensions and capacities	
Vessel Length	106.8 m
Vessel Beam	19.2 m
Max Draft	6.5 m
Gross Tonnage	7,131 tonnes
Cruising Speed	17 knots

Figure 5: Seismic Vessel – *PGS Apollo*

Figure 6: Support Vessel – *MV Thor Alpha* (for example)

2.3 Navigational Safety

During the Taranaki West 3D Seismic Survey, the seismic vessel will be towing 10 streamers of 8.1 km in length, severely restricting its manoeuvrability. Avoidance of collision will rely on all vessels obeying the International Regulations for the Prevention of Collisions at Sea (COLREGS) 1972. COLREGS is implemented in NZ waters under the Maritime Transport Act 1994. A Notice to Mariners will be issued and a coastal navigation warning will be broadcast daily on maritime radio advising of the presence of the seismic vessel in the Operational Area and the vessel's restriction in ability to manoeuvre while the streamers are deployed. The seismic vessel will have Automatic Identification System (AIS) technology on-board, allowing the vessel to receive information about the positions of other vessels and to transmit information about its position to others.

During the consultation process, all known users of the Operational Area were provided with information about the survey and PGS has offered web-based near real time position updates to fishing fleets. Furthermore, a support vessel will notify boats that are unaware of the seismic operations as necessary. In accordance with International Maritime Law, the survey vessels will display the appropriate lights and day shapes while undertaking the survey. Tail buoys equipped with a light and radar reflector will mark the end of the streamers, allowing detection during day and night.

2.4 Survey design – Alternatives and Mitigations

The majority of seismic surveys conducted worldwide use acoustic sources as they generate low frequency signals allowing the formation of images of the underlying geology below the seafloor. PGS will use a 'bolt acoustic source' for the Taranaki West 3D Seismic Survey, with the acoustic source consisting of 2 sub-arrays. The source level and array configuration was selected in order to provide sufficient power to ensure that the geological objective of the survey could be fulfilled, whilst minimising acoustic disturbance. A source level of 3,660 in^3 has been identified as an optimum power level given the survey objectives. The seismic vessel will be fitted with PGS Geostreamer© Solid streamers which further reduce noise and drag.

Seismic operations will be undertaken in summer to take advantage of settled weather. This timing not only makes for more amenable working conditions for crew, but also serves to reduce environmental effects in the following ways:

- Minimises down-time to ensure that the duration of the survey is as short as possible; and
- Minimises overlap with winter baleen whale migrations through the Operational Area.

3 LEGISLATIVE FRAMEWORK

The NZ Government's oil, gas, mineral and coal resources are administered by NZ Petroleum & Minerals and are often regarded as the Crown Mineral Estate. The role of NZ Petroleum & Minerals is to maximise the gains to NZ from the development of mineral resources, in line with the Government's objectives for energy and economic growth.

The legislative framework, relating to the Taranaki West 3D Seismic Survey is described below.

3.1 Crown Minerals Act 1991

The Crown Minerals Act 1991 sets the broad legislative framework for the issuing of permits for prospecting, exploration and mining of Crown-owned minerals in New Zealand, which includes those minerals found on land and offshore to the boundary of the extended continental shelf. This act was amended on 24 May 2013.

The Crown Minerals Act regime comprises the Crown Minerals Act 1991, two minerals programmes (one for petroleum and one for other Crown-owned minerals), and associated regulations. Together, these regulate the exploration and production of Crown-owned minerals (NZP&M, 2015).

The Petroleum Minerals Programme 2013 applies to all applications for permits for petroleum activities. It sets out the policies and procedures to be followed for the allocation of petroleum resources, while the requirements to be met by permit holders are defined in the regulations. The programme also defines specific requirements for consultation with iwi and hapū, including the matters that must be consulted on (such as all permit applications) and the consultation principles.

3.2 Marine Mammals Protection Act 1978

DOC administers and manages all marine mammal sanctuaries in accordance with the Marine Mammals Protection Act 1978 (and associated general policy). Marine mammal sanctuaries are established to provide protection of marine mammals from harmful human impacts, particularly in sensitive areas such as breeding grounds, migratory routes and the habitats of threatened species. There are currently six gazetted marine mammal sanctuaries along the coast of NZ, plus one whale sanctuary which was established under the Kaikoura (Te Tai o Marokura) Marine Management Act 2014.

A marine mammal sanctuary does not exclude all fishing or seabed mining activities; however, restrictions can be placed on seismic surveys and/or mining in order to prevent or minimise disturbance to marine mammals. In order to conduct a seismic survey within a marine mammal sanctuary, an operator must notify the Director-General of DOC and submit a written Environmental Impact Assessment not less than three months before commencing the survey. The operator must also comply with any additional conditions that are imposed by DOC relating to operations within the sanctuary.

The closest marine mammal sanctuary to the proposed Operational Area is the West Coast North Island Marine Mammal Sanctuary which is located approximately 125 km to the northeast. A full description of the sanctuary can be found in **Section 4.3.2**.

3.3 Exclusive Economic Zone & Continental Shelf (Environmental Effects) Act 2012

The EEZ Act came into force on 28 June 2013, and established the first comprehensive environmental consenting regime for activities in NZ's EEZ and Continental Shelf. The purpose of the EEZ Act is to promote the sustainable management of the natural resources of the EEZ and Continental Shelf. Sustainable management involves managing the use, development and protection of natural resources in a way, or at a rate, that enables people to provide for their economic well-being while:

- Sustaining the potential of natural resources (excluding minerals) to meet the reasonably foreseeable needs of future generations;
- Safeguarding the life-supporting capacity of the environment; and
- Avoiding, remedying, or mitigating any adverse effects of activities on the environment.

Based on considerations such as effects on the environment or existing interests, protection of rare and vulnerable ecosystems and economic benefit to NZ, the EEZ Act classifies activities within the EEZ and Continental Shelf as:

- **Permitted** – the activity can be undertaken provided the operator meets the conditions specified within the regulations. Seismic surveys fall within this classification and the conditions state that the person undertaking the activity must comply with the *2013 Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations* (the Code of Conduct);
- **Non-notified discretionary** – the activity can be undertaken if the applicant obtains a marine consent from the Environmental Protection Authority (EPA), who may grant or decline the consent and place conditions on the consent. The consent application is not publically notified and the EPA has a statutory timeframe of 60 working days in which to process the application;
- **Discretionary** – the activity may be undertaken if the applicant obtains a marine consent from the EPA. The consent application will be notified, submissions will be invited and hearings will be held if requested by any party, including submitters. The process has a statutory timeframe of 140 working days in which the EPA must assess the consent application; and
- **Prohibited** – the activity may not be undertaken.

The EPA monitors for compliance of seismic surveys with the Code of Conduct, and may conduct audits of seismic vessels before, during or after the survey. The EPA has the authority to take enforcement action in relation to any non-compliant activities (including seismic surveys) within the EEZ.

3.4 2013 Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations

The Code of Conduct was developed by DOC to manage the potential impacts of seismic operations on marine mammals. Under the EEZ Act – *Permitted Activities Regulations*, seismic surveys within the EEZ must now comply with the Code of Conduct.

The Code of Conduct aims to:

- Minimise disturbance to marine mammals from seismic survey activities;
- Minimise noise in the marine environment arising from seismic survey activities;
- Contribute to the body of scientific knowledge on the physical and behavioural impacts of seismic surveys on marine mammals through improved, standardised observations and reporting;
- Provide for the conduct of seismic surveys in NZ continental waters in an environmentally responsible and sustainable manner; and
- Build effective working relationships between government, industry and research stakeholders.

Under the Code of Conduct, three levels of seismic survey are defined based on the power level of the acoustic array. Level 1 surveys (>427 cubic inches) are typically large scale geophysical investigations, Level 2 surveys (151 – 426 cubic inches) are lower scale seismic investigations often associated with scientific research, and Level 3 surveys (<150 cubic inches) include all small scale, low impact surveys. The Taranaki West 3D Seismic Survey is classified as a Level 1 survey. The Code of Conduct requirements for a Level 1 seismic survey are provided below.

3.4.1 Notification

The notification requirements of the Code of Conduct have been adhered to and followed with the formulation of this MMIA. A letter was received by the Director-General of Conservation on 7 October 2015 notifying DOC of PGS's intentions to carry out the Taranaki West 3D Seismic Survey.

3.4.2 Marine Mammal Impact Assessment

Under normal circumstances, a MMIA must be submitted to the Director-General no less than one month prior to the start of a seismic survey. Each MMIA shall:

- Describe the activities related to the survey;
- Describe the state of the local environment in relation to marine species and habitats, with a particular focus on marine mammals;
- Identify the actual and potential effects of the activities on the environment and existing interests, including any conflicts with existing interests;
- Identify the significance (in terms of risk and consequence) of any potential negative effects and define the criteria used in making each determination;
- Identify persons, organisations or Tangata Whenua with specific interests or expertise relevant to the potential impacts on the environment;
- Describe any consultation undertaken with persons described above, and specify those who have provided written submissions on the proposed activities;
- Include copies of any written submissions from the consultation process;
- Specify any possible alternative methods for undertaking the activities to avoid, remedy or mitigate any adverse effects;
- Specify the measures that the operator intends to take to avoid, remedy or mitigate the adverse effects identified;
- Specify a monitoring and reporting plan; and
- Specify means of coordinating research opportunities, plans and activities relating to reducing and evaluating environment effects.

3.4.3 Areas of Ecological Importance

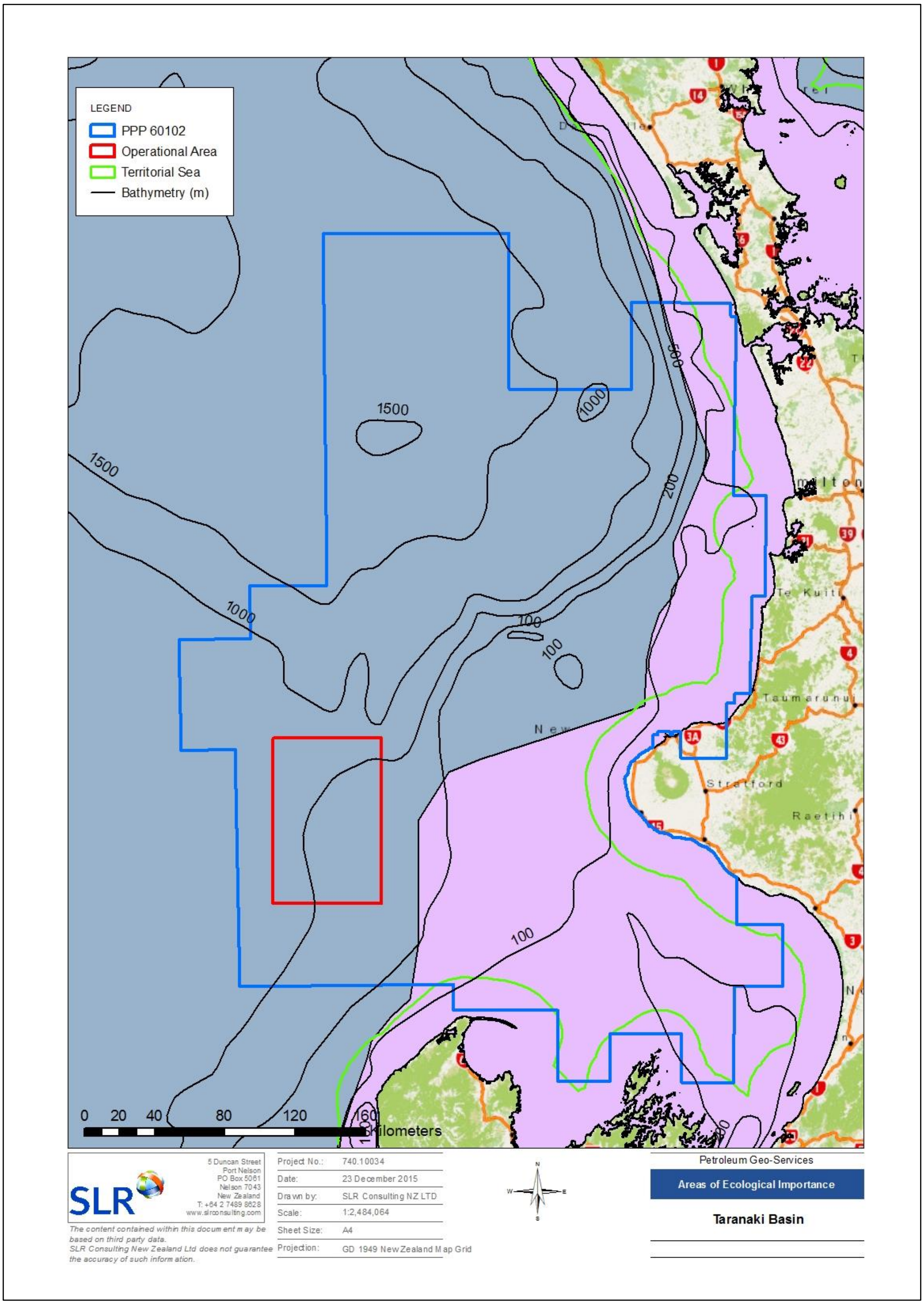
Any seismic survey operations within an Area of Ecological Importance require more comprehensive planning and consideration, including the development of additional mitigation measures.

The extent of the Area of Ecological Importance around New Zealand was determined from DOC's database of marine mammal sightings and strandings, fisheries-related data maintained by the Ministry for Primary Industries, and the National Aquatic Biodiversity Information System (NABIS). Where data was incomplete or absent, technical experts have helped refine the Area of Ecological Importance maps.

The Code of Conduct states that, under normal circumstances, a seismic survey will not be planned in any sensitive, ecologically important areas; during key biological periods where Species of Concern (see **Section 4.2.4.1** for a list of the Species of Concern) are likely to be feeding, migrating, calving, or resting; or where risks are particularly evident such as in confined waters.

The Taranaki West 3D Seismic Survey sits just outside the Area of Ecological Importance (**Figure 7**).

Figure 7: Relationship between the Operational Area and Area of Ecological Importance



The Code of Conduct requires STLM to be undertaken for any seismic surveys that will operate within an Area of Ecological Importance, on this basis STLM is not required for the Taranaki West 3D Seismic Survey. Regardless of this, and in keeping with the precautionary principle, PGS opted to conduct STLM to validate the suitability of the Code of Conduct mitigation zones. STLM predicts sound propagation whilst accounting for the specific configuration of the acoustic array and the local environmental conditions within the Operational Area (i.e. bathymetry, substrate, water temperature and underlying geology). The model results predict whether or not the mitigation zones outlined in the Code of Conduct are sufficient to protect marine mammals from behavioural and physiological impacts in accordance with the following thresholds:

- The behavioural threshold is exceeded if marine mammals are subject to Sound Exposure Levels (SELs) greater than 171 dB re 1µPa^2-s; and
- The physiology threshold is exceeded if marine mammals are subject to SELs greater than 186 dB re 1µPa^2-s (injury criteria).

Results from the Taranaki West 3D Seismic Survey STLM are discussed in **Section 5.1.2.1**.

3.4.4 Observer Requirements

All Level 1 seismic surveys require the use of MMOs in conjunction with Passive Acoustic Monitoring (PAM). MMOs visually detect marine mammals while the PAM system detects marine mammal vocalisations with hydrophones and is overseen by PAM operators. MMOs and PAM operators must be qualified according to the criteria outlined in the Code of Conduct.

To undertake a seismic survey in compliance with the Code of Conduct, the minimum qualified observer requirements are:

- There will be at least two qualified MMOs on-board at all times;
- There will be at least two qualified PAM operators on-board at all times;
- The roles of MMOs and PAM operators are strictly limited to the detection and collection of marine mammal sighting data, and the instruction of crew on the Code of Conduct and the crew's requirements when a marine mammal is detected within mitigation zones (including pre-start, soft start and operating at full acquisition capacity requirements);
- At all times when the acoustic source is in the water, at least one qualified MMO (during daylight hours) and at least one qualified PAM operator will maintain 'watch' for marine mammals; and
- The maximum on-duty shift for an MMO or PAM operator must not exceed 12 hours per day.

If observers (i.e. MMOs or PAM operators) consider that there are higher than expected numbers of marine mammals encountered during seismic survey operations, they are required to immediately notify the Director General of Conservation. Adaptive management procedures will be agreed following a discussion between DOC and the Operator. The MMO/PAM team will implement any required adaptive management actions.

Due to the limited detection range of current PAM technology for ultra-high frequency cetaceans, any such detection will require an immediate shutdown of an active source or will delay the start of operations, regardless of signal strength or whether distance or bearing from the acoustic source has been determined. It is not necessary to determine whether the marine mammal is within a mitigation zone. However, shutdown of an activated source will not be required if visual observations by a MMO confirm the acoustic detection was of a species falling into the category of 'Other Marine Mammals' (i.e. not a Species of Concern).

If the PAM system malfunctions or becomes damaged, seismic operations may continue for 20 minutes without PAM while the PAM operator diagnoses the problem. If it is found that the PAM system needs to be repaired, seismic operations may continue for an additional two hours without PAM as long as the following conditions are met:

- It is during daylight hours and the sea state is less than or equal to Beaufort 4;
- No marine mammals were detected solely by PAM in the relevant mitigation zones in the previous two hours;
- Two MMOs maintain watch at all times during seismic operations when PAM is not operational;
- DOC is notified via email as soon as practicable, stating time and location in which seismic operations began without an active PAM system; and
- Seismic operations with an active source, but without an active PAM system, do not exceed a cumulative total of four hours in any 24 hour period.

3.4.5 Operational and Reporting Requirements

MMOs and PAM operators are required under the Code of Conduct to record and report all marine mammal sightings during the survey. All raw datasheets must be submitted directly to DOC at the earliest opportunity, but no longer than 14 days after the completion of each deployment. A written final trip report must also be provided to DOC at the earliest opportunity, but no later than 60 days after the completion of the project.

The operational duties of MMOs and PAM operators during seismic operations are outlined in (**Table 5**).

3.4.6 Pre-start Observations

A Level 1 acoustic source can only be activated if it is within the specified Operational Area and adheres to the following protocol:

- The acoustic source cannot be activated during daylight hours unless:
  - At least one qualified MMO has made continuous visual observations around the source for the presence of marine mammals, from the bridge (or preferably even higher vantage point) using both binoculars and the naked eye, and no marine mammals have been observed in the respective mitigation zones for at least 30 minutes; and
  - Passive acoustic monitoring for the presence of marine mammals has been carried out by a qualified PAM operator for at least 30 minutes before activation and no vocalising cetaceans have been detected in the respective mitigation zones.
- The acoustic source cannot be activated during night-time hours or poor sighting conditions (visibility of 1.5 km or less or in a sea state greater than or equal to Beaufort 4) unless:
  - Passive acoustic monitoring for the presence of marine mammals has been carried out by a qualified PAM operator for at least 30 minutes before activation; and
  - The qualified observer has not detected any vocalising cetaceans in the relevant mitigation zones.

Table 5: Operational Duties of MMOs and PAM Operators

Operational duties	
MMO duties	PAM operator duties
Provide effective briefings to crew members, and establish clear lines of communication and procedures for on-board operations	Provide effective briefings to crew members, and establish clear lines of communication and procedures for on-board operations
Continually scan the water surface in all directions around the acoustic source for presence of marine mammals, using a combination of naked eye and high-quality binoculars from optimum vantage points for unimpaired visual observations	Deploy, retrieve, test and optimise PAM hydrophone arrays
Determine distance/bearing and plot positions of marine mammals whenever possible during sightings using GPS, sextant, reticle binoculars, compass, measuring sticks, angle boards or other appropriate tools	When on duty, concentrate on continually listening to received signals and/or monitor PAM display screens in order to detect vocalising cetaceans, except when required to attend to PAM equipment
Record/report all marine mammal sightings, including species, group size, behaviour/activity, presence of calves, distance and direction of travel (if discernible)	Use appropriate sample analysis and filtering techniques
Record sighting conditions (Beaufort sea state, swell height, visibility, fog/rain and glare) at the beginning and end of the observation period, and whenever there is a significant change in weather conditions	Record and report all cetacean detections, including, if discernible, identification of species or cetacean group, position, distance and bearing from vessel and acoustic source. Record the type and nature of sound, time and duration over which it was heard.
Record acoustic source power output while in operation, and any mitigation measures taken	Record general environmental conditions, acoustic source power output while in operation, and any mitigation measures taken.
Communicate with DOC to clarify any uncertainty or ambiguity in application of the Code of Conduct	Communicate with DOC to clarify any uncertainty or ambiguity in application of the Code of Conduct
Record/report to DOC any instances of non-compliance with the Code of Conduct	Record/report to DOC any instances of non-compliance with the Code of Conduct

In addition to the above normal pre-start observation requirements, when arriving at a new location in the survey programme for the first time, or when returning to the Operational Area following a port call, the initial acoustic source activation must not be undertaken at night or during poor sighting conditions unless either:

- MMOs have undertaken observations within 20 Nm of the planned start up position for at least the last two hours of good sighting conditions preceding proposed operations, and no marine mammals have been detected; or
- Where there have been less than two hours of good sighting conditions preceding proposed operations (within 20 Nm of the planned start up position), the source may be activated if:
    - PAM monitoring has been conducted for two hours immediately preceding proposed operations;
    - Two MMOs have conducted visual monitoring in the two hours immediately preceding proposed operations;
    - No Species of Concern have been sighted during visual monitoring or detected during acoustic monitoring in the relevant mitigation zones in the two hours immediately preceding proposed operations;
    - No fur seals have been sighted during visual monitoring in the relevant mitigation zone in the 10 minutes immediately preceding proposed operations; and

- No other marine mammals have been sighted during visual monitoring or detected during acoustic monitoring in the relevant mitigation zones in the 30 minutes immediately preceding proposed operations.

3.4.7 Soft Starts

A soft start consists of gradually increasing the source's power, starting with the lowest capacity acoustic source, over a period of at least 20 minutes and no more than 40 minutes. The operational source capacity is not to be exceeded during the soft start period.

The acoustic source will not be activated at any time except by soft start, unless the source is being reactivated after a single break in firing (not in response to a marine mammal observation within a mitigation zone) of less than 10 minutes immediately following normal operations at full power, and the qualified observers have not detected marine mammals in the relevant mitigation zones. No repetition of the less than 10 minute break period in the commencement of a soft start is allowed under the Code of Conduct.

3.4.8 Delayed Starts and Shutdowns

Species of Concern with calves within a mitigation zone of 1.5 km

If, during pre-start observations or while the acoustic source is activated (including during soft starts), a qualified observer detects at least one Species of Concern with a calf within 1.5 km of the source, start-up will be delayed or the source will be shut down and not reactivated until:

- A qualified observer confirms the group has moved to a point that is more than 1.5 km from the source; or
- Despite continuous observation, 30 minutes has elapsed since the last detection of the group within 1.5 km of the source, and the mitigation zone remains clear.

Species of Concern within a mitigation zone of 1 km

If during pre-start observations or while the acoustic source is activated (including during soft starts), a qualified observer detects a Species of Concern within 1 km of the source, start-up will be delayed or the source will be shut down and not reactivated until:

- A qualified observer confirms the Species of Concern has moved to a point that is more than 1 km from the source; or
- Despite continuous observation, 30 minutes has elapsed since the last detection of a Species of Concern within 1 km of the source, and the mitigation zone remains clear.

Other Marine Mammals within a mitigation zone of 200 m

If during pre-start observations prior to initiation of the acoustic source soft-start procedures, a qualified observer detects a marine mammal other than a Species of Concern within 200 m of the source, start-up will be delayed until:

- A qualified observer confirms the marine mammal has moved to a point that is more than 200 m from the source; or
- Despite continuous observation, 10 minutes has elapsed since the last detection of a NZ fur seal within 200 m of the source and 30 minutes has elapsed since the last detection of any other marine mammal within 200 m of the source, and the mitigation zone remains clear.

Once all marine mammals that were detected within the relevant mitigation zones have been observed to move beyond the respective mitigation zones, there will be no further delays to the initiation of soft start procedures.

4 ENVIRONMENTAL DESCRIPTION

4.1 Physical Environment

4.1.1 Meteorology

The climate of New Zealand is complex, varying from warm subtropical in the far north to cool temperate in the far south. Anticyclones are a major feature of the weather in the Australian-New Zealand region. These circulation systems migrate eastwards across NZ every six to seven days, with their centres generally passing across the North Island. Overall, anticyclones follow northerly paths in the spring and southerly paths in the autumn and winter.

Between the anticyclones and associated cold fronts are troughs of low pressure orientated northwest to southeast. Cold fronts approaching from the west bring with them an increase in cloud levels and strengthening of north-westerly winds. Periods of rain lasting up to several hours follow the passing of the front. After the front has gone through, the weather conditions change again, this time to cold showery south-westerly winds.

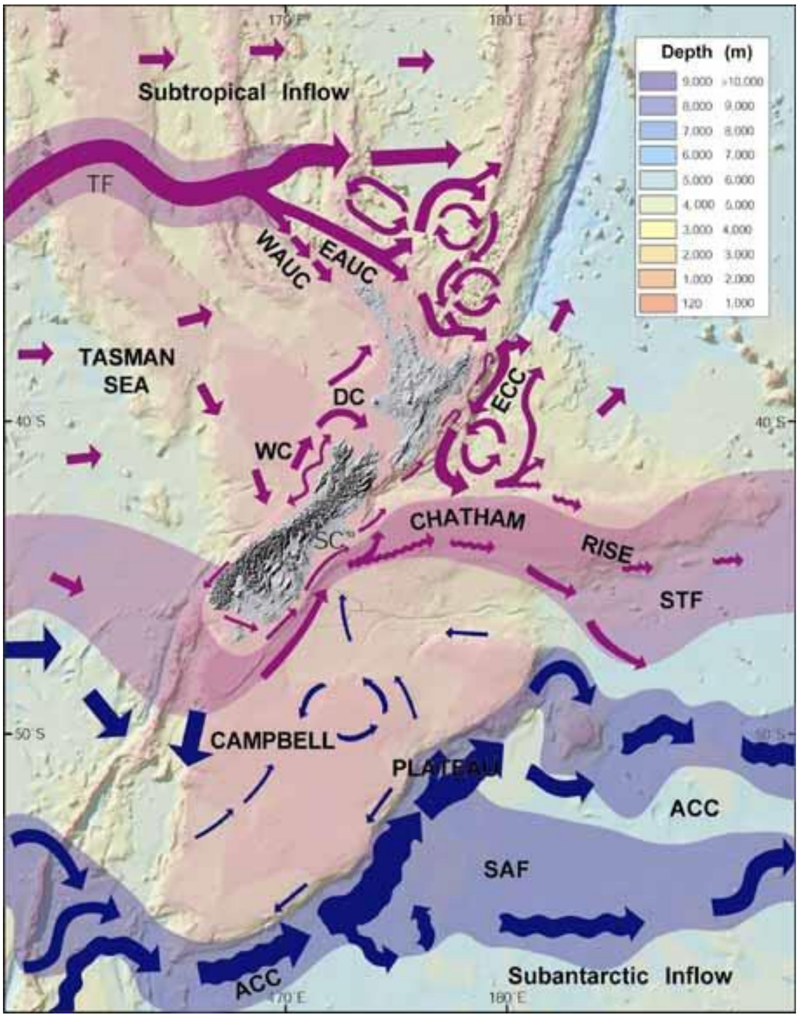
4.1.2 Currents and Waves

NZ lies in the path of eastward-flowing currents that are driven by winds blowing across the South Pacific Ocean. This results in NZ being exposed to the southern branch of the South Pacific subtropical gyre, driven by the southeast trade winds to the north and the Roaring Forties westerly winds to the south (Gorman *et al*., 2005). The anti-clockwise circulation of the gyre is initiated by the winds and is then further modified by the spin of the earth.

The primary ocean currents are illustrated in **Figure 8**. The eastward flow out of the Tasman Sea splits into two currents across the top of the North Island; the West Auckland Current flowing from Cape Reinga towards Kaipara, and the East Auckland Current flowing from North Cape towards the Bay of Plenty (Brodie, 1960; Heath, 1985; Stanton, 1973). As the West Auckland Current progresses south, it is met in the North Taranaki Bight by the north-flowing Westland Current. The Westland Current flows from the west coast of the South Island up to the west coast of the North Island where it weakens and becomes subject to seasonal variability. The convergence zone of the two currents is highly variable (Brodie, 1960; Ridgway, 1980; Stanton, 1973).

Seasonal variation in the West Auckland Current and Westland Current results in varying temperatures and salinity off the west coast of central New Zealand. During winter, the West Auckland Current extends further south, bringing with it warmer waters. In contrast, the West Auckland Current is weaker in the summer months and the Westland Current dominates, bringing with it colder waters (Ridgway, 1980; Stanton, 1973).

Figure 8: Ocean Circulation around the New Zealand Coastline.



(**Source:** Te Ara (2015) http://www.teara.govt.nz/en/map/5912/ocean-currents-around-New-Zealand)

The Operational Area is situated in a high energy wave climate due to its exposed location in the Tasman Sea, with the energetic Cook Strait to the southeast. Here long period swells are often enhanced by the predominant west to southwest winds. The swells reaching the Operational Area from the Tasman Sea are often large as they are virtually unimpeded by any land masses (Pickrill & Mitchell, 1979).

The prevailing deep water waves off the west coast of central NZ are south-westerly through to westerly (Pickrill & Mitchell, 1979). Pickrill & Mitchell (1979) reported that there are no strong seasonal cycles in this wave climate, with short period rhythmic fluctuations associated with the passage of weather systems across the Tasman Sea more important. Due to these weather systems, the wave climate is mixed with locally generated storm waves and longer period swells originating from high energy storm centres to the south (Pickrill & Mitchell (1979).

In contrast to Pickrill & Mitchell (1979), MacDiarmid *et al*. (2011) reported that closer inshore in the South Taranaki Bight, wave heights show a seasonal cycle, with mean significant wave heights peaking in late winter (August and September) and lowest in late summer. Within the South Taranaki Bight the largest waves are found off the western end of Cape Egmont, with wave height decreasing further south as a result of increasing shelter from prevailing south-westerly swells (MacDiarmid *et al*., 2011). Wave heights in excess of 8 m can occur during stormy conditions within the Bight, particularly in the winter and early spring (MacDiarmid *et al*., 2011).

4.1.3 Thermoclines and Sea Surface Temperature

During spring and summer, thermal stratification of the water column can develop as a result of solar heating of the upper water column (i.e. 40 – 50 m below the sea surface). The stratification profile varies with local environmental conditions: where storm conditions can cause significant vertical mixing and breakdown of the thermal structure, but local tides and currents can either enhance or degrade thermocline structure. As a result, a well-defined thermocline is not always present.

Thermoclines can be observed through processed seismic data. A thermocline is characterised by a negative sound speed gradient and can be acoustically reflective. This is a result of a discontinuity in the acoustic impedance of water created by the sudden change in density resulting from the temperature difference. A change in temperature of 1°C can result in a change of sound speed by 3 ms^{-1} (Simmonds *et al*., 2004).

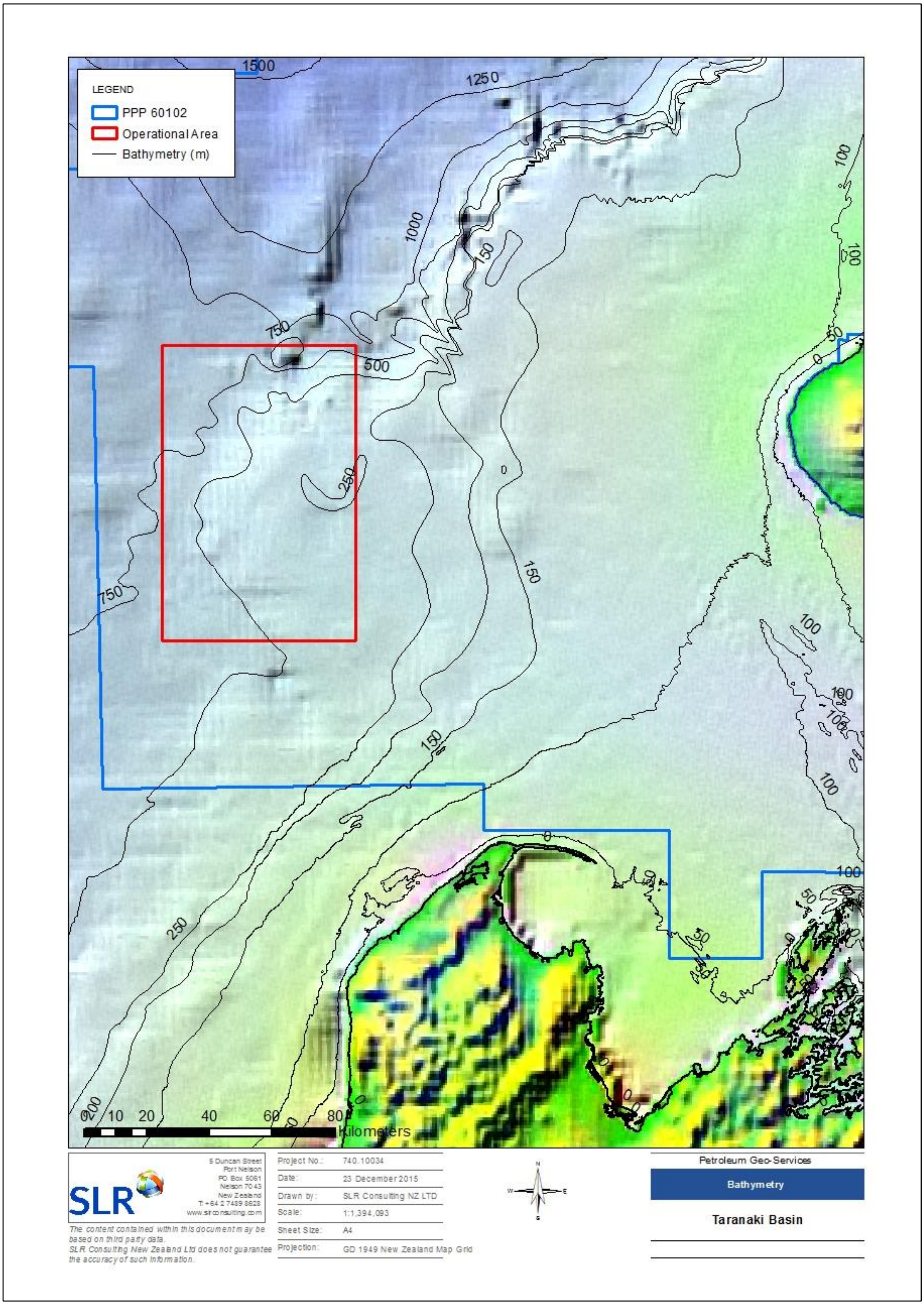
4.1.4 Bathymetry and Geology

NZ is surrounded by a gently sloping zone; the continental shelf. The continental shelf extends from the coast out to a water depth of 100 – 200 m. Beyond the continental shelf, the gradient of the seabed steepens and passes into the continental slope which descends relatively rapidly from the edge of the shelf down to depths in excess of 4,000 m. At the foot of the slope, the gradient flattens out into ocean basins which are wide undulating but relatively flat zones lying at depths of 4,000 – 5,000 m. These zones cover most central parts of the major oceans (Te Ara, 2015).

The surface of the continental shelf is predominantly flat (punctuated by local banks and reefs), whereas the slope is irregular with large marine valleys (submarine canyons). These canyons tend to occur in slope areas of relatively steep gradient (e.g. off Kaikoura) and generally run from the edge of the continental shelf to the foot of the continental slope.

The width of NZ's continental shelf varies: the Taranaki continental shelf has a 150 km wide opening to the Tasman Sea, occupies 30,000 km^2, and slopes gently towards the west with an overall gradient of <0.1° (Nodder, 1995). Through the Operational Area the seabed slopes towards the northwest. The shallowest water of 235 m occurs close to the eastern boundary, but reaches depths of up to 750 m in the northwest (**Figure 9**).

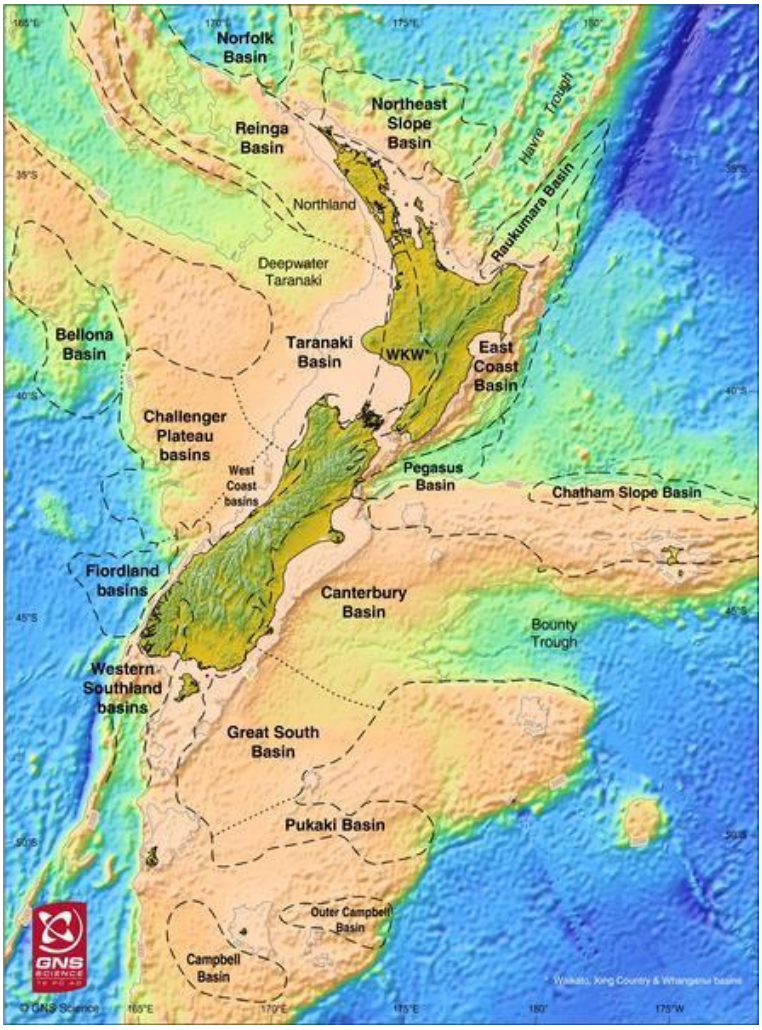
Figure 9: Bathymetry of the Operational Area



NZ's varied underwater topography is the result of NZ's breakup from Gondwana which created the continental slopes, opened the Tasman Sea floor and created sedimentary basins. Rivers eroded the land and transported sediments containing organic matter into these basins. This erosion resulted in the deposition of shoreline sands, followed by marine silts and mud several kilometres thick, compacted by the weights of the overlying sediments. Due to their permeable and porous properties, the deposited materials made ideal hydrocarbon reservoir rock, with impermeable overlying silts, mud and carbonates forming the seals.

There are eight sedimentary basins underlying NZ's continental shelf with known or potential hydrocarbons present (**Figure 10**). To date, commercial quantities of oil and gas have only been produced from the Taranaki Basin.

Figure 10: New Zealand's Sedimentary Basins.



(**Source:** http://www.gns.cri.nz/Home/Our-Science/Energy-Resources/Oil-and-Gas/NZs-Sedimentary-Basins)

The Operational Area traverses the Taranaki Basin. This basin lies at the southern end of a rift that developed sub-parallel to the Tasman Sea rift and now separates Australia from New Zealand. The Taranaki Basin occupies the site of a late Mesozoic extension on the landward side of the Gondwana margin, and covers approximately 330,000 km². The structure of the basin is controlled by movements along the Taranaki, Cape Egmont and Turi fault zones (NZP&M, 2013).

Coastal basement rocks in the Taranaki Basin originate from a number of different terrains. Crustal slabs can comprise sedimentary, plutonic, and volcanic rocks. The terrains around NZ are grouped into the Paleozoic (540 – 300 million years ago) Western Province, and the Permian to early Cretaceous (300 – 100 million years ago) Eastern Province. At the boundary between these two provinces is a zone of volcanic arc rocks which form the western section of the Taranaki Peninsula.

Surficial marine sediments across the Taranaki shelf follow a gradient from the coastal zone to the continental shelf, with fine to medium sand typical of coastal sediments and silt and muds prevailing further offshore. West-southwest storm generated waves and currents are most likely the predominant sediment transport agents in the South Taranaki Bight (MacDiarmid *et al*., 2011).

4.2 Biological Environment

4.2.1 Plankton

Plankton is the collective term for drifting organisms that inhabit the pelagic zone (water column) of the world's oceans. Plankton fulfil the role of primary producers in the ocean and form the basis of the marine food web. Plankton travel with the ocean currents and although some plankton can move vertically within the water column, their horizontal distribution is primarily determined by the surrounding currents.

'Plankton' refers to animals, algae, protists, archaea and bacteria. There are three broad functional planktonic groups:

- Bacterioplankton – free-floating bacteria (important in nutrient cycling);
- Phytoplankton – free-floating plants (capable of photosynthesis); and
- Zooplankton – free-floating animals (includes larval stages of larger animals).

Further inshore and to the southeast of the Operational Area, the semi-enclosed area of the South Taranaki Bight and Western Cook Strait is one of the most biologically productive coastal regions in NZ. This productivity is due to various features including the Kahurangi upwelling, sediment discharges from the Kapiti Coast, coastal erosion and surf zone sediment re-suspension, phytoplankton blooms in Tasman and Golden Bays, and energetic mixing of waters in Cook Strait (MacKenzie, 2014).

The Kahurangi upwelling originates off Cape Farewell on the northern South Island coast. The system is described by MacKenzie (2014) and is summarised as follows. The upwelling generates a short and tightly coupled food chain leading from plankton through to higher trophic levels. Cool, nutrient rich waters (from up to 100 m deep) are brought to the sun-lit surface layers via upwelling, resulting in the stimulation of phytoplankton growth. A turbulent wake containing a number of eddies then streams off the Kahurangi Shoals, moving the highly productive plume into the Taranaki Bight and the western approaches of Cook Strait. Zooplankton grazers exploit the increasingly abundant phytoplankton biomass associated with the maturing eddies. As eddies migrate north-eastward there are characteristic changes in the species makeup of the zooplankton communities that have important effects on the pelagic food chain (Bradford-Grieve *et al.,* 1993). Of particular importance is the presence of *Nyctiphanes australis* in mature eddies. This is a krill species that provides an important food source for pelagic fish, seabirds, and baleen whales.

4.2.2 Invertebrates

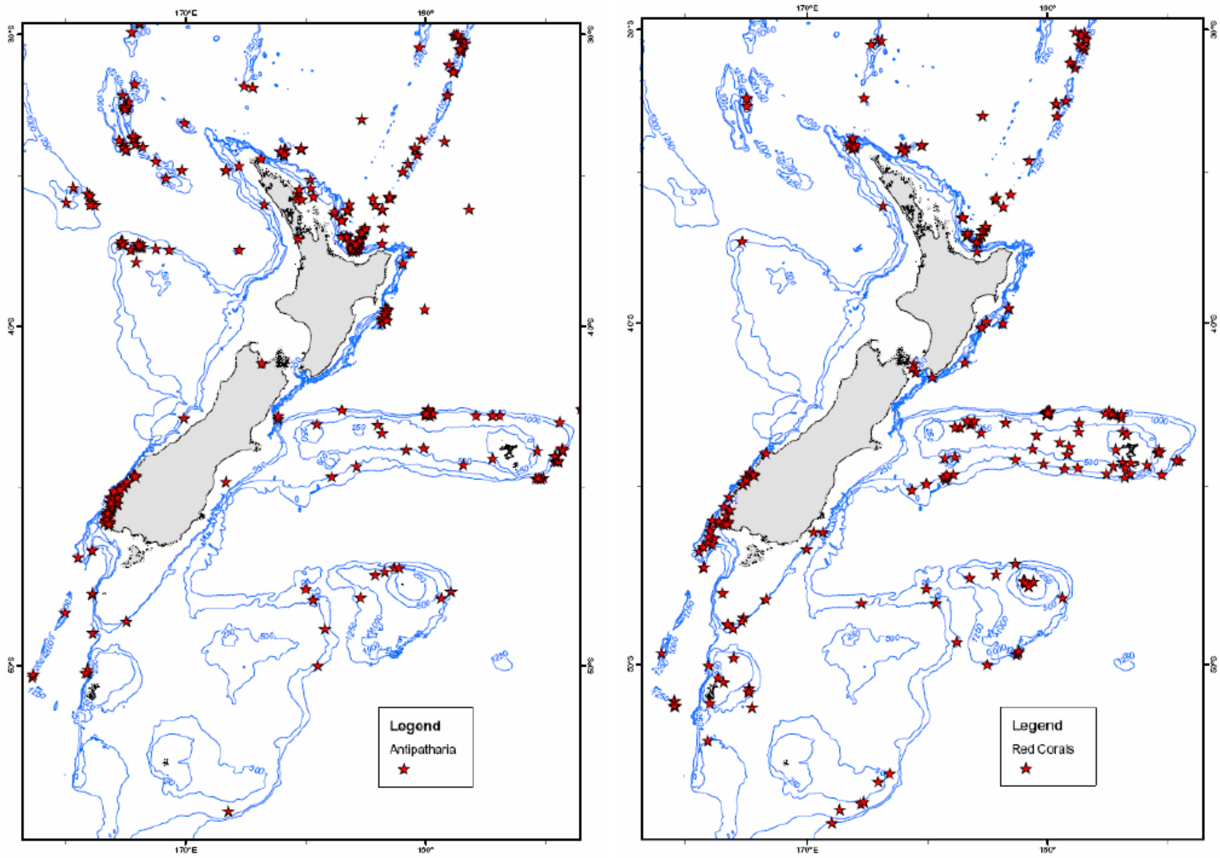
The offshore benthic ecosystems in Taranaki are generally characterised by soft sand/mud substrates that support a range of faunal species: mainly polychaete worms, cumaceans, amphipods (small crustaceans), and bivalves. The habitat is considered to be relatively homogenous with low levels of diversity (Asher, 2014; Skilton, 2014). The benthic communities in Taranaki are not rare or threatened. Less is known about the benthic communities in the Operational Area; however there is no evidence to suggest that this region is significantly different with regards to biodiversity.

NZ has a rich and diverse range of corals that are present from the intertidal zone down to 5,000 m (Consalvey *et al*., 2006). They occur either as individuals or as compact colonies of individual polyps and can live for hundreds of years. Deep-sea corals are fragile, sessile, slow-growing and long-lived. They have limited larval dispersal and are restricted to certain habitats. Of the protected marine invertebrate species, the deep sea corals are the most relevant to this MMIA.

Within NZ's EEZ, black coral and stylasterid hydrocoral (formerly known as red coral) are protected under the Wildlife Act 1953. Within NZ waters, 58 species of black coral have been identified, and although their depth and geographical distributions have not been systematically analysed, it appears that most live on seamounts or other hard substrate in depths ranging from 200 to 1,000 m.

NIWA have developed a database of black coral distribution around NZ based on records from commercial fishing by-catch. From this data the presence of black and stylasterid coral appears to be greatest in the north and east of NZ (particularly Chatham Rise). There are no known significant densities of black coral or stylasterid coral in the Operational Area (**Figure 11**).

Figure 11: Records of Black Corals (left) and Stylasterid Corals (right) in NZ.



(**Source:** Consalvey *et al.* (2006))

4.2.3 Fish Species

Fish populations from the Operational Area are represented by various demersal and pelagic species, most of which are widely distributed from north to south and from shallow coastal water to beyond the shelf edge.

A general summary of the fish species potentially present in the Operational Area is presented in **Table 6**. The information for this summary was collated from the NABIS database, O'Driscoll *et al.* (2003); Hurst *et al.* (2000); Hurst *et al*. (2000a); Bagely *et al*. (2000); Anderson *et al.* (1998) and MacDiarmid *et al*. (2011). Over the summer months, a number of larger pelagic species visit the Operational Area waters. Examples can include sunfish, flying fish, marlin, albacore tuna, skipjack tuna, mako sharks and blue sharks.

Table 6: Fish Species Potentially Present in the Operational Area

Common Name		
Albacore tuna	Hake	Rig
Anchovy	Hammerhead shark	Rough skate
Barracouta	Hapuku	Rubyfish
Basking shark	Hoki	Scaly gurnard
Bass	Horse mackerel	School shark
Bigeye tuna	Jack mackerel	Short-tailed black ray
Black marlin	John dory	Silver dory
Blue mackerel	Ling	Silverside
Blue marlin	Long-finned beryx	Silver warehou
Blue shark	Mako shark	Sea perch
Bluenose	Moonfish	Skipjack tuna
Broadbill swordfish	Murphy's mackerel	Smooth skate
Bronze whaler shark	Northern spiny dogfish	Snapper
Carpet shark	Pacific Bluefin tuna	Spiny dogfish
Common warehou	Pale ghost shark	Squid
Dark ghost shark	Porae	Striped marlin
Frostfish	Porcupine fish	Tarakihi
Flying fish	Porbeagle shark	Thresher shark
Gemfish	Ray's bream	Trevally
Giant stargazer	Red cod	Turbot
Golden mackerel	Red snapper	Two saddle rattail
	Redbait	White shark/great white shark

Both long-finned and short-finned eels are present in freshwater systems present throughout NZ. These eels live the majority of their lives in the freshwater systems until they have matured to breeding size. At this stage, adult eels go through physical changes in order to migrate to spawning areas in the Pacific (such as Tonga) (Te Ara, 2015b). It is thought that adult eels of both species use the waters of the South Taranaki Bight and beyond during these migrations (Ben Potaka, pers. comm.) and could therefore pass through the Operational Area on a seasonal basis (Feb – Apr).

Eight species of fish are listed as protected under Schedule 7A of the Wildlife Act 1953: basking shark, deepwater nurse shark, great white shark, manta ray, oceanic white-tip shark, spiny-tailed devil ray, spotted black grouper, and whale shark. Additionally, the great white, basking and oceanic white-tip sharks are also protected under the Fisheries Act, prohibiting NZ flagged vessels from taking these species from all waters, including beyond NZ's EEZ. Of these species, the great white shark and basking shark have the greatest potential to occur in the Operational Area.

4.2.4 Cetaceans

Forty seven cetacean taxa (whales and dolphins) are recognised from NZ waters (Baker *et al.,* 2016). Taxonomically, cetaceans are split into two suborders; toothed whales (odontocetes) and baleen whales (mysticetes).

Baleen whales are large and use baleen to filter plankton prey from seawater. Odontocetes have teeth, are highly social, and hunt and navigate in large groups. While both groups use sound to communicate, only odontocetes echolocate. Odontocetes direct sounds ("clicks") into their environment and use the reflected sound waves to interpret their surroundings (identify objects and locate prey). This reliance on sound for communication, feeding and navigation makes cetaceans vulnerable to the effects of anthropogenic noise: therefore precautions must be taken during seismic surveys in order to minimise potential effects. Mitigation measures for the Taranaki West 3D Seismic Survey are summarised in **Section 6**.

4.2.4.1 Cetacean Distribution in the Operational Area

Due to their often elusive nature and general inaccessibility, cetaceans are notoriously difficult to study. Furthermore, deep-diving, offshore and migratory species are less well documented due to the logistical challenges that arise from these behaviours. These characteristics mean that cetacean distribution data is largely incomplete; hence it is important to consider multiple sources of information to better understand cetacean occurrence. Information is generally available in the form of detection data (acoustic detections or sightings from dedicated and opportunistic surveys) or can be inferred from stranding information, knowledge of migration paths and habitat preferences of each species.

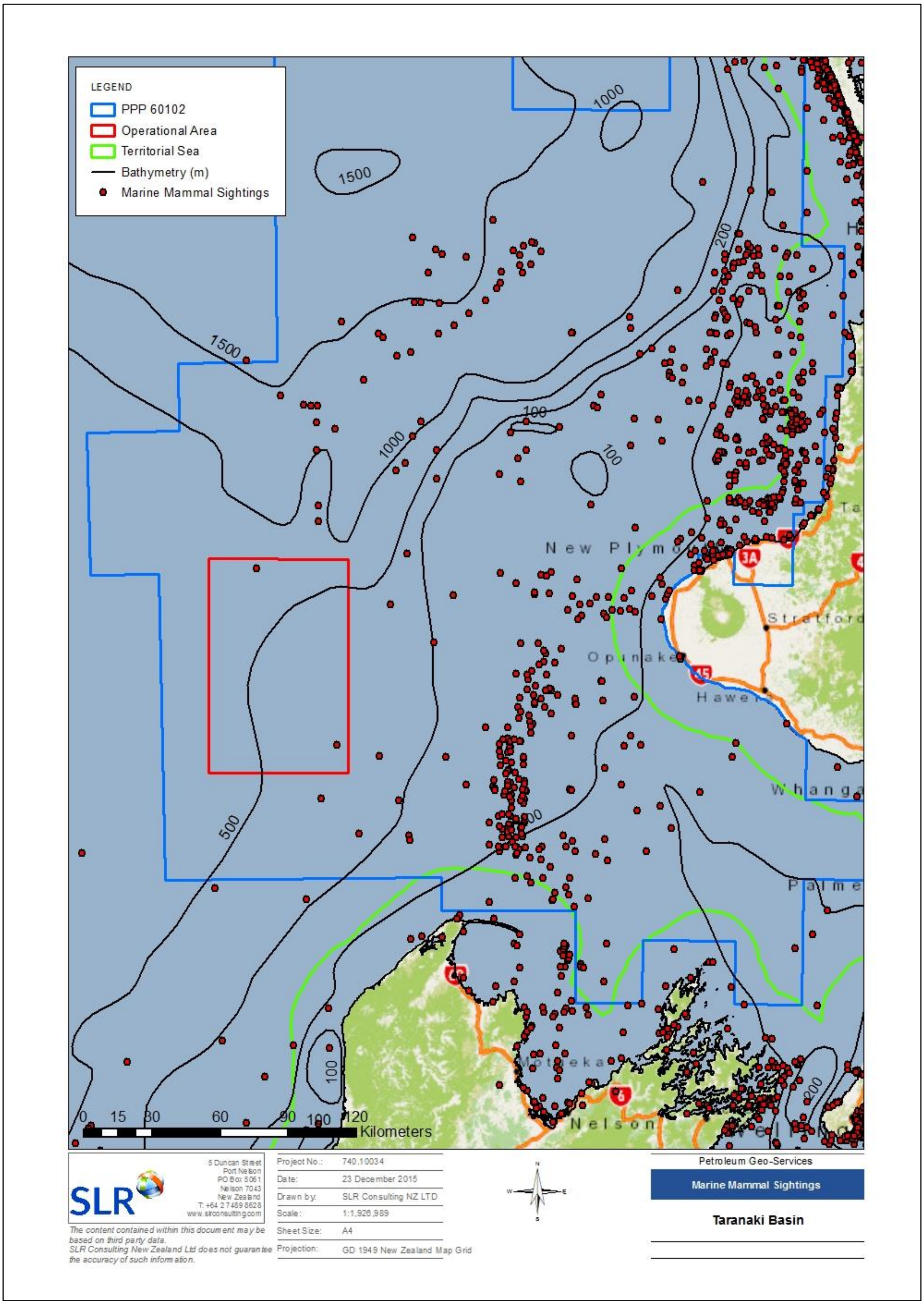
Interpretation of cetacean distribution data requires caution. In particular, caution should be exercised for those areas that are lacking in sightings data as this does not strictly indicate an absence of cetaceans; rather it could simply reflect a lack of observer effort. These 'data gaps' are common in areas that have low levels of boat activity, no dedicated cetacean surveys, or are relatively inaccessible. To populate this section we have used both information from the DOC sightings database and Torres (2012). Although these sources are considered to provide the most comprehensive distribution data for this region, it should be noted that the majority of sightings recorded are from locations to the east of the Operational Area. A lack of sightings data for the Operational Area itself is apparent and here we make the assumption that species seen in the outer South Taranaki Bight are likely to also use the waters of the Operational Area. Based on this, the MMIA aims to provide a broad overview of cetaceans which could be present in the Operational Area. It is noteworthy that data collected during the Taranaki West 3D Seismic Survey will be a valuable contribution towards better understanding the distribution of cetaceans in these offshore waters.

The DOC sighting database includes over 8,000 sightings of marine mammals, of which numerous records were contributed by previous seismic surveys. **Figure 12** provides a summary of all sightings from the database in the vicinity of the Operational Area.

The DOC stranding database is not as relevant to this Operational Area given its offshore location; however, for species that are rarely observed at sea, stranding data has been used to indicate potential presence in the wider vicinity of the Operational Area.

A summary of cetacean species that could be present in the Operational Area is provided in **Table 7**, and a basic ecological summary for the majority of these species is provided in **Section 4.2.4.3**.

Figure 12: Cetacean sightings in the vicinity of the Operational Area



(**Source:** Department of Conservation, 2015)

Table 7: Cetacean Species Potentially Present in the Operational Area

Species	Scientific name	NZ Threat Status (Baker *et al*., 2016)	Species of Concern?	IUCN Status	Likelihood of Occurrence in Operational Area	Season most likely present
Southern right whale	*Eubalaena australis*	**Nationally vulnerable**	Yes	Least concern	Occasional visitor	Year round
Pygmy right whale	*Caperea marginata*	Data deficient	Yes	Data deficient	Occasional visitor	Year round*
Antarctic minke whale	*Balaenoptera bonarensis*	Not threatened	Yes	Data deficient	Occasional visitor	Year round*
Dwarf minke whale	*Balaenoptera acutorostrata*	Not threatened	Yes	Data deficient	Occasional visitor	Year round*
Sei whale	*Balaenoptera borealis*	Migrant	Yes	Endangered	Occasional visitor	Year round*
Bryde's whale	*Balaenoptera edeni*	**Nationally critical**	Yes	Data deficient	Rare visitor	Summer
Antarctic blue whale	*Balaenoptera musculus intermedia*	Migrant	Yes	Endangered	Occasional visitor	Year round
Pygmy blue whale	*Balaenoptera musculus brevicauda*	Migrant	Yes	Endangered	**Likely**	Year round
Fin whale	*Balaenoptera physalus*	Migrant	Yes	Endangered	Occasional visitor	Year round*
Humpback whale	*Megaptera novaeangliae*	Migrant	Yes	Least concern	**Likely**	May – August (northern migration)
Sperm whale	*Physeter Macrocephalus*	Not threatened	Yes	Vulnerable	**Likely**	Year round, especially summer
Pygmy sperm whale	*Kogia breviceps*	Not threatened	Yes	Data deficient	Occasional visitor	Year round*
Dwarf sperm whale	*Kogia sima*	Vagrant	Yes	Data deficient	Rare visitor	Year round*
Arnoux's beaked whale	*Beradius arnouxi*	Migrant	Yes	Data deficient	Rare visitor	Year round*
Andrew's beaked whale	*Mesoplodon bowdoini*	Data deficient	Yes	Data deficient	Occasional visitor	Year round*
Ginko-toothed whale	*Mesoplodon ginkgodens*	Vagrant	Yes	Data deficient	Occasional visitor	Year round*
Gray's beaked whale	*Mesoplodon grayi*	Not threatened	Yes	Data deficient	Occasional visitor	Year round*
Strap-toothed whale	*Mesoplodon layardi*	Data deficient	Yes	Data deficient	Occasional visitor	Year round*
Shepherd's beaked whale	*Tasmacetus shepherdi*	Data deficient	Yes	Data deficient	Occasional visitor	Year round*
Cuvier's beaked whale	*Ziphius cavirostris*	Data deficient	Yes	Data deficient	Occasional visitor	Year round*
Southern bottlenose whale	*Hyperoodon planifrons*	Data deficient	Yes	Least concern	Rare visitor	Year round*
Common dolphin	*Delphinus delphis*	Not threatened	No	Least concern	**Likely**	Year round, especially summer
Short-finned pilot whale	*Globicephala macrorhynchus*	Migrant	Yes	Data deficient	Occasional visitor	Summer
Long-finned pilot whale	*Globicephala melas*	Not threatened	Yes	Data deficient	**Likely**	Year round, especially summer
Risso's dolphin	*Grampus griseus*	Vagrant	No	Least concern	Occasional visitor	Year round*
Dusky dolphin	*Lagenorhynchus obscurus*	Not threatened	No	Data deficient	Occasional visitor	Year round*
Killer whale – Type A	*Orcinus orca*	**Nationally critical**	Yes	Data deficient	**Likely**	Year round
False killer whale	*Pseudorca crassidens*	Not threatened	Yes	Data deficient	Occasional visitor	Year round*
Spotted/Striped dolphin	*Stenella sp.*	Vagrant	No	Least concern	Rare visitor	Summer
Bottlenose dolphin	*Tursiops truncatus*	**Nationally endangered**	Yes	Least concern	Occasional visitor	Year round*

** Limited data on which to base seasonality assessment, hence a year round presence has been assumed*

4.2.4.2 Migration paths through the Operational Area

In general terms, southern hemisphere baleen whales typically migrate south in spring from their tropical breeding grounds to their Antarctic feeding grounds; returning back to the tropics during autumn-winter for the breeding season (DOC, 2007). The indicative migration paths for humpback, sperm, Bryde's and southern right whales are shown in **Figure 13**. The northern migration routes are relatively well known for some species, however the southwards routes are not. There are exceptions to this general migratory pattern and they are described in the individual species accounts below.

The Taranaki West 3D Seismic Survey is expected to take place in December and January. During the height of summer large concentrations of baleen whales will be utilising higher latitude feeding grounds in the Antarctic or the sub-Antarctic therefore there is less potential for overlap with migratory corridors during this period. The migration north would be expected to commence in early winter i.e. well after the proposed seismic operations have been completed. Overall, it is expected that little overlap with baleen whale migration will occur.

Figure 13: Whale Distribution and Migration Pathways in NZ Waters.

(**Source:** http://www.teara.govt.nz/en/map/7052/whales-in-new-zealand-waters)

4.2.4.3 Ecological summaries of cetacean species in Taranaki Basin

4.2.4.3.1 Southern right whale

Southern right whales (*Eubalaena australis*) can reach between 15 – 18 m in length. They are slow moving whales, often swimming at speeds less than 9 km/hr, making them vulnerable to ship-strikes. These whales produce a range of different vocalisations. In NZ waters, a majority of 'upcalls' are recorded and on average vocalisations have frequencies of below 1 kHz (Webster & Dawson, 2011).

The distribution of southern right whales is strongly influenced by season with most individuals spending summer months in latitudes 40 – 50°S (Oshumi & Kasamatsu, 1986) where they take advantage of the seasonal proliferation of their planktonic prey (copepods and euphausiids) (Tormosov *et al*., 1998; Rowantree *et al.,* 2008). Right whales feed predominantly on zooplankton and tend to 'skim feed' by swimming through swarms of prey with their mouth wide open. This is done either at the surface or at depth (Braham & Rice, 1984).

Southern right whales have been classified as 'nationally vulnerable' under the NZ Threat Classification System; however, recent data indicates that populations are making a recovery (worldwide, southern right whales are regarded by the IUCN as 'of least concern'). Historic whaling activities through the nineteenth century heavily reduced numbers around NZ: with pre-exploitation abundance estimated to be between 28,800 and 47,100 individuals (Jackson *et al.,* 2016). Following the cessation of this whaling activity only 30–40 mature females were thought to remain (Jackson *et al*., 2016). Today whale numbers remain low, at an estimated 12% of pre-exploitation abundance (Jackson et al., 2016). Genetic evidence suggests that southern right whales present around mainland NZ and the NZ subantarctic are part of a single stock (Carroll *et al.,* 2011). It is thought that this single NZ population ranges between two winter breeding grounds; the primary breeding ground in the subantarctic, where Port Ross, Auckland Islands is the principal calving area (Rayment *et al.,* 2012), and a secondary breeding ground off mainland NZ (Carroll *et al.,* 2011). Southern right whales are the only baleen whale to breed in NZ waters, and the coastal waters around mainland NZ represent a historic calving ground for this species, with recent evidence suggesting that a slow recolonisation of this range is currently occurring (Patenaude, 2003; Carroll *et al.,* 2011; DOC, 2015).

The Torres (2012) study indicates that southern right whales utilise the waters of the South Taranaki Bight, particularly during winter months (July to October). Although nine sightings of southern right whales were recorded, all but one of these records occurred in coastal waters. The offshore sighting occurred to the north east of the Operational Area (Torres, 2012).

Based on this information, southern right whales could be present as occasional visitors in the Operational Area, but typically sightings occur in sheltered inshore waters in winter and spring; hence little overlap is predicted between southern right whale presence and the Taranaki West 3D Seismic Survey. It is possible that individuals could transit offshore through the Operational Area outside of the winter breeding season.

4.2.4.3.2 Pygmy right whale

The pygmy right whale (*Caperea marginata*) is the smallest species of baleen whale (Reilly *et al.,* 2008b; Baker, 1999). Little is known of the life history of this species (Shirihai, 2006), but it is thought to feed predominantly on zooplankton (e.g. calanoid copepods and euphausiids) (Kemper, 2002).

Knowledge of the acoustic repertoire of the species is limited to a single recording of a juvenile in Australia which revealed at least one type of call which was described as a short thump-like pulse with a downsweep in frequency and decaying amplitude (Dawbin & Cato, 1992).

Live sightings of this species are very rare (Reilly *et al.,* 2008). Australasian distribution was described by Kemper (2002) as being 32 – 47 °S, with young calves being seen in waters from 35 – 47 °S.

Sightings from New Zealand waters are mainly from around Stewart Island and in Cook Strait (Kemper, 2002). The DOC stranding database lists fourteen strandings of relevance to the Operational Area (three from Taranaki and 11 from Tasman). This stranding record, together with the habitat preference for offshore deep waters suggest that pygmy right whales are likely to utilise waters in the Operational Area.

4.2.4.3.3 Minke whale

Minke whales are baleen whales that feed on krill, crustaceans and small fish. They perform dives which last on average between three to nine minutes (maximum 20 minutes). Minke whales produce low frequency pulse train calls. The overall frequency range of these vocalisations is 100 – 500 Hz, with the main energy in the lower sector of this range. These calls are used for communicating over large distances.

Antarctic or southern minke whales and dwarf minke whales are both known to occur in NZ waters. The Antarctic minke is a southern hemisphere species, being very abundant in Antarctic waters in summer. They are commonly seen at lower latitudes in other seasons, although their winter distribution is not well-known (Reilly *et al.,* 2008). The dwarf minke has a wide-spread distribution and occurs over most latitudes in both northern and southern hemispheres. In the southern hemisphere, as with the Antarctic minke, they feed in Antarctic waters in summer with a broader latitudinal distribution in other seasons (Reilly *et al.,* 2008). Outside of summer months, dwarf minkes are thought to occur in shallower coastal water over the continental shelf (Jefferson *et al.,* 2008; Perrin, 2009) than their Antarctic counterparts.

In NZ, the DOC sighting and stranding data indicates that the distribution of minke whales (species not distinguished) extends around mainland NZ and subantarctic waters. There were 60 reported sightings of minke whale (both species) in NZ's EEZ between 1970 and 2013, the majority of which were in spring (38%). This timing aligns well with the southern migration towards the Antarctic feeding grounds that these species utilise over the summer months. Torres (2012) further supports this finding, with five recorded minke whale sightings occurring in September to October. All of these sightings were made in offshore waters to the northeast of the Operational Area (Torres, 2012).

Based on this information, it is considered that minke whales could be present as occasional visitors in the Operational Area.

4.2.4.3.4 Sei whale

Sei whales are found worldwide and visit NZ waters in summer to feed during their seasonal migrations between the tropics and the southern ocean (Reilly *et al.,* 2008a). Unlike other baleen whales they have a slightly more temperate distribution preferring water temperatures of 8 - 18°C (Reilly *et al.,* 2008a). Over summer, southern hemisphere populations reside in waters between 45 and 60°S, remaining largely between the sub-tropical and Antarctic convergences. The winter breeding distributions of sei whales are largely unknown.

Sei whales are baleen whales and have a diet that varies with region and season to include copepods, euphausiids, and amphipods (Reilly *et al.,* 2008a). This species of whale commonly feeds at dawn (Shirihai & Jarrett, 2006). The acoustics of sei whales are not well studied and there are indications of geographic variations in frequency and the nature of the calls. Vocalisations from sei whales recorded in Antarctic waters included low frequency tonal calls (0.45 ±0.3 s long and 0.433 ±0.192 kHz in frequency) and broadband 'growls' or 'wooshes'.

Torres (2012) notes three sei whale sightings in offshore waters of the South Taranaki Bight during summer months (November to February). Although these sightings occurred to the east of the Operational Area, Sei whales are generally found in deep, offshore waters (Horwood, 2009) and could be present as occasional visitors in the Operational Area.

4.2.4.3.5 Bryde's whale

Bryde's whales are typically restricted to tropical and warm-temperate waters, and unlike many other baleen whales probably do not undertake long systematic migrations (Kato, 2002). In general, the latitudinal range of this species is considered to be between 40°N and 40°S (as summarised in Riekkola, 2013).

Bryde's whales in NZ are concentrated in northern North Island waters, in particular the Hauraki Gulf which has been identified as an important breeding area (Baker & Madon 2007; Wiseman *et al*., 2011). Little is known about seasonal latitudinal movements of Bryde's whales in NZ. It is likely that a small sub-population of whales regularly use the Hauraki Gulf, but that these individuals are not completely isolated from a larger (but unknown) regional population (Baker *et al.,* 2011). The only systematic investigations of Bryde's whale distribution in NZ waters are restricted to the Hauraki Gulf and the east coast of Northland. Opportunistic sighting data is however available for other regions and confirms that Bryde's whales are occasionally sighted in offshore Taranaki waters during summer months (Torres, 2012).

Whale species that remain at or near the sea surface for extended periods are particularly vulnerable to ship strike. Bryde's whales in the Hauraki Gulf of NZ are known to exhibit such behaviour whereby they spend 90% of their time in the top 12 m of the water column (Constantine *et al*., 2012). For this reason, ship strike is a major cause of mortality to Bryde's whales near the Port of Auckland (Constantine *et al*., 2012). Riekkola (2013) investigated potential mitigation measures to reduce the incidence of ship strike to Bryde's whales in Hauraki Gulf and concluded that a reduction in vessel speed (from 13.2 to 10 knots) would effectively reduce the likelihood of lethal injury in any strike incident from 51% to 16%.

Bryde's whales appear to visit Taranaki waters on the rare occasion, but the Operational Area is clearly outside the regional population strong-hold for this species. Therefore it is highly unlikely they will be present during the Taranaki West 3D Seismic Survey.

4.2.4.3.6 Blue whale

Blue whales are the largest animal to ever live, with adults reaching up to 33 m long and weighing up to 180 tonnes (Baker, 1999; Todd, 2014). Two subspecies of blue whale are known from NZ waters: the pygmy blue whale and the Antarctic blue whale. These two subspecies are difficult to distinguish which has resulted in the generic reporting of 'blue whales' in both stranding and sighting data.

Visual or acoustic detections of blue whales have occurred widely through NZ waters (Olsen *et al*., 2013; Miller *et al*., 2014). They are most commonly heard on the west coast of the North Island, and the east coast of the South Island. Blue whales vocalise at a low frequency (average of 0.01 – 0.110 kHz but some calls have a precursor of 0.4 kHz) (McDonald *et al*., 2001; Miller *et al*., 2014) resulting in their vocalisations being able to travel hundreds of kilometres through the water. Their calls can reach levels of up to 188 dB re 1ɥPa m^{-1} (Aroyan *et al*., 2000; Cummings & Thompson, 1971).

Blue whales depend on krill (euphausiids) as their primary food source. They can be seen lunge feeding on surface swarms of krill or diving to depths of up to 100 m for 10 – 20 minutes; although they are capable of diving to depths of up to 500 m for as long as 50 minutes (Todd, 2014). As blue whales have the highest prey demand of any predator (Rice, 1978; DOC, 2007), large aggregations of food in upwelling areas are extremely important. Worldwide, aggregations of blue whales are known to occur in areas of upwelling that coincide with lower sea surface temperature relative to surrounding waters and high concentrations of euphausiids (Fiedler *et al*., 1998; Burtenshaw *et al*., 2004; Croll *et al*., 2005; Gill *et al*., 2011).

A concentration of pygmy blue whales has recently been identified in the South Taranaki Bight, where a research trip in 2014 confirmed that the South Taranaki Bight is a foraging ground for this subspecies which targets the krill *Nyctiphanes australis* here (Torres *et al*., 2015). Genetic analysis identified blue whales in the Bight as belonging to a distinct haplotype; hence these individuals may comprise a unique population. The absolute distribution of blue whales changes on a seasonal and year by year basis depending on climatic patterns that drive the distribution of their prey. In El Nino conditions whales tend to be located west of the Bight, but inside the Bight during more typical weather patterns (Torres and Klinck 2016).

In February 2016 a field survey gathered the first evidence of breeding behaviour in the waters of, and to the west of, the South Taranaki Bight with 1) a high density of mother/calf pairs being observed, 2) the first ever aerial footage of blue whale nursing behaviour being documented, and 3) observations of sexual competition ('racing behaviour') among adult males (Torres and Klinck 2016). In addition to these reproductive observations, sightings of blue whales have been made in all months of the year, suggesting a year-round presence of this population in the South Taranaki Bight region (Torres, 2013; Torres and Klinck 2016).

The IUCN Red List of Threatened Species currently lists the Antarctic blue whale as "critically endangered" and the pygmy blue whale as "data deficient". In contrast, the NZ threat classification system classifies blue whales as "migrant" and therefore does not designate a threat status; however, blue whales are listed as a "Species of Concern" under the Code of Conduct. In light of the new evidence for blue whale breeding behaviour in the South Taranaki Bight, it is possible that the NZ threat classification for blue whales will change in the future.

Blue whales (particularly pygmy blue whales) clearly utilise the waters in the vicinity of the Operational Area and are likely to be seen during the Taranaki West 3D Seismic Survey.

4.2.4.3.7 Fin whale

Fin whales are found worldwide in primarily offshore waters (Reilly *et al*., 2013). Their summer distribution in the South Pacific is between 50 and 65°S (Miyashita *et al.,* 1995) and they are thought to move into warmer, lower latitudes in winter to breed, although their breeding grounds are largely unknown.

The diet of fin whales varies locally and seasonally. In the southern hemisphere, they feed almost exclusively on krill. However elsewhere, they consume a range of other species, such as fish, squid, krill and other crustaceans (Mizroch *et al.,* 1984; Shirihai & Jarrett, 2006).

Fin whales use sound to communicate over large distances. Calls have been described as short (<1 second) down-swept tones, ranging from 28 to 25 Hz at source levels of 189 +/-4dB re 1ɥPa m^{-1} (Širović *et al*., 2004).

Fin whales have been sighted in offshore waters in the vicinity of the Operational Area during summer months (see Torres, 2012). Torres (2012) introduced the possibility that they, like blue whales, could also feed on krill aggregations in the South Taranaki Bight. Therefore this species can be considered as an occasional visitor to the Operational Area.

4.2.4.3.8 Humpback whale

Humpback whales are a migratory species, undertaking the longest migration between feeding and breeding grounds of any mammal (Jackson *et al.,* 2014). During summer months, humpbacks feed in Antarctic waters and migrate north to tropical waters for breeding in winter. For the 'Southwest Pacific Ocean' humpback whale population (known as Stock F), this migration route passes through NZ waters (Berkenbusch *et al.,* 2013), whereby whales move northwards up the east coast of the South Island and through Cook Strait from May to August. Animals on their southern migration may move down both coasts of the North Island from September to December (Gibbs & Childerhouse, 2000). Recent satellite tagging data of humpback whales at the Kermadec Islands in spring indicate that individual whales that use this staging point travel south well offshore of the east coast of the North Island (NZGeo, 2016). Whales do not forage during their migrations, but depend on stored fat reserves to sustain them though these journeys. On their migrations, humpback whales spend considerable time in coastal regions over the continental shelf (Jefferson *et al.,* 2008).

Between 2004 and 2015, DOC has conducted an annual winter survey for humpback whales in Cook Strait with the aim of documenting the recovery of this species through time. The first four surveys ran for two weeks, with those surveys from 2008 onwards running over a full four week period (DOC, 2015a). The number of individual humpbacks seen per year has ranged from 15 (in 2006) to 137 (in 2015). Genetic samples collected during these surveys have been matched to whales in the wider south pacific region, with whales passing through Cook Strait having also been observed off Australia and New Caledonia.

Although both male and female humpbacks produce communication calls, only males emit the long, loud, and complex 'songs' associated with breeding activities. These songs consist of several sounds in a low register, varying in amplitude and frequency, and typically last from 10 to 20 minutes (American Cetacean Society, 2014). In addition to vocalisations, 'social sounds' of humpbacks are known to include sounds generated from surface activities such as breaching and tail-slapping.

Based on Torres (2012) humpback whales utilise the waters surrounding the Operational Area. As the majority of sightings (73%) were made between June and November, it is likely that these offshore waters are utilised by humpback whales as migratory pathways. Although Torres (2012) reported a peak in sightings between June and November, they are observed at other times of the year, therefore it is possible that this species will be encountered during the Taranaki West 3D Seismic Survey.

4.2.4.3.9 Sperm whale

Sperm whales are the largest of the toothed whale species. They are distributed globally and have a wide geographical and latitudinal distribution. Sperm whales are usually found in open ocean waters deeper than 1,000 m and above the continental slope. Although all whales have significant cultural importance in NZ, sperm whales in particular are regarded as chiefly figures of the ocean realm and are commonly recognised as taonga (treasure) to Māori.

Squid is the most common prey of sperm whales, and foraging dives can last over an hour (Evans & Hindell, 2004; Gaskin & Cawthorn, 1967; Gomez-Villota, 2007). During these dives, whales can reach depths of up to 3,000 m. At these depths, the whales become entirely reliant on sound to locate prey and to navigate. To do so, sperm whales produce echolocation clicks which are believed to enable them to determine the direction and distance of prey (Ocean Research Group, 2015). In addition, sperm whales also use clicks as a means of communication, to identify members of a group and to coordinate foraging activities (Andre & Kamminga, 2000). All of these sounds will allow any sperm whales in the proximity to the seismic vessel to be detected by the on-board PAM system.

Detailed descriptions of sperm whale distribution in NZ waters are limited to the Kaikoura region where an aggregation of this species is routinely associated with the Kaikoura Canyon. Here, photo-identification studies have been used to estimate that between 60 and 108 sperm whales are present in any one season (Childerhouse *et al.,* 1995). Torres (2012) reported that sperm whale sightings in the South Taranaki Bight/Greater Cook Strait region typically occurred in deep offshore water and were limited to the summer months. Sightings were distributed throughout Taranaki waters, including within the Operational Area and waters to the north and south. Hence, sperm whales are likely to be encountered during the Taranaki West 3D Seismic Survey.

4.2.4.3.10 Pygmy sperm whale

Little is known of the ecology of the pygmy sperm whale (*Kogia breviceps*), although stranded individuals have revealed some information about diet preferences and acoustics. From this it is apparent that around New Zealand this species primarily feeds on cephalopods, with a minor component of fish and crustaceans (Beatson, 2007). This species is known to emit click trains between 60 kHz and 200 kHz (Marten, 2000).

This species occurs in deep offshore water (beyond the edge of the continental shelf) in temperate and tropical waters (Taylor *et al.,* 2012). Strandings of this species are relatively common in New Zealand waters, particularly on the east coast of the North Island. There are thirteen strandings of relevance to the Operational Area (three in Taranaki and ten in Manawatu). Stranding events along the New Zealand coastline are largely of single animals; however, the presence of stranded mother/calf pairs is noteworthy from January to April (Baker, 1999). This indicates a summer breeding season for this species in New Zealand waters.

4.2.4.3.11 Dwarf sperm whale

Little is known about the ecology of dwarf sperm whales (*Kogia sima*) due to their cryptic nature at sea. They are thought to prefer warm offshore waters (Caldwell and Caldwell, 1989), and appear to feed primarily on deep water cephalopods, but are also known to take other prey species (Ross, 1979). Prey is detected by high frequency echolocation clicks with peak frequencies greater than 100 kHz (Merkens *et al.,* 2015).

The DOC data lists no strandings or sightings of relevance to the Operational Area; however this species has been included here on the basis that they are indistinguishable from pygmy sperm whales at sea. However the preference of dwarf sperm whales for warmer waters would suggest that any *Kogia spp.* seen during the Taranaki West 3D Seismic Survey would most likely be pygmy sperm whales.

4.2.4.3.12 Beaked whales

Very little is known about the distribution of beaked whales within NZ’s EEZ. Their preference for deep offshore waters and their elusive behaviour at sea contribute to this paucity of knowledge (Baker, 1999). Eleven species of beaked whales are present in NZ; however, it is difficult to identify specific habitat types and behaviour for each individual species, as most of the information comes from stranded whales, which in some cases provides the only knowledge that they exist within NZ waters. Beaked whales are mostly found in small groups in cool, temperate waters with a preference for pelagic deep ocean waters or continental slope habitats at depths down to 3,000 m. They are deep divers and feed predominately on deep-water squid and fish species.

Of the eleven species known to NZ waters, eight are represented in the stranding record for South Taranaki and Tasman regions, in lieu of sighting data, this stranding data has been used here to indicate a presence of beaked whales in the vicinity of the Operational Area. These records contribute to a total of 36 beaked whale stranding events in these regions of which 36% are Gray’s beaked whales. It is therefore assumed that beaked whales could be present during the Taranaki West 3D Seismic Survey.

4.2.4.3.13 Common dolphin

Worldwide, there are two species of common dolphin; the short-beaked common dolphin and the long-beaked common dolphin. The short-beaked common dolphin occurs in NZ waters, from which they are known to occur in all regions, along the coastline of both the North and South Islands (Berkenbusch *et al.,* 2013). No total abundance estimate is available for the NZ population; however, based on the frequency of sightings it is likely that numbers are substantial.

Common dolphins are social animals and often form groups of several thousand individuals. They have been sighted at depths ranging from 6 – 141 m (Constantine & Baker, 1997). In addition, results from the study of stomach contents of common dolphins in NZ waters indicates and onshore-offshore diel migration (Meynier *et al.,* 2008). Jack mackerel, anchovy and arrow squid have been found to be the predominant prey species for common dolphins in NZ (Meynier *et al.,* 2008).

Common dolphins are known to produce whistles, echolocation click trains and burst pulse calls. Echolocation click trains are involved in locating prey and navigation whereas burst pulse calls and whistles are a form of communication. Petrella *et al.,* (2012) determined the whistle characteristics of common dolphins in the Hauraki Gulf, indicating that the average frequency and length of whistles are 10 – 14 kHz and 0.27 seconds, respectively.

Common dolphins are the most frequently encountered species in the South Taranaki Bight/wider Cook Strait region, particularly off Farwell Spit (Torres, 2012). Most sightings occur over summer months, but this seasonality is likely a reflection of observational bias (Torres, 2012). Although Torres (2012) reported a preference of habitats with water depths between 0 and 100 m and a decline in observations further offshore, common dolphins have been observed in offshore waters in the vicinity of the Operational Area. As a result, common dolphins will almost certainly be encountered during the Taranaki West 3D Seismic Survey.

4.2.4.3.14 Pilot whales

There are two species of pilot whale worldwide (the long-finned and short-finned) with both species present in NZ waters. However, the long-finned pilot whale is more frequently encountered in NZ waters than the short-finned pilot whale which prefers a slightly warmer subtropical habitat.

Pilot whales are a toothed whale which feed on fish and squid in deep water along shelf breaks. NZ studies indicate that pilot whales predominantly feed on cephalopods, usually arrow squid and common octopus (Beatson *et al.,* 2007).

Pilot whales often travel in large groups (over 100 individuals), and have a high stranding rate along the NZ coastline. Strandings generally peak in spring and summer months (O'Callaghan *et al.,* 2001), with Farewell Spit, directly to the south of the Operational Area well known for mass whale stranding incidents.

An assessment of the DOC stranding database for Farewell Spit from 1937 to 2014 revealed that at least 28 mass stranding events occurred during this period; the largest of these involved 345 individuals. Long-finned pilot whales accounted for virtually all of these strandings with short-finned pilot whales only accounting for one of these events (in 1977 where 95 individuals stranded). November, December and January were the most common months in which mass strandings occurred, with these months accounting for 21 of the 28 incidents assessed. Pilot whale strandings are also not uncommon along the Taranaki coast; however, large mass strandings are unknown from this region.

Sightings of pilot whales in the vicinity of the Operational Area are reasonably common with most occurring in summer (see Torres, 2012). Based on the sighting and stranding data, it is likely that long-finned pilot whales will be encountered during the Taranaki West 3D Seismic Survey.

4.2.4.3.15 Risso's dolphin

Risso's dolphins (*Grampus griseus*) are found throughout tropical and temperate oceans in deep waters of the continental slope and outer shelf (Kruse *et al.,* 1999). In particular, they are frequently associated with areas exhibiting steep seafloor topography (such as seamounts) where they are thought to feed at night on vertically migrating squid (Taylor *et al*.,, 2012). The skin of this species is characteristically scarred, and it is thought that squid bites may be responsible for at least some of this scarring. Risso's dolphins locate prey using short echolocation clicks with peak frequencies around 50 kHz (Madsen et al., 2004).

The stranding database holds three records for this species in the vicinity of the Operational Area, all of which are from the Manawatu coast. In addition, live sightings have been made off Taranaki, with a pod of 6 being sighted here in 2013.

4.2.4.3.16 Dusky dolphin

Dusky dolphins are primarily a coastal dolphin found in water depths less than 2,000 m above the continental shelf and slope. Dusky dolphins are more commonly seen in cooler waters around the South Island and lower North Island (Wursig *et al.,* 2007). The dusky dolphin is present year round in NZ waters (Berkenbusch *et al.,* 2013), and a population is resident in Admiralty Bay from April to July where they forage during the day. There is also a substantial population in the Kaikoura area, which has been estimated at 12,000 individuals, with approximately 2,000 individuals present at any one time (Markowitz *et al.,* 2004).

Little is known about dusky dolphin movements, but photo-identification data confirms that individuals travel up to 1,000 km between locations around the South Island (Wursig *et al*., 2007). Evidence also suggests that this species spends more time in offshore waters during the winter months (Wursig *et al.,* 2007). Dusky dolphins feed on a range of pelagic and benthic prey species including southern anchovy, squid, hake and lantern fishes (Hammond *et al*., 2008). They generally forage in relatively shallow waters, but can forage up to 130 m deep.

Few sighting records of dusky dolphins have been made in the vicinity of the Operational Area (see Torres, 2012); however, seven of the 16 sightings by Torres (2012) were in water depths greater than 100 m, including one in close proximity to the Operational Area. This information indicates that this species may occasionally use waters within the Operational Area, but is typically found further inshore in more sheltered waters.

4.2.4.3.17 Killer whale

Killer whales are the largest member of the dolphin family. They are widespread globally from warm equatorial to cold polar waters. A number of morphological forms of killer whales are recognised (Types A – D) (Baker *et al.,* 2010). The majority of killer whale sightings in NZ coastal waters are believed to be Type A, with other types occurring largely in Antarctic waters, but occasionally visiting waters around NZ (Visser, 2007). Type A killer whales are classified as 'nationally critical' by the NZ Threat Classification System on account of their small population size.

Type A killer whales have been seen in all coastal regions of NZ, including the South Taranaki Bight (Visser, 2000). The population size of Type A killer whales in NZ was estimated at 115 individuals (95% CI 65–167) in 1997 based on a photo identification catalogue of known individuals (Visser, 2000). Visser (2000) presented some evidence of seasonality of sightings in the greater Cook Strait area, with killer whales more likely to be present from November to February; however, Torres (2012) found sightings to be relatively evenly distributed through time and postulated that the peak in summer months may simply reflect an observational bias.

Killer whales are known to echolocate and to produce tonal sounds (whistles). Their whistles have been noted to possess an average dominant frequency of 8.3 kHz and to generally last 1.8 seconds (Thomsen *et al*., 2001). Variations of these whistles (often referred to as dialects) have been documented between pods (Deecke *et al.,* 2000). In addition, the use of echolocation has also been demonstrated to vary between groups, depending on the target prey species of a particular group (Barrett-Lennard *et al.,* 1999).

New Zealand killer whales are believed to travel an average of 100 – 150 km per day and most groups encountered are opportunistic foragers (Visser, 2000). Within the NZ Type A population there may be some finer scale geographic segregation of groups which is currently poorly understood (Visser, 2000; Olavarria *et al.,* 2014). Given their wide ranging, highly mobile nature, it is likely that this species passes through waters of the Operational Area from time to time, but sighting data indicates that this area is not of particular ecological significance (most sightings are further inshore). The mobility of this species and their typically opportunistic foraging behaviour indicates that killer whales can readily move between areas to maximise foraging opportunities and avoid disturbance.

It is possible that killer whales occasionally pass through the Operational Area and therefore they could be present during the Taranaki West 3D Seismic Survey.

4.2.4.3.18 False killer whale

False killer whales are present throughout tropical and warm tropical waters (Baird, 2002). In New Zealand this species is known to form close associations with bottlenose dolphins in shallow waters off north-eastern New Zealand to take advantage of warm oceanic waters here between December and May (Zaeschmaer, 2013). The diet of this species is largely comprised of fish and cephalopods that are targeted during dives of up to 500 m (Shirihai and Jarrett, 2006).

The stranding database holds two records for this species in the vicinity of the Operational Area (one from Taranaki and one from Manawatu), and one group of 12 false killer whales were sighted from a seismic survey in the Taranaki Basin in 2013.

4.2.4.3.19 Spotted and striped dolphins

The pantropical spotted dolphin (*Stenella attenuata*) and the striped dolphin (*S. coeruleoalba*) are rare visitors to New Zealand’s oceanic waters with concentrations typically associated with tropical and warm temperate waters. Both species use echolocation to detect prey items which include small fish, squid and crustaceans (Robertson and Chivers, 1997; Archer, 2002), with striped dolphins typically feeding in waters depths of 200 – 700 m (Hammond *et al*., 2008).

For both species, the southern extent of their latitudinal range is 40°S, which bisects the Operational Area; although sightings this far south are rare. The stranding database holds five records for this species in the vicinity of the Operational Area (three from Tasman, one from Taranaki and one from Manawatu).

4.2.4.3.20 Bottlenose dolphin

Bottlenose dolphins are widely distributed throughout the world in cold temperate and tropical seas, with NZ being the southernmost point of their range. There are three 'in-shore' populations of bottlenose dolphins in NZ; approximately 450 utilise habitat along the northeast coast of Northland, 60 utilise habitat in Fiordland and there is a largely unquantified population living in the coastal waters between the Marlborough Sounds and the West Coast. There appears to be little or no gene flow between the three in-shore populations (Baker *et al.,* 2010). In addition to the inshore populations, bottlenose dolphin sightings are common in offshore waters right around NZ where estimates suggest an 'offshore' population size of at least 163 individuals (Zaeschmar *et al.,* 2013). These offshore dolphins are typically seen in larger groups than the inshore dolphins (Torres, 2012). Torres (2012) documented only two sightings of what were presumed to be offshore dolphins. These sightings involved groups of > 50 individuals, with the closest sighting in offshore waters southeast of the Operational Area (Torres, 2012).

Bottlenose dolphins feed on fish, krill and crustaceans and are known to feed cooperatively (Shirihai & Jarrett, 2006). Bottlenose dolphins produce 'clicks' which are used for echolocation purposes (0.8-24 kHz) and 'whistles' which are used as a form of communication (40 – 130 kHz).

The relative lack of sightings for bottlenose dolphins in the South Taranaki Bight and surrounding waters suggests that this species only occasionally utilises this area and is therefore unlikely to be in the Operational Area during the Taranaki West 3D seismic survey.

4.2.5 Pinnipeds

Nine species of pinnipeds are known from NZ waters. Of these only the NZ fur seal is predicted to occur in the Operational Area.

4.2.5.1 NZ Fur Seal

New Zealand fur seals are native to NZ and Australia and have a wide distribution around mainland NZ and its offshore islands. On mainland NZ, breeding colonies are mostly located in the South Island. Commercial sealing ceased in 1894, and this species has subsequently been undergoing a recolonisation of its historic range, with an increase in population size and an expansion northwards of its breeding distribution (Lalas & Bradshaw, 2001). A reliable total abundance estimate is not available for this species, but estimates in the vicinity of 100,000 individuals have been suggested (Harcourt, 2001).

New Zealand fur seals often forage along continental shelf breaks, but foraging habitat varies with season whereby both inshore and deeper offshore foraging habitat is used throughout the year (Harcourt *et al.,* 2002; Mattlin *et al.,* 1998). They are known to dive for up to 12 minutes (~ 200 m) (Mattlin *et al.,* 1998) to feed on fish (e.g. lantern fish, hoki, barracouta, ahuru and jack mackerel,) and cephalopods (arrow squid and octopus) (as summarised by Baird, 2011).

The breeding season for NZ fur seals extends from mid-November to mid-January, with peak pupping occurring in mid-December (Crawley & Wilson, 1976). Pups are suckled for approximately 300 days, during which females will alternate between foraging at sea and returning to the rookery to feed their young (Boren, 2005). Breeding colonies are a considerable distance from the Operational Area, with the closest located at Pillar Point at the base of Farewell Spit in the southeast and the Sugar Loaf Islands Marine Protected Area, just off New Plymouth in the east.

New Zealand fur seals are consistently observed in offshore New Zealand waters, particularly in the vicinity of continental shelf breaks which are thought to represent important foraging habitat. A shelf break runs through the Operational Area; hence this species will certainly be seen during the Taranaki West 3D Seismic Survey.

4.2.6 Marine Reptiles

There are seven species of marine reptiles known to occur in NZ waters: the logger head turtle, the green turtle, the hawksbill turtle, the olive Ridley turtle, the leatherback turtle, the yellow-bellied sea snake and the banded sea snake (DOC, 2015b). Apart from the leatherback sea turtles, marine reptiles are generally found in warm temperate waters and as a result most of NZ's marine reptiles are found off the northeast coast of the North Island.

Marine reptiles do occasionally visit waters off central NZ, although mainly during summer months when the warmer currents push down the western side of NZ. Loggerhead turtles, olive ridley turtles, leatherback turtles, and yellow-bellied sea snakes have been observed in the vicinity of the Operational Area (DOC, 2015b); however, they are rare visitors and are unlikely to be present during the Taranaki West 3D seismic survey.

4.2.7 Seabirds

NZ supports the most diverse seabird assemblage on earth, 86 species of seabird utilise the marine waters off NZ (DOC, 2015c), and 84 breed in NZ waters (MacDiarmid *et al.,* 2011). Approximately half of the breeding seabirds are classified as endemic (Taylor, 2000). The seabirds present in NZ include albatross, cormorants/shags, fulmars, petrels, prions, shearwaters, terns, gulls, penguins, and skuas.

The Taranaki Bight and surrounding waters is visited by a large diversity of seabirds that either pass through or use the area as a foraging destination. Various references, e.g. NABIS (2015) Scofield & Stephenson (2013), Robertson *et al.* (2013), and NZ Birds Online (2015) have been used to identify the offshore seabirds most likely to be observed in and around the Operational Area. A summary of these species is presented in **Table 8**.

Table 8: Seabird Species Potentially Present in the Operational Area

Common Name	Scientific Name	NZ Threat Status (Robertson *et al*. 2013)
Gibson's albatross	*Diomedea antipodensis gibsoni*	Nationally Critical
Antipodean Albatross	*Diomedea antipodensis antipodensis*	Nationally Critical
Salvin's mollymawk	*Thalassarche salvini*	Nationally Critical
Black petrel	*Procellaria parkinsoni*	Nationally Vulnerable
Flesh-footed shearwater	*Puffinus carneipes*	Nationally Vulnerable
Hutton's shearwater	*Puffinus huttoni*	Declining
White-chinned petrel	*Procellaria aequinoctialis*	Declining
Sooty shearwater	*Puffinus griseus*	Declining
White-fronted tern	*Sterna striata striata*	Declining
Northern diving petrel	*Pelecanoides urinatrix urinatrix*	Relict
Fluttering shearwater	*Puffinus gavia*	Relict
Broad-billed prion	*Pachyptla vittata*	Relict
Cook's petrel	*Pterodroma cookie*	Relict
Mottled petrel	*Pterodroma inexpectata*	Relict
Grey-backed storm petrel	*Garrodia nereis*	Relict
White-faced storm petrel	*Pelagodroma marina maoriana*	Relict
Fairy prion	*Pachyptila turtur*	Relict
Northern royal albatross	*Diomedea epomophora Sandfordi*	Naturally Uncommon
Southern royal albatross	*Diomedea epomophora epomophora*	Naturally Uncommon
Buller's mollymawk	*Thalassarche bulleri bulleri*	Naturally Uncommon

Campbell Island mollymawk	*Thalassarche impavida*	Naturally Uncommon
Chatham Island mollymawk	*Thalassarche eremita*	Naturally Uncommon
Northern giant petrel	*Macronectes halli*	Naturally Uncommon
Grey petrel	*Procellaria cinerea*	Naturally Uncommon
Snare's cape petrel	*Daption capense austral*	Naturally Uncommon
Westland petrel	*Procellaria westlandica*	Naturally Uncommon
Buller's shearwater	*Puffinus bulleri*	Naturally Uncommon
Brown skua	*Catharacta anterctica lonnbergi*	Naturally Uncommon
Arctic skua	*Stercorarius parasiticus*	Migrant
Arctic tern	*Sterna paradisaea*	Migrant
Wandering/snowy albatross	*Diomedea exulans*	Migrant
Short-tailed shearwater	*Puffinus tenuirostris*	Migrant
Southern giant petrel	*Macronectes giganteus*	Migrant
Wilson's storm petrel	*Oceanites oceanicus*	Migrant
Snare's Cape Petrel/Cape pigeon	*Daption capense capense*	Migrant
Black browed mollymawk	*Thalassarche melanophys*	Coloniser
Indian ocean yellow-nosed mollymawk	*Thalassarche carteri*	Coloniser
Australasian gannet	*Morus serrator*	Not Threatened
White-headed petrel	*Pterodroma lessonii*	Not Threatened
Grey faced petrel	*Pterodroma macroptera gouldi*	Not Threatened

4.2.7.1 Seabird Breeding Areas

New Zealand has the greatest number of endemic breeding seabird species worldwide. No seabird breeding occurs within the Operational Area. In addition, due to the distance from the closest coastal area (Farewell Spit is approximately 75 km away); no seabird breeding areas will be affected by the Taranaki West 3D Seismic Survey.

4.3 Overview of Marine Ecosystem

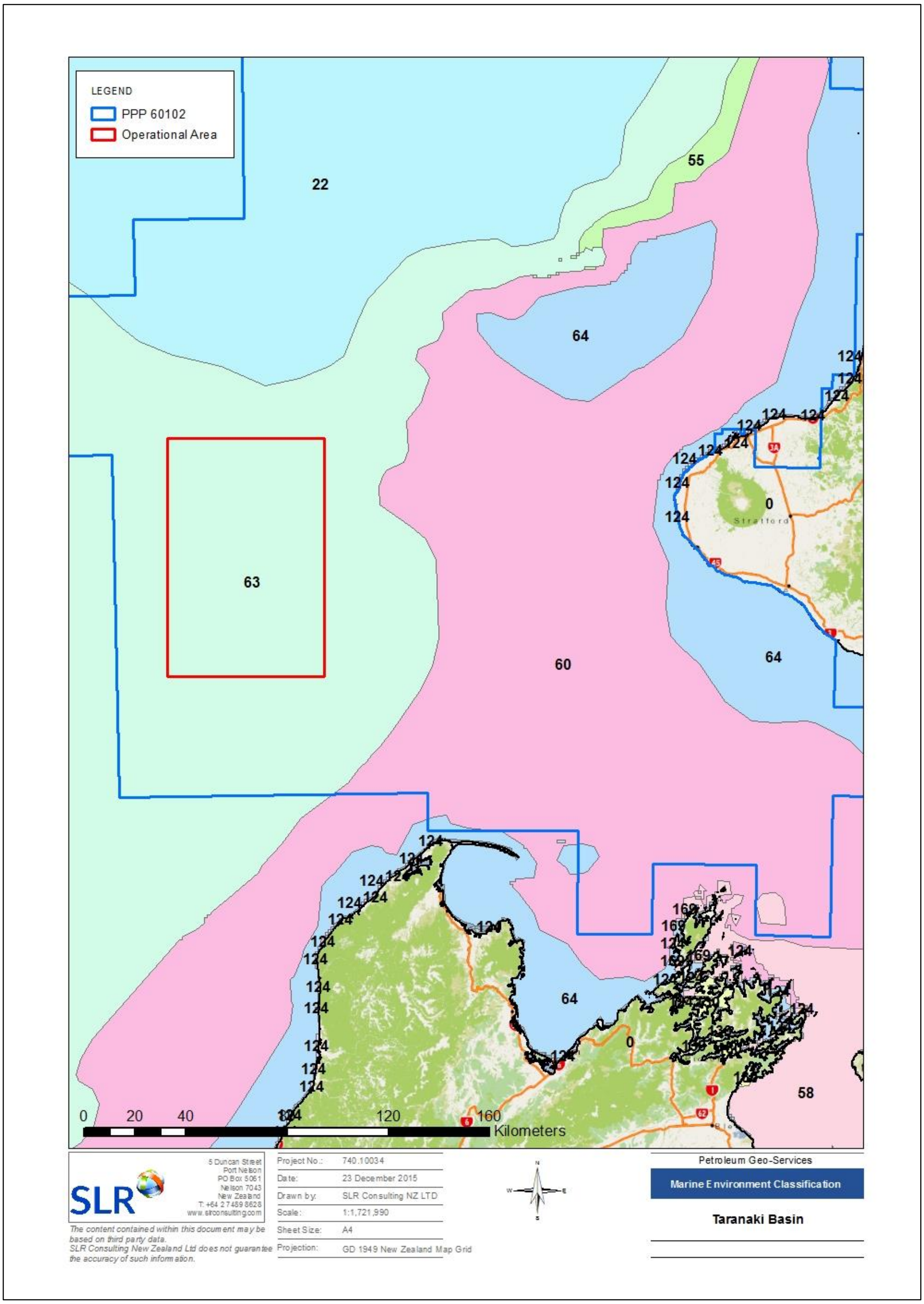
4.3.1 New Zealand Marine Environmental Classification

The NZ Marine Environment Classification covers NZ's Territorial Sea and EEZ and provides a spatial framework for structured and systematic management. Geographic domains are divided into units that have similar environmental and biological characters (Snelder *et al.,* 2005). Units are characterised by physical and biological factors (i.e. depth, solar radiation, sea surface temperatures, waves, tidal current, sediment type, seabed slope and curvature).

Under the NZ Marine Environmental Classification 20-class level the Taranaki West 3D Seismic Survey falls within group 63 (**Figure 14**). These groups are described in further detail below, following the definitions by NIWA (Snelder *et al.,* 2005).

Class 63: is extensive on the continental shelf including much of the Challenger Plateau and the Chatham Rise. Waters are of moderate depth (mean = 754 m) and have moderate annual radiation and wintertime SST. Average chlorophyll a concentrations are also moderate. Characteristic fish species (29 sites) include orange roughy, Johnson's cod, Baxter's lantern dogfish, hoki, smooth oreo and javelin fish. The most commonly represented benthic invertebrate families (14 sites) are Carditidae, Pectinidae, Dentaliidae, Veneridae, Cardiidae, Serpulidae and Limidae.

Figure 14: NZ Marine Environmental Classifications around the Operational Area



4.3.2 Regional Coastal Environment

The Operational Area is located well offshore and does not approach the coast. As the coastal environment will not be affected by the Taranaki West 3D Seismic Survey, no further details of the coastal environment or associated protected natural areas are included in this MMIA.

4.4 Cultural Environment

The concept of whakapapa is fundamental to Māori culture. It is defined as the genealogical descent of all living things from gods to the present time. Since whakapapa is extended beyond the sphere of the living to things such as rocks and mountains, it implies not only a strong sense of genealogy, but also the interconnectedness between Māori and the natural environment.

Māori believe in the importance of protecting Papatuanuku (earth) including the footprints and stories left on the whenua (land) and wai (water) by ancestors. This is exemplified by the role of kaitiakitanga (guardianship) which is passed down from generation to generation. The role of kaitiakitanga is central to the preservation of wahi tapu (sacred places or sites) and taonga (treasures).

Tangaroa (the ocean) is treasured by all Māori communities. It is valued as a source of kaimoana (seafood) and for its commercial fisheries, for its estuaries and coastal waters, for its wahi tapu and spiritual pathways, and for transport and communication (Nga Uri O Tahinga Trust, 2012). Although the conservation of many of these features is discussed in other sections of this report, it is important to stress their equal cultural, spiritual and historical significance to iwi. As custodians of rohe moana (a coastal and marine area over which an iwi or a hapū exercises its kaitiakitanga), kaitiakitanga calls upon ancestral knowledge to manage the natural resources.

Of particular cultural importance is the coastal environment. Although the Operational Area does not overlap with the coastal environment, and no cultural concerns with regard to the Taranaki West 3D Seismic Survey were raised by iwi during consultation, the sections below outlining a brief overview of iwi along the Taranaki and Top of the South coast have been included for completeness.

4.4.1.1 TeTai Hauāuru

The Te Tai Hauāuru/Taranaki region is subdivided among eight iwi: Ngāti Tama, Ngāti Mutunga, Te Ātiawa, Taranaki, Ngā Ruahine, Ngāti Ruānui, Ngā Rauru and Ngati Maru. Māori settlers first arrived in the region between 1250 and 1300 AD but in the early 1800s war parties descended into Taranaki and many people migrated south.

The coastal environment within the rohe of Taranaki iwi contains a number of features and resources of value. The Coastal Marine Area is known to Taranaki iwi as Ngā Tai a Kupe (the shores and tides of Kupe). Resources found along the extent of the coastline of Ngā Tai a Kupe provide iwi with a constant supply of food. The reefs provide paua, kina, kōura (crayfish), kūkū (mussels), pūpū (molluscs), ngākihi (limpets), pāpaka (crab), toretore (sea anemones), and many other reef species, while tāmure, kahawai, pātiki (flounder/flatfish), mako and other fish are caught along the coastline in nets and on fishing lines.

The Mohakatino coastal region is a testimony to this troubled past as it was the scene of numerous battles between Ngāti Tama and northern iwi and now contains numerous urupa (burial sites). The disputed nature of this land has also contributed to the value of the mātaitai resources in the area (TRC, 2015).

The coastal strip extending south from Pukearuhe to Mimi also contains many wahi tapu sites. In particular, the pā sites (Māori villages - Titooki, Whakarewa, Otumatua and Pukearuhe) and the cliffs in the area are central to Ngāti Tama heritage. The cliffs were used to develop a unique fishing technique applied to catch mako (shark), tamure (snapper), and araara (trevally). Additionally, they contained many tauranga waka (canoe berths) which have now become physical symbols of an historical association with the area (TRC, 2010). The Paraninihi Marine Reserve is located along this coastline and is managed using an “integrated management approach” that involves Ngāti Tama iwi authority in decision making alongside DOC and the Conservation Board.

Ngāti Mutunga iwi’s strong sense of tradition illustrates its cultural, historical and spiritual links to the marine environment. The iwi heavily relies on natural resources as food supplies and to this day, food is gathered within the rohe moana between Titoki Ridge and Waiau Stream following traditional values and tikanga (teachings). Similarly to Ngāti Tama, Ngā Mutunga used the cliffs to fish mako, tamure, kahawai, and araara. The cliffs also hold numerous tauranga waka (canoe berths).

Te Ātiawa rohe ranges from Te Rau o te Huia to Herekawe Stream. Historically, Te Ātiawa people migrated south in large numbers in response to attacks from northern iwi. Many Te Ātiawa people returned to Taranaki in the middle of the 19th century. As with all coastal iwi, many heritage features including wahi taapu and traditional food gathering sites lie along the coastline of this rohe. Te Ātiawa iwi authority applied for a recognition agreement with the crown which was subsequently confirmed and covers the common marine and coastal area extending from the Herekawe Stream to the Onaero River in Te Atiawa's rohe (from mean high water springs on the landward side, out to 12 Nm).

Numerous sites of significance can be found along the coastline between Onukutaipari to Ouri Stream. Kaimoana reefs and waahi tapu which hold particular meaning to Taranaki iwi are counted among them (although these have not yet all been located). Moreover, Taranaki iwi places substantial historical and spiritual importance in the Sugar Loaf (Ngā Motu) Islands.

The rohe of Ngā Ruahine lies to the south of Cape Egmont; the coastal boundaries begin at Taurangatara Stream in the north and continue south to Hawera (TKM, 2015), forming the southern boundary of Taranaki iwi. Ngā ruahine is collectively made up of various hapu, including Kanihi-Umutahi, Okahu-Inuawai, Ngati Manuhiakai, Ngati Tu, Ngati Haua, and Ngati Tamaahuroa-Titahi. These hapu all claim ancestry back to the Aotea waka, captained by Turi, however each hapu differs in their eponymous tupuna (name-sake) and residence and rohe (Nga Ruahine, 2014).

The people of Ngati Ruanui descended from Ruanaui, the son of Turi’s daughter Tāneriria. Within a few generations, the descendants of Ruanaui had dispersed throughout South Taranaki to become the main tribe in the south (Te Ara, 2015). The rohe of Ngati Ruanui lies between the Waingongoro River near Hawera and the Whenuakura River, south of Patea (TKM, 2015).

The people of Ngā Rauru descend from early ancestors who came to South Taranaki from the east coast of the North Island. These people travelled by sea and eventually landed at Patea and Waitotara. With the arrival of the Aotea canoe, the early ancestors married the Turi descendants from the Aotea (Te Ara, 2015). As at 1840, the rohe of Ngā Rauru lay at Kaihau-a-Kupe (the mouth of the Whanganui River) where six settlements were found, then extended from Kaieerau along the watershed to Motuhou, Kaihokahoka (ki uta), Taurangapiopio, Mataimoana, Taurangakawa and north into the Matemateaonga Ranges. Along the coastline of Ngā Rauru’s rohe lay a number of pa, kainga and marae, including Rangitaawhi and Wai-o-Turi which remains today (Ngaa Rauru Kiitahi, 2003).

4.4.1.1.1 Te Tau Ihu Iwi

Eight tangata whenua tribes have interests in the top of the South Island: Rangitāne, Ngāti Kuia, Ngāti Apa, Ngāti Toa, Ngāti Koata, Ngāti Rarua, Ngāti Tama, and Te Atiawa. Rangitāne, Ngāti Kuia, and Ngāti Apa are of Kurahaupo waka origins, Ngāti Toa, Ngāti Koata, and Ngāti Rarua descend from the Tainui waka, while Ngāti Tama and Te Atiawa are from northern Taranaki (Tokomaru and Kurahaupo waka, respectively) (The Prow, 2015). During the consultation process for the Taranaki West 3D Seismic Survey, only three of the Te Tau Ihu iwi were involved with face-to-face meetings. These were the iwi represented by Manawhenua ki Mohua (Ngati Tama, Te Atiawa and Ngati Rarua). The remaining five iwi groups received letters about the survey. The decision to only involve Manawhenua ki Mohua iwi in direct consultation was made based on their particular interests in Golden Bay, the closest region to the Operational Area.

Ngāti Kuia descended from three ancestors who disembarked from the Kurahaupo in north-west Nelson as the waka circumnavigated NZ upon arrival from Hawaiki. Ngāti Kuia migrated eastwards, eventually establishing settlements in the Pelorus Valley and Sounds, D'Urville Island, and along the eastern coast of Tasman Bay (The Prow, 2015).

Rangitane migrated south from the Wairarapa, led by chiefs who traded land at Wairarapa for waka to travel to the South Island. Through battles and shifting alliances they developed positions in the Wairau, Queen Charlotte Sound, Awatere and northern Kaikoura Coast (The Prow, 2015).

A small number of Ngāti Apa first crossed to the outer Marlborough Sounds from the Rangitikei district. Troops from the Rangitikei, Manawatu and Kapiti districts mounted a sizeable assault on Ngāti Tumatakoiri in the western top of the south, eventually overthrowing Tumatakokiri. After Tumatakokiri's defeat by Ngāti Apa, Ngāti Kuia and Ngāi Tahu, Ngāti Apa consolidated their holdings from the Waimea west to Golden Bay and Buller, as well as in Queen Charlotte Sound (The Prow, 2015).

Ngāti Toa, Ngāti Koata and Ngāti Rarua had been forced to abandon their lands around Kawhia Harbour by their better-armed Tainui cousins, Waikato and Ngāti Maniapoto. After a stay with relatives in north Taranaki, the Toa chief, Te Rauparaha, led Te Heke Tataramoa down the west coast of the North Island. The Kawhia tribes and contingents of Ngāti Tama, Ngāti Mutunga and Te Atiawa conquered and occupied the districts of Rangitikei, Manawatu, Horowhenu, Otaki, Porirua and Wellington (The Prow, 2015). After establishing themselves there, the allies turned their attention to the South Island to get utu (revenge) on Kurahaupo who had challenged them at Kapiti, and to avenge insults. From 1828 – 1832 war parties conquered Te Tau Ihu, with iwi subsequently agreeing on the division of lands. Ngāti Toa and some Ngāti Rarua occupied the Wairau, Port Underwood and northern Kaikoura. Te Atiawa spread through Queen Charlotte Sounds and Tory Channel. Ngāti Koata settled at D'Urville Island, the Croisilles and outer Pelorus, while Ngāti Toa stayed in Pelorus Valley and the inner Sound. Ngāti Tama got Nelson, while Te Atiawa and some Tama occupied Motueka, Mohua and Te Tai Tapu (west coast south of Farewell Spit) (The Prow, 2015).

For the Iwi of Te Tau Ihu, their associations with the coastal marine area are an integral part of their identity. The marine area is culturally, spiritually, historically and traditionally significant to the Iwi of Te Tau Ihu; whānau were (and still are) dependant on the coast for their physical and spiritual wellbeing. This connection with the coast and associated resources is due to a number of reasons such as the creation of pūrākau (legends), the length of occupation, the abundance of natural resources, and the coastal trails found across the region. Stretches of coastline were clearly acknowledged and recognised as belonging to, and being defended by, a particular hapū. Pā, kainga, and fishing stations were built along the coast in the Sounds, Tasman and Golden Bays (Te Tau Ihu, 2014).

Coastal fisheries and other resources were controlled and managed by the various hapū. Almost every type of kaimoana could be found along the coast. The estuaries, beaches and offshore islands of Te Tau Ihu provided the tūpuna (ancestors) of modern day Māori with a bountiful supply of marine mammals, sea birds, shellfish, fish, and plant life. Estuarine areas were especially prized and contained pā, kainga and important fishing stations. In the mud and sand, tūpuna collected tuangi (cockles), pipi, tuatua, pūpū, kūtai (mussels) and tio (oysters) while inanga, tuna (eels) and kokopū were harvested from the rivers and streams. In the breeding season tāmure, kanae (mullet), herrings, pātiki, sole, mango, kahawai, mackerel, and warehou were caught. Birds were harvested for a range of uses, including the use of their feathers for garment decoration. Marine mammals (whales and seals) were also harvested and highly valued; whales were harvested for their oil, flesh, bones and teeth, while seals provided meat and skins (Te Tau Ihu, 2014).

4.4.2 Customary Fishing and Iwi Fisheries Interests

Māori maintain a strong relationship with the sea; the collection of kaimoana is a fundamental part of their life. For coastal hapū, kaimoana is often vital to sustain the mauri (life force) of tangata whenua, and provides an important food source for whānau (family) and hospitality to manuhiri (guests). The ability to provide reasonable amounts of these foods is a marker of a tribe’s mana (power/status) (Tainui Waikato, 2013). There are a number of marine species which iwi value highly such as: snapper, kahawai, blue cod, flat fish, sharks, grey mullet, sea urchin (kina), scallops, mussels, paua, pipi, toheroa, cockles and tuatua. Traditional management of the marine environment entails a whole body of knowledge on the sea’s natural resources, their seasonality and the manner in which they can be harvested. This customary wisdom is held sacred by tangata whenua and only passed on to those who will look after it.

Under the Maori Fisheries Act (2004) recognised iwi across the country were allocated fisheries assets including fishing quota. In addition to the fishing quota held by individual iwi, each recognised iwi is allocated income shares in Aotearoa Fisheries Limited which is managed and overseen by Te Ohu Kai Moana (Maori Fisheries Commission).

NZ iwi also have customary fishing rights which are provided for under the Fisheries (Kaimoana Customary Fishing) Regulations 1998. These regulations stem from the Treaty of Waitangi (Fisheries Claims) Settlement Act (1992) and are separate, and in addition to, the commercial fisheries assets described above.

The allocation of customary fishing rights is undertaken by Tangata Kaitiaki/Tiaki in accordance with tikanga Māori (customs and practices). Tangata Kaitiaki/Tiaki are individuals or groups appointed by the local Tangata Whenua and confirmed by the Minister of Fisheries that can authorise customary fishing with their rohe moana (see Section **4.4.2.1**). Under the regulations, customary fishing rights can be caught by commercial fishing vessels on behalf of the holder of the customary fishing right. However, all of the catch under a customary fishing authorisation can only be used for customary purposes such as tangi (funerals) and cannot be commercially sold or traded. Customary fishing rights are in addition to recreational fishing rights and do not remove the right of Tangata Whenua to catch their recreational limits.

4.4.2.1 Rohe Moana

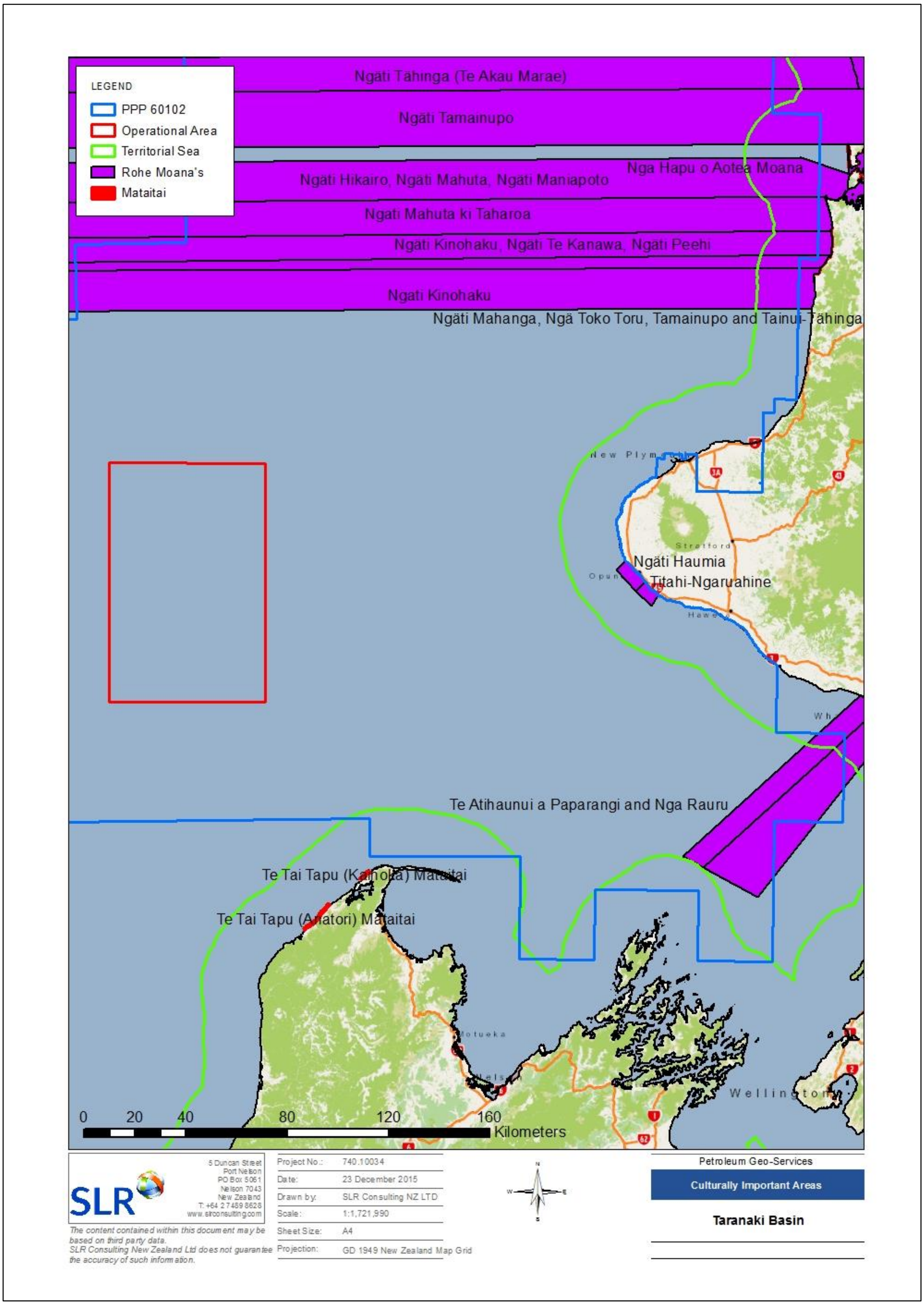
The Fisheries (Kaimoana Customary Fishing) Regulations (1998) allows traditional management to govern the fishing practices within an area deemed significant to Tangata Whenua. Under these regulations, Tangata Whenua can establish management areas to oversee fishing within these areas and create management plans for their overall area of interest. Customary management areas include Taiapure, Mataitai Reserves and rohe moana. Of these areas, only rohe moana are of relevance to the Operational Area.

A rohe moana is an area where kaitiaki are appointed for the management of customary kaimoana collection within their rohe under the Kaimoana Customary Fishing Regulations (1998). The Customary Fishing Regulations allow hapū to: appoint kaitiaki, establish management controls, give authorisation/permits to exercise customary take, specify responsibility for those acting under the customary fishing regulations, provide penalties to be imposed for any breach of the regulations, and allow for restrictions or prohibitions over certain areas to prevent stock depletion or overexploitation. The purpose of the rohe moana is for the better provision for the recognition of Rangitiratanga (sovereignty) and of the right secured in relation to fisheries by Article II of the Treaty of Waitangi.

There are a number of rohe moana north of the Operational Area which extend from the coastline out to the EEZ (**Figure 15**); however no rohe moana are in the immediate vicinity of the Operational Area.

An additional rohe moana, the 'Deepwater Customary Pataka' has been proposed. This pataka (food supply) represents an agreement between 16 iwi groups, Sealords and Te Ohu Kaimoana to facilitate customary fishing in the deeper waters of South Taranaki Bight. In essence, the Sealords fleet will be able to take fish for customary purposes and supply the customary catch to the relevant iwi interest groups for customary events such as tangi (funerals).

Figure 15: Rohe Moana in the Vicinity of the Operational Area



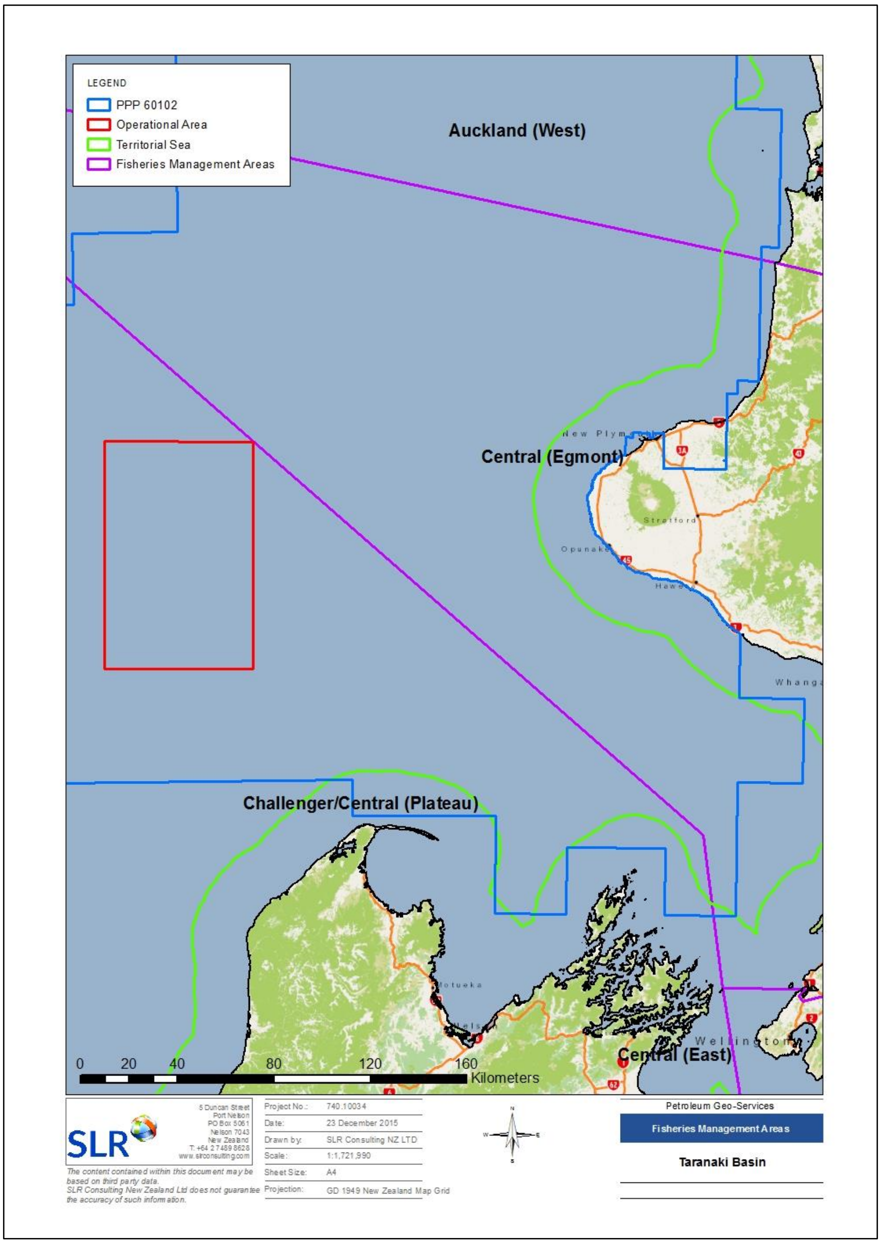
4.5 Economic Environment

This section focuses on the users of the environment within and in the vicinity of the Operational Area. Particular emphasis has been put on commercial fishing, shipping, and the petroleum industry.

4.5.1 Commercial Fishing

Ten Fisheries Management Areas have been implemented within NZ waters in order to manage the Quota Management System, with the Operational Area falling within areas FMA7 (Challenger) and FMA8 (Central) (**Figure 16**). These management areas are regulated by the Ministry for Primary Industries. Over 1,000 fish species occur in NZ waters (Te Ara, 2015a), with the Quota Management System providing for the commercial utilisation and sustainable catch of 96 species. These 96 species are divided into separate stocks, with each stock managed independently.

Figure 16: Fisheries Management Areas within NZ waters



Finfish species caught within FMA7 and FMA8 are listed in **Table 9**. Here the top five species, according to reported commercial catch for the 2014/2015 fishing year are presented.

Table 9: Total Allowable Commercial Catch Allocations for Finfish in FMA7/8

FMA7		FMA8	
Species	**Catch (tonnes)**	**Species**	**Catch (tonnes)**
Barracouta	6,974	Trevally	1,824
Red Cod	1,482	Tarakihi	1,463
Stargazer	1,093	Snapper	1,272
Spiny Dogfish	1,015	Gurnard	1,019
Tarakihi	1,002	Grey Mullet	898

Although **Table 9** provides an indication of targeted fish species, the Operational Area is much smaller than FMA7 and FMA8 combined; therefore, regional variations are not well represented by catch data. Jack mackerel, for instance, is not considered one of the top five species by catch for these two fishing areas, yet consultation indicated that this is the fleet most likely to overlap spatially with the Taranaki West 3D Seismic Survey. Also, care must be taken when interpreting this catch data as the small size of the Operational Area compared to the FMA's may exaggerate the amount of fish caught within the Operational Area.

Consultation has been undertaken with Deepwater Group, Sealords, Talley's, Egmont Seafoods, Compass Rose Fisheries and Whanganui Iwi Fisheries to advise them of the proposed seismic operations and the span of gear that will be used. A summary of engagements is provided in **Appendix C**. These companies will be provided with contact details of the vessel closer to the commencement date.

4.5.2 Commercial Shipping

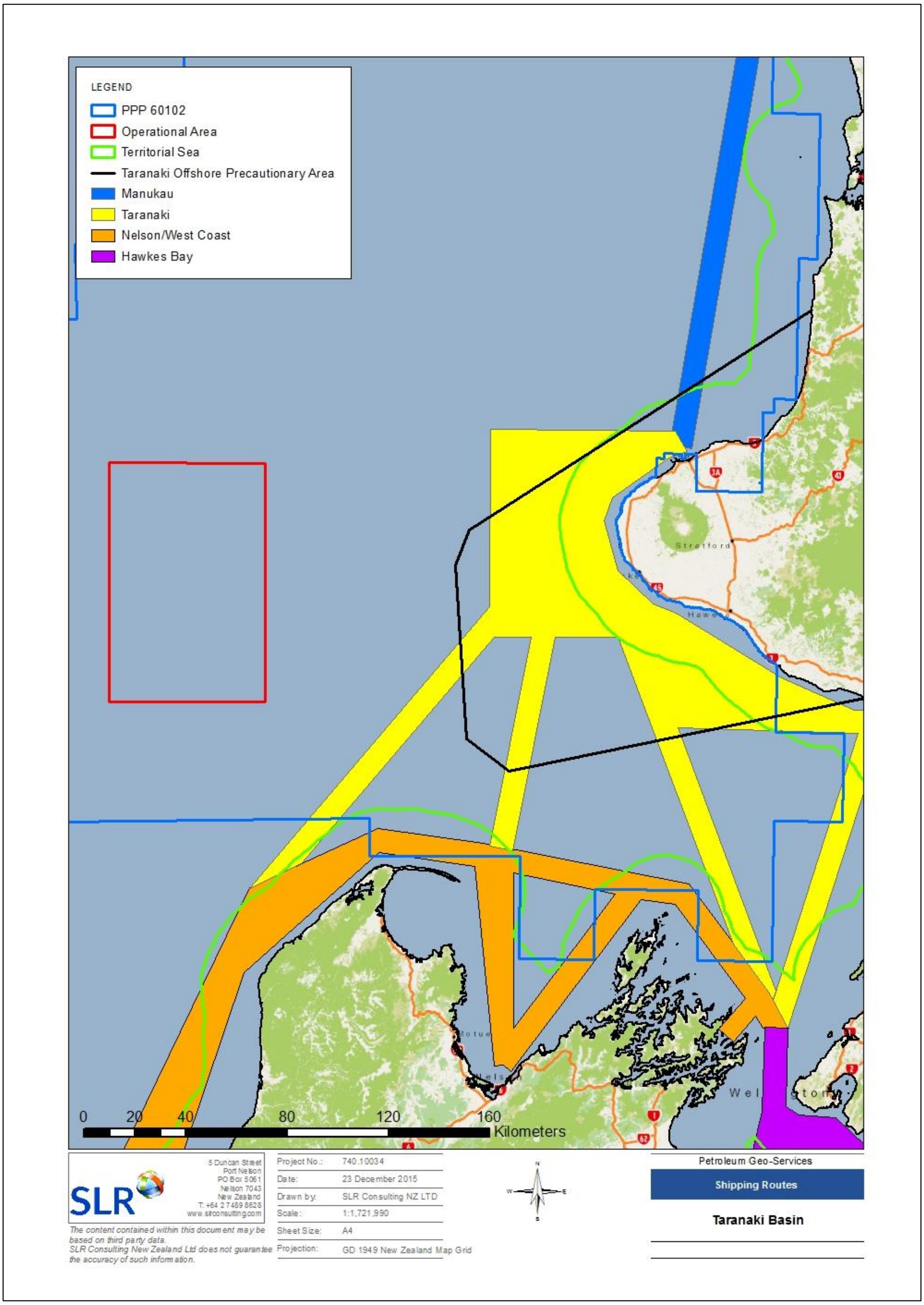
Port Taranaki and Port Nelson are the closest of the major ports to the Operational Area. Port Taranaki is situated along the west coast of the North Island at New Plymouth, while Port Nelson is located along the top of the South Island in Nelson.

Port Taranaki is the only deep water seaport on NZ's west coast, and has a maximum draft of 12.5 m. It is a modern port, offering nine fully serviced berths that cater to a wide variety of cargo requirements. Cargo moving through Port Taranaki is typically related to the farming, engineering and petrochemical industries.

Port Nelson services key local industries including forestry, fishing and pip fruit exports. It provides modern infrastructure, the third largest slipway in New Zealand, and is the most accessible port in the country. The main channel is dredged annually in order to maintain a depth of 7.6 m at chart datum (the lowest expected tide level).

There are no dedicated shipping lanes between Port Taranaki, Port Nelson and any other NZ port; commercial shipping vessels will take the shortest route with consideration of the weather conditions and forecast at the time. The general shipping routes between NZ ports in the vicinity of the Operational Area are shown in **Figure 17.**

Figure 17: General Shipping Routes Within and Surrounding the Operational Area



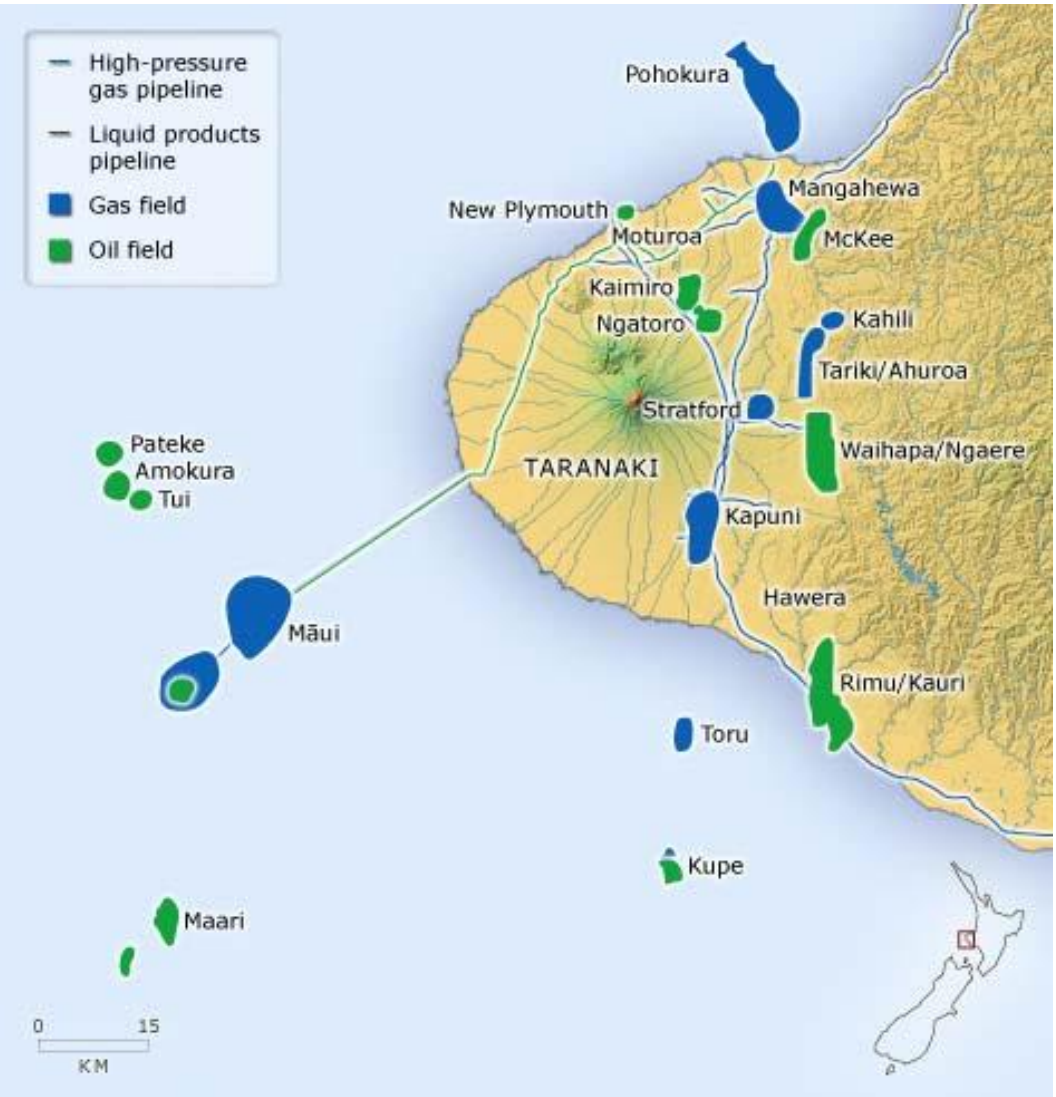
4.5.3 Petroleum Exploration

Hydrocarbon exploration and production activities in Taranaki have been ongoing for the last 100 years and offshore for more than 50 years. Since exploration began, more than 350 onshore and offshore wells have been drilled. All of New Zealand's offshore producing oil and gas fields are currently located in the Taranaki Basin. Producing offshore fields include: Maari, Māui, Kupe, Pohokura, and Tui (**Figure 18**). All of these fields are inshore of the Operational Area.

The use of seismic surveys for exploration has been commonplace off the Taranaki coastline since the 1950s. To date, there have been no recorded incidents of harm to marine mammals as a result of seismic operations in the Taranaki Basin.

SLR or PGS are not aware of any concurrent seismic surveys on the west coast of New Zealand during the proposed operational period.

Figure 18: Oil and Gas Fields in the Taranaki Basin



(**Source:** http://www.teara.govt.nz/en/map/8934/taranaki-oil-and-gas-fields-2006)

5 POTENTIAL ENVIRONMENTAL EFFECTS AND MITIGATION MEASURES

This section presents an overview of the potential environmental effects that may arise from the operation of the Taranaki West 3D Seismic Survey. Effects could potentially occur either under normal operating situations (planned activities) or during an accidental incident (unplanned event). Proposed mitigation measures are also provided throughout this section.

An Environmental Risk Assessment (ERA) has been undertaken using a risk matrix to identify the significance of each potential effect based on a likelihood and consequence approach (**Table 10**). The joint Australian & NZ International Standard Risk Management – Principles and Guidelines, (ASNZS ISO 31000:2009) has been used to develop the ERA. These guidelines define risk as 'the uncertainty upon objectives', while the effect is a deviation from the expected – either positive or negative. This assessment considers the consequence (**Table 11**) and likelihood (**Table 12**) of each potential environmental effect, including its geographical scale (site, local and regional) and its duration. A description of the risk matrix categories is provided in **Table 13.**

The predicted effect in the ERA matrix is based on the assumption that proposed mitigation measures to avoid remedy or mitigate environmental effects are in place. The predicted effect of each activity covered in this report is discussed in the following sections.

The main steps used in the ERA are:

- Identification of the activities (planned and unplanned) that might result in potential environmental effects or effects on existing marine users;
- Identification of the key potential environmental sensitivities vulnerable to those identified activities; and
- Development of measures to be implemented to avoid, remedy or mitigate each potential effect.

Table 10: Environmental Risk Assessment

		Consequence of Effect			
		4 - Negligible	**3 - Minor**	**2 - Moderate**	**1 - Major**
Likelihood of Effect	**1 - Almost certain**	High	High	Extreme	Extreme
	2 - Likely	Medium	Medium	High	Extreme
	3 - Possible	Low	Medium	Medium	High
	4 - Unlikely	Low	Low	Medium	High

Table 11: Consequence Definitions for Marine Effects

Consequence level	Marine Fauna	Environment & Recovery Period	Natural Environment and Ecosystem functional effects	Proportion of habitat affected	Existing Interests (commercial fishers, recreational fishers, cultural interests, maritime traffic)
1 - Major	Regional medium-term or local long-term impact to communities and populations. Affects recruitment levels of populations or their capacity to increase.	Recovery measured in months up to a year if seismic activities are stopped. Large scale (10-100 km^2).	A major change to ecosystem structure and function with potential for total collapse of some ecosystem processes. Different dynamics now occur with different species or groups now affected. Diversity of most groups is drastically reduced and most ecological functional groups (primary producers etc.) have disappeared. Most ecosystem functions such as carbon cycling, nutrient cycling, flushing and uptake have declined to very low levels.	Activity may result in major changes to ecosystem or region; 60-100% of habitat effected.	Recovery longer term if seismic activities are stopped. Significant change required to the existing interests activities.
2 - Moderate	Local medium-term impact to communities and populations. But long-term recruitment/ dynamics not adversely impacted.	Recovery short term (weeks-months) if activity stopped. Medium scale (1-10 km^2).	Ecosystem function altered measurably and some function or components are missing/ declining/ increasing well outside historical acceptable range and/or allowed/ facilitated new species to appear.	Potential adverse effects more widespread; 20-60% of habitat is affected.	Recovery short term if seismic activities are stopped. Existing interests may have to alter their activities as a result of the seismic operations for a short period of time.
3 - Minor	Local short-term impact to communities and populations. Does not threaten viability of community or population.	Rapid recovery would occur if stopped. Localised (<1 km^2). Short term (weeks) impact.	Measurable changes to the ecosystem components (biological or physical environment) without there being a major change in function (i.e. no loss of components). Affected species do not play a keystone role - only minor changes in relative abundance of other constituents.	Measurable but localised; potential effects are slightly more widespread; 5-20% of habitat area is affected.	Localised effect and short term impact. Recovery to the existing interest activities would occur if seismic activities stopped.
4 – Negligible	No detectable adverse effects to communities or populations of these species.	Localised effect (immediate area). Temporary impact (days).	Interactions may be occurring but it is unlikely that there would be any change outside of natural variation. No lasting effects.	Measurable but localised, affecting 1-5% of area of original habitat area.	No effect. No negative interactions with existing interests to carry out their normal activities.

Table 12: Definition of 'Likelihood' of Effect

Likelihood	Definition
1 - Almost Certain	Will occur many times. Will be continuously experienced unless action is taken to change events.
2 - Likely	Likely to occur 50-99% of the time. Will occur often if events follow normal patterns of process or procedure.
3 - Possible	Uncommon, but possible to occur, for 25-50% of the time.
4 - Unlikely	Unlikely to occur but may occur in for 1-25% of the time.

Table 13: Risk Matrix Categories

	Extreme Risk: (1 – 2)	Significant/fatal impacts to marine mammals, marine fauna, marine environment or existing users of the marine environment. Unacceptable for project to continue under existing circumstances. Requires immediate action and mitigation measures to be implemented, and once implemented will take a relatively long period of time to recover, in some cases not at all. Seismic operations would be shut down.
	High Risk: (3 – 4)	Behavioural effects to marine mammals and marine fauna are likely to occur and physical effects may develop closer to the acoustic source. This effect is presumed to be temporary to long-term. Manageable under risk control and mitigation measures to avoid, remedy or mitigate adverse effects are implemented. A period of time may be required for the behaviour of marine mammals and marine fauna to return to their original state. Requires management decisions to be made on measures to avoid, remedy or mitigate adverse effects for project. Potential shut down of operations until mitigation zones are clear or discussions have been held between DOC and the operator.
	Medium Risk: (6 – 9)	Small environmental impact on marine mammals, marine fauna or on marine environment from exposure to the acoustic source or the presence of the seismic vessel and seismic array. No mitigation measures are required for marine mammals, marine fauna or environmental conditions to return to their original behaviour or situation. Potential to cause interruptions to seismic operations.
	Low Risk: (12 – 16)	No environmental impact on marine mammals anticipated from operations. No regulatory violation or action anticipated. Seismic operations are acceptable with continued observation and monitoring by the MMO's and PAM operators. No impact on existing interests, marine fauna, natural marine environment from the seismic activities.

5.1 Planned Activities – Potential Effects and Mitigations

5.1.1 Physical presence of seismic vessel and towed equipment

The physical presence of the survey vessels and the towed span of associated acoustic equipment has the potential to cause an effect on some components of the existing environment, commercial, recreational, cultural and social activities. Each potential effect is discussed in the following sections.

5.1.1.1 Potential effects on marine mammals

Vessel presence has the potential to affect marine mammals in four primary ways: 1) Disruption of normal behaviour; 2) Displacement of individuals from habitat; 3) Ship strikes - collision between a marine mammal and vessel; and 4) Entanglement risks associated with towed equipment.

The disruption of normal behaviour and displacement from an area is of particular concern when these changes occur frequently over a prolonged period and/or when they affect critical behaviours (i.e. feeding, breeding and resting). Although there is potential for the physical presence of the survey vessels and associated acoustic equipment to cause some changes in marine mammal behaviours and/or displacement from habitat, such disturbance is predicted to be temporary and localised during the Taranaki West 3D Seismic Survey due to the limited duration of survey operations. In addition, in order to be affected by the presence of the survey vessels and associated equipment, a marine mammal must first be in close proximity while the seismic vessel is acquiring.

An emerging global concern is the collision of marine mammals and vessels. This is commonly referred to as ‘ship strike’. Jensen & Silber (2003) reviewed the global database of ship strike incidents. This study considered a total of 292 records of ship strikes and identified 11 different species that were at a high risk, with fin whales (75 records) and humpback whales (44 records) the most commonly implicated species. Of the high risk species identified in the Jensen & Silber (2003) study, it is considered that nine could potentially be present within the Operational Area: Bryde’s whales, blue whales, fin whales, humpback whales, killer whales, minke whales, sei whales, southern right whales, and sperm whales.

During a ship strike incident, vessel type also affects the likelihood of mortality. Navy vessels and container/cargo ships/freighters are involved in the majority of fatal ship strikes: with records indicating that seismic vessels have only been responsible for one known fatality globally since records began in the late 1800s (Jensen & Silber, 2003). Records of sub-lethal effects are less reliable on account of the difficulty in assessing injury in free swimming cetaceans following a collision.

Perhaps the primary contributing factor that dictates the severity of a ship strike incident is the speed of the vessel; with likelihood of mortality increasing with increasing vessel speed. Jensen & Silber (2003) reported that the mean vessel speed that resulted in mortality during a ship strike was 18.6 knots. The typical speed of a seismic vessel during acquisition is ~4.5 knots; less than four times slower than the mean fatal speed reported by Jensen & Silber (2003).

It is possible that marine mammals could interact with and become entangled in the towed seismic equipment; however, this is highly unlikely to occur on account of marine mammals displaying exceptional abilities to detect and avoid obstacles in the water column and the lack of loose surface lines associated with the towed equipment. Marine mammals are known to interact with fishing gear; however, a point of difference with seismic surveys is that there is no food attractant involved (i.e. bait or catch). To SLR’s knowledge, there has never been a reported case of a marine mammal becoming entangled in seismic equipment.

In accordance with the Code of Conduct, MMOs will be on-watch during daylight hours for all periods of acquisition during the Taranaki West 3D Seismic Survey. In addition to this, at least one MMO will be stationed on the bridge during good weather while the seismic vessel is in transit to and from the Operational Area in order to maximise the marine mammal data collected during the survey. The Marine Mammal Mitigation Plan (MMMP) outlines the protocol that MMOs will follow during the Taranaki West 3D Seismic Survey; this is included as **Appendix E**.

In addition, MMOs will be vigilant for marine mammal entanglements, will be expected to report any dead marine mammals observed at sea, and will notify DOC immediately should any live sightings of Hector's/Maui's dolphins be made throughout the Operational Area, or should any humpback whales or southern right whales be detected within the territorial sea. MMOs will provide weekly reports to DOC (both National Office and Taranaki) and the Environmental Protection Authority.

Given the information detailed above, it is considered that the risk to marine mammals arising from the physical presence of the survey vessels and towed equipment during the Taranaki West 3D Seismic Survey is ***medium***.

5.1.1.2 Potential effects on seabirds

A high number of seabirds are likely to be present within the Operational Area (see **Section 4.2.7**), increasing the likelihood of an encounter between seabirds and the seismic vessels. Seabirds frequently interact with vessels at sea, and while many of these interactions are harmless, such as the provision of perching opportunities that would otherwise not be available, some interactions can lead to injury or death (i.e. collision or entanglement in vessel rigging, particularly at night). Seabirds flying at night can become disorientated as a result of artificial lighting, and this is particularly the case for fledglings and novice flyers in coastal locations (Telfer *et al*., 1987). The use of artificial lighting on-board a vessel can increase the risk of seabird collisions (Black, 2005).

Behavioural observations of seabirds around seismic operations are limited. However, bird counts and distributional analyses of shorebirds and waterfowl from the Wadden Sea (an intertidal zone of the North Sea) showed no significant change as a result of a seismic survey, although a trend for temporary avoidance within a 1 km radius of the seismic vessel was observed (Webb & Kempf, 1998).

Even though no specific mitigations are in place to reduce the likelihood of a collision between seabirds and the survey vessels, the vessels used in the Taranaki West 3D Seismic Survey confer no greater collision threat than any other vessel in the area would. Furthermore, the slow operational speed of the vessels most likely reduces any potential for detrimental interactions; in fact the presence of the seismic vessel could provide a resting place for seabirds that would otherwise be unavailable. The short-term duration of the survey limits the temporal scale of potential effects (both negative and positive).

Diving seabirds in close proximity to the acoustic source are unlikely to be engaged in active foraging as most small pelagic fish species that would be potential prey are expected to avoid the immediate area surrounding the seismic vessel and towed equipment.

In summary, the risk to seabirds from the physical presence of the seismic vessel, support vessel and the towed equipment is considered to be ***low***.

5.1.1.3 Potential effects on fisheries and marine traffic

The Taranaki West 3D Seismic Survey could potentially interfere with commercial fishing activities by causing a temporary displacement of fishing operations as the survey passes through areas of fishing ground within the Operational Area. Seismic data acquisition could also cause displacement of fish stocks; however, such effects will be strictly temporary on account of the short term nature of seismic operations.

Likewise, other marine traffic that transit through the Operational Area may be required to change course slightly to avoid the seismic survey operations.

Commercial users have been advised of PGS's proposed operations and will be kept informed with regard to survey commencement dates and progress. Although it is assumed that any potential effects will be temporary, PGS will undertake the following mitigation measures to further minimise any effects:

- Seismic operations will occur 24 hours a day, 7 days a week (weather and marine mammal encounters permitting) to minimise the overall duration of the survey;
- The survey vessels will comply with the COLREGS (e.g. radio contact, day shapes, navigation lights, etc);
- PGS will notify other commercial users of the proposed survey and has agreed to provide a secure web-based platform that other commercial users can access to receive near real-time updates of the seismic vessels' position and scheduling forecasts;
- A support vessel will be present;
- PGS will issue a Notice to Mariners and a coastal navigation warning will be broadcast on marine radio; and
- A tail buoy with lights and radar reflector will be displayed at the end of each streamer to mark the overall extent of the towed equipment.

With the above mitigation measures in place, the environmental risk to any fishing vessels or other marine traffic is considered to be ***medium***.

5.1.1.4 Potential effects on marine archaeology, cultural heritage or submarine infrastructure

Physical effects on marine archaeology, cultural heritage or submarine infrastructure would typically only occur if the towed equipment were to come into contact with the seabed. During normal seismic operations there is no intention for this to occur, therefore no effects are predicted. The loss of equipment during an unplanned incident is further discussed in **Section 5.2.2.**

Areas of archaeological interest or cultural significance are typically associated with coastal, intertidal and subtidal environments, instead of offshore areas like those in the Operational Area. As the Taranaki West 3D Seismic Survey will occur outside the territorial sea, the potential for interactions with marine archaeology and cultural heritage is minimised.

It is considered that the potential interference with any marine archaeology, cultural heritage, or submarine infrastructure is ***low***.

5.1.2 Acoustic disturbance to the marine environment

During a seismic survey the level of lateral attenuation is dependent on propagation conditions; in good propagation conditions, noise will travel further and background noise levels may not be reached for >100 km, while in poor propagation conditions, background levels can be reached within a few tens of kilometres (McCauley, 1994). Most of the emitted energy during seismic surveys is of low frequency (0.001 – 0.3 kHz) which attenuates slowly (Richardson *et al.,* 1995).

The acoustic pulse from the seismic source produces a steep-fronted wave that is transformed into a high-intensity pressure wave; a shock wave with an outward flow of energy in the form of water movement. The result is an instantaneous rise in maximum pressure, followed by an exponential drop in pressure. The environmental effects on an animal in the vicinity of a sound source are defined by individual interactions with these waves.

In general, a high intensity acoustic disturbance will cause a behavioural response in animals (typically avoidance or a change in behaviour). The nature (continuous or pulsed) and intensity of the noise, as well as the species, gender, reproductive status, health and age of an animal influences the duration and intensity of the animal's observed response.

A behavioural response is an instinctive survival mechanism that serves to protect an animal from injury. Consequently, animals may suffer temporary or permanent physiological effects in cases when the external stimulus (e.g. acoustic disturbance) is too high or the animal is unable to elicit a sufficient behavioural response (e.g. move away fast enough).

As a result of the exposure level and sensitivity threshold of each species, the potential effects of an acoustic disturbance can range from a change in behaviour and related effects such as displacement, disruption of feeding, breeding or nursery activities and interference with communications, to physiological effects such as changes in hearing thresholds, damage to sensory organs, or traumatic injury. Indirect effects are also possible and could lead to ecosystem level effects, for example behavioural changes in prey species that affects their accessibility to predators.

DOC developed the Code of Conduct as a tool to specifically minimise the potential effects of acoustic disturbances from seismic surveys, including behavioural and physiological effects. Complying with the Code of Conduct is the primary way in which potential acoustic effects from the Taranaki West 3D Seismic Survey will be managed.

Potential acoustic exposure of marine fauna during the Taranaki West 3D Seismic Survey was assessed by way of STLM. STLM uses input parameters based on the source array, and bathymetry data of the Operational Area. The results of the STLM are presented below.

5.1.2.1 Sound Transmission Loss Modelling

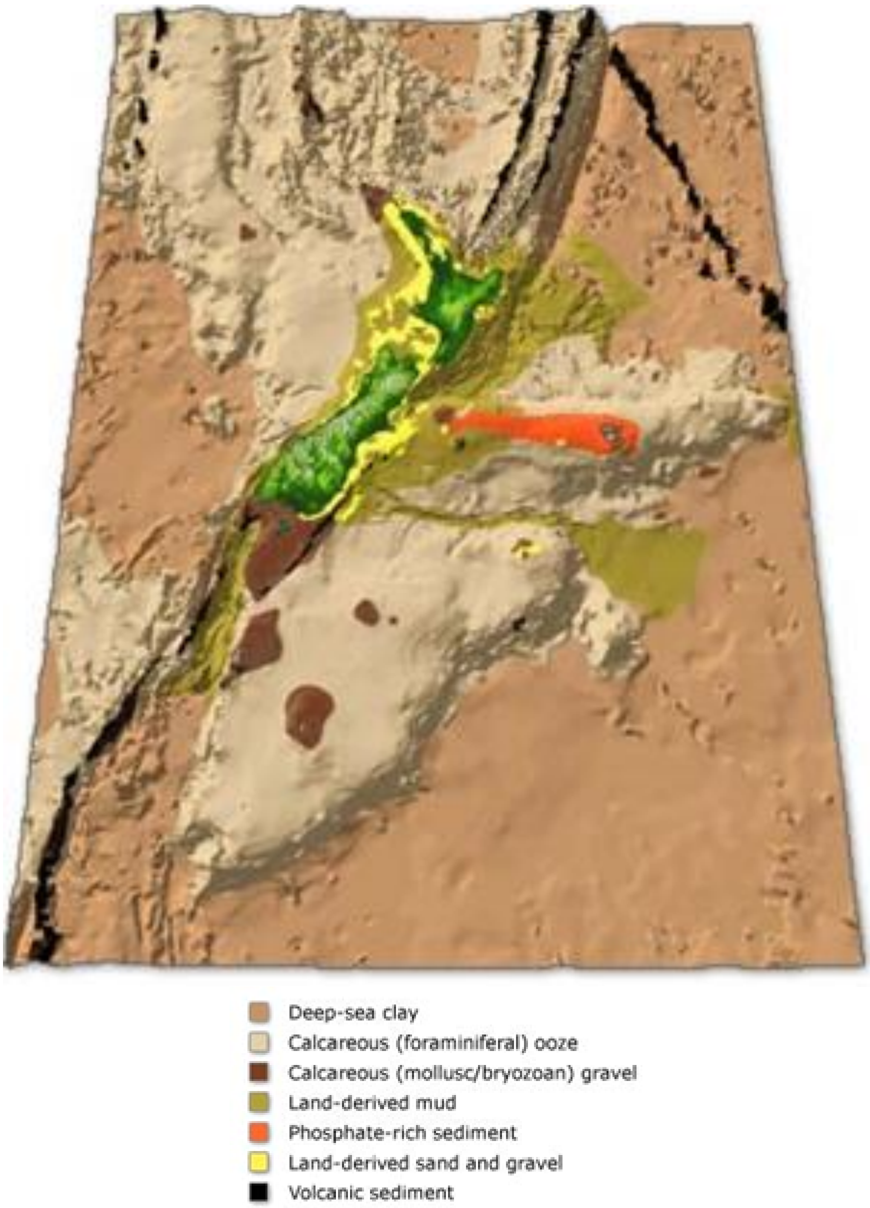
Over and above the requirements of the Code of Conduct, PGS undertook STLM to predict received SELs from the Taranaki West 3D Seismic Survey to assess for compliance with the mitigation zones outlined in the Code of Conduct (short-range modelling) and to predict sound propagation into sensitive areas (long-range modelling). The modelling methodology addressed both the horizontal and vertical directionality of the acoustic array and considered the different water depths and substrate types found throughout the Operational Area.

It is worth noting that the STLM was undertaken early in the survey planning phase before refinements to equipment had been made. Hence, the modelling was based on the largest possible acoustic source that was under consideration for use during the survey (4,130 in^3), subsequently a smaller source has been selected for use during the Taranaki West 3D Seismic Survey (3,660 in^3). On this basis, the standard mitigation zones are considered to be conservative.

The complete modelling report is provided in **Appendix D**.

The Operational Area is relatively large and encompasses a range of bathymetry and seabed substrate types which represent 'geo-acoustic regions'. The Continental Shelf around NZ is covered mainly with land-derived sand, gravel and mud sediment (**Figure 19**).

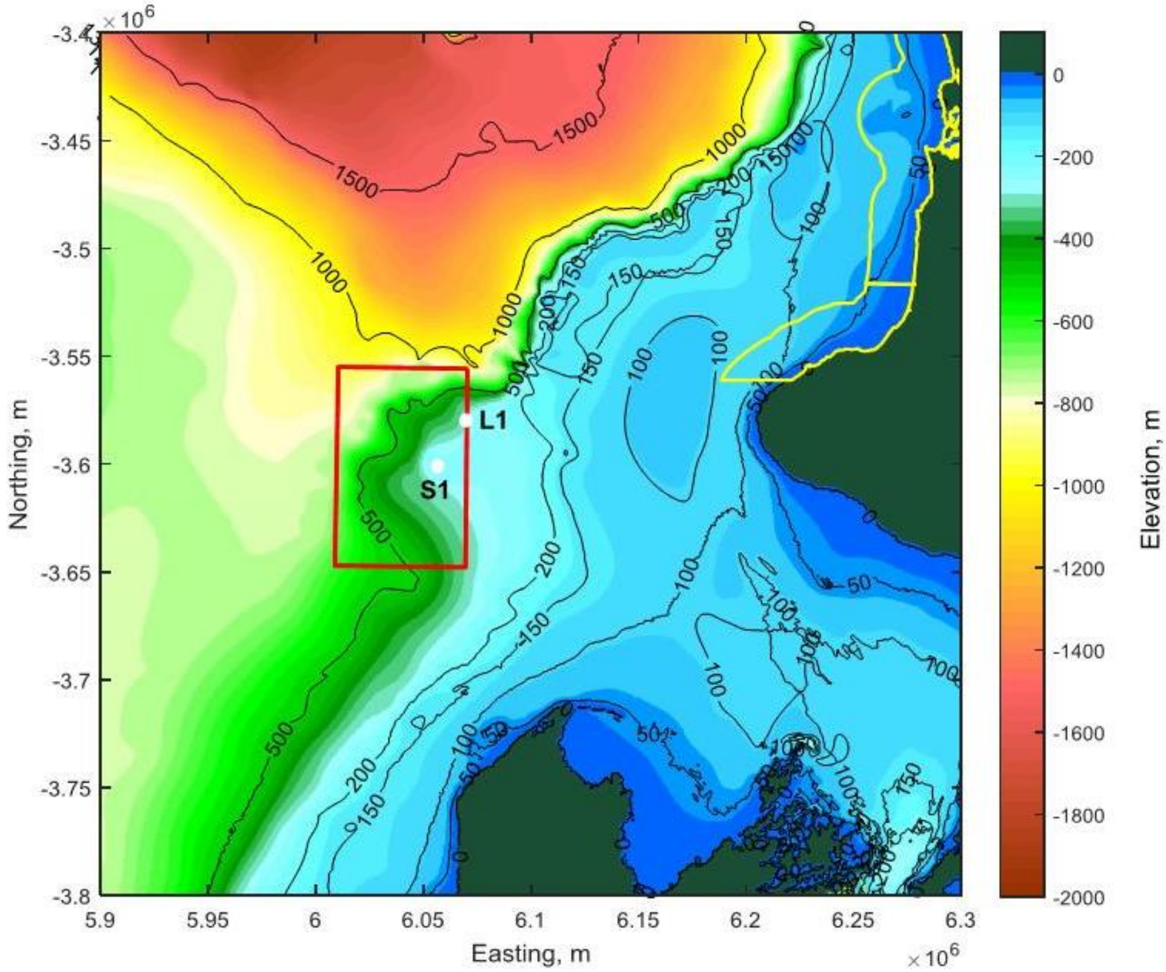
Figure 19: A Summary of Geo-acoustic Regions of New Zealand



In order to predict the highest SELs possible during the Taranaki West 3D Seismic Survey, the worst case modelling location and conditions were selected as follows:

- The shallowest water depth, 235 m (**Figure 20**);
- An autumn sound speed profile; and
- Fine to very fine sand seabed.

Figure 20: Modelling location for the Operational Area based on shallowest water depth



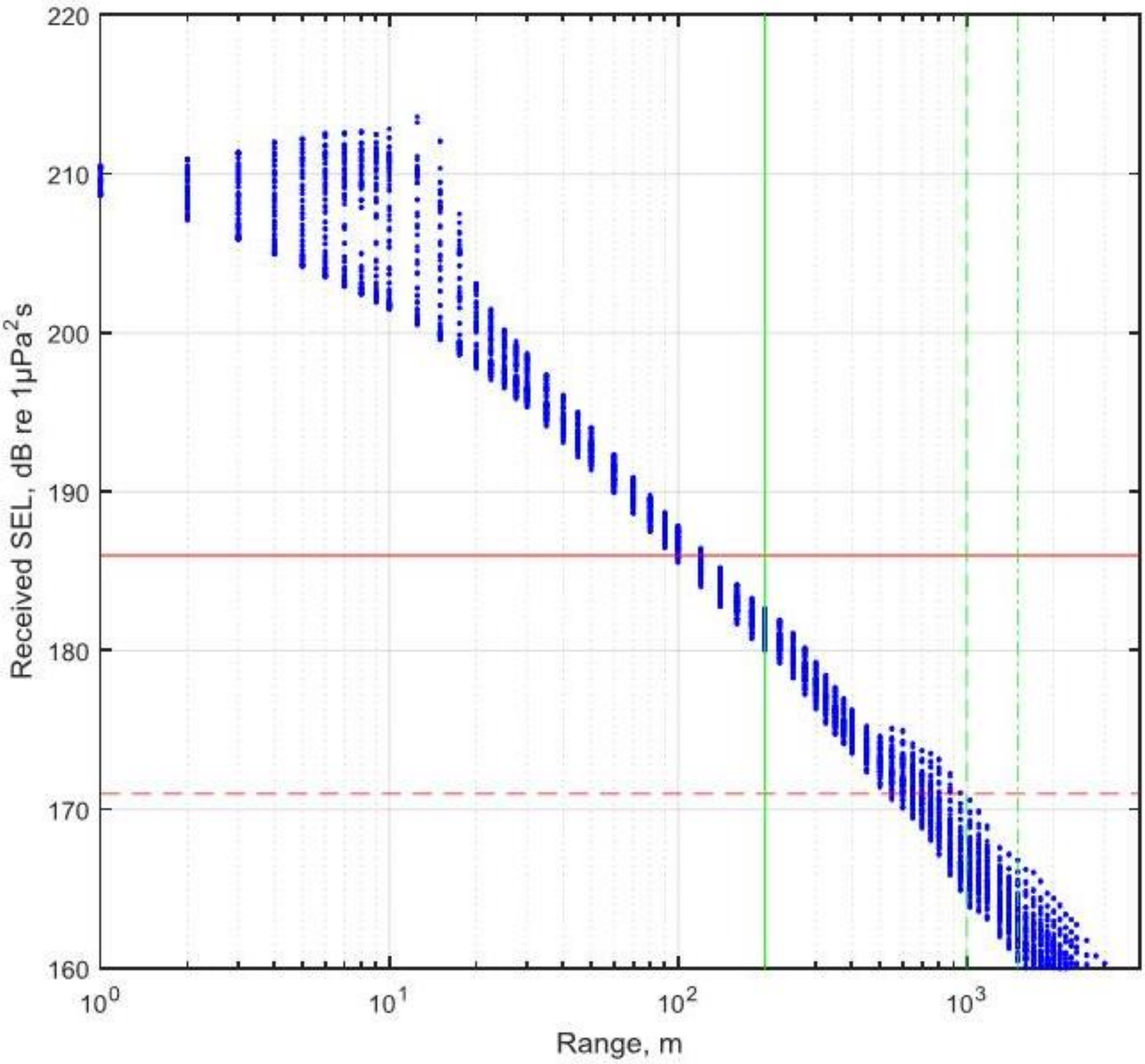
Short range modelling results

Short range modelling allows for predictions to be made about the likelihood of compliance with the standard Code of Conduct mitigation zones. The model results predicted that the maximum SELs would be below the thresholds for both physiological disturbance (186 dB re 1 µPa^2-s) and behavioural disturbance (171 dB re 1 µPa^2-s) at the standard Code of Conduct mitigation zones (i.e. 200 m, 1,000 m, and 1,500 m) (**Figure 21; Table 14**). Therefore, these results confirm that the standard mitigation zones will be sufficient to protect marine mammals from both behavioural and physiological disturbance.

Table 14 Predicted maximum SELs for all azimuths at each mitigation zone

Range from centre of array (m)	**200**	**1,000**	**1,500**
Predicted Maximum SEL (dB re 1µPa^2-s)	182.7	170.7	166.8
Relevant Code of Conduct threshold (dB re 1µPa^2-s)	≤ 186	≤ 171	≤ 171

Figure 21: Maximum received SELs from the 4,130 in^3 acoustic source

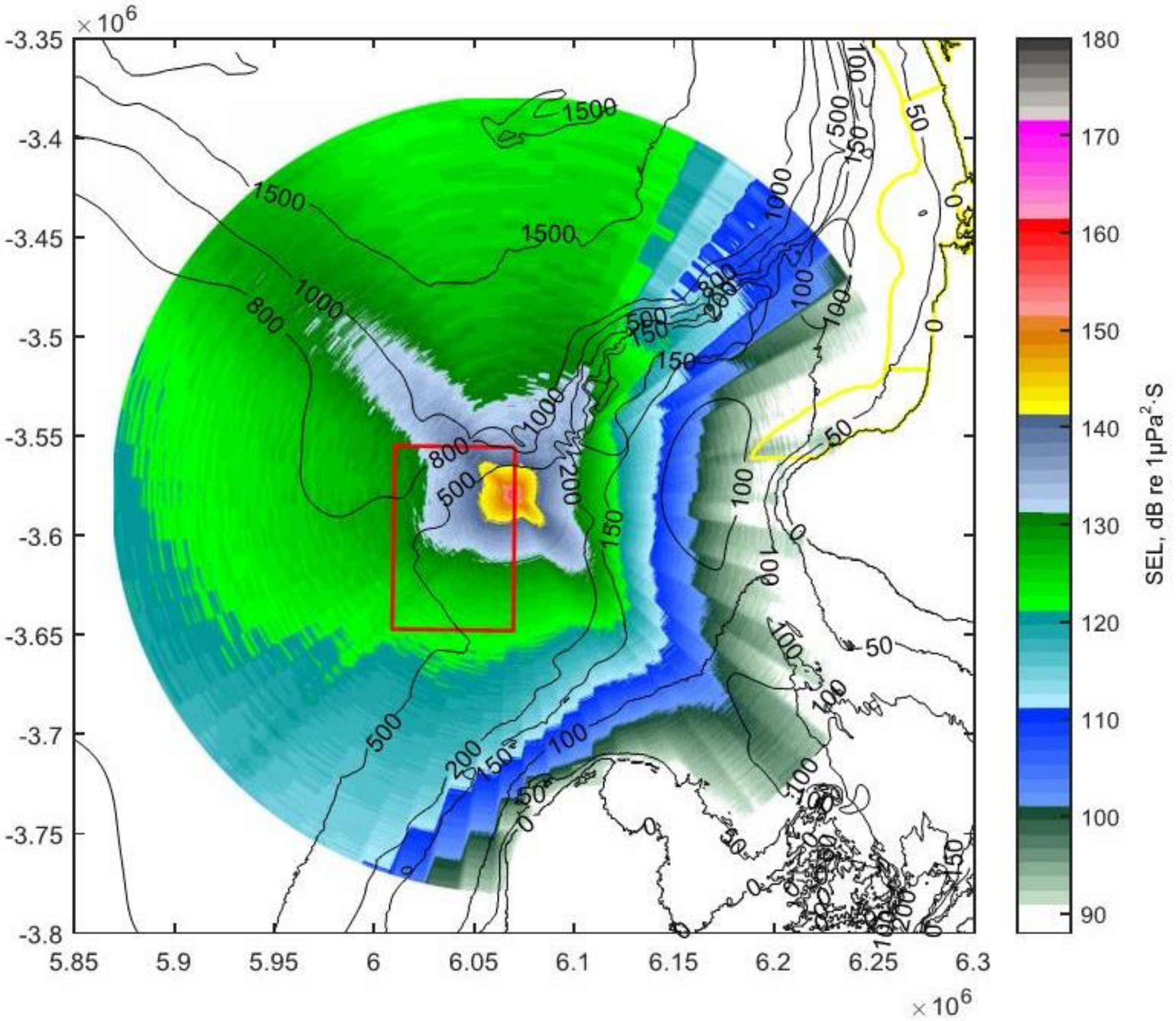


Long range modelling results

Long-range modelling predicted that the received noise levels at far-field locations vary significantly with angle and distance from the source. These varying far-field SELs are due to a combination of the directivity of the source array, and propagation effects caused largely by the bathymetry. Sound travelling 'up-slope' (from deep to shallow water) attenuates rapidly as can be seen to the east of L1 (off Cape Egmont); whereas sound traveling down-slope propagates extensively; particularly in the northwest quadrant.

The southern boundary of the West Coast North Island Marine Mammal Sanctuary is over 120 km from the source location L1. The maximum SELs at the sanctuary boundary are predicted to be approximately 90 dB re 1 µPa^2-s; well below both the thresholds defined by the Code of Conduct. These results indicate that marine mammals within the sanctuary are not expected to be subject to either behavioural or physiological disturbance.

Figure 22 Maximum SELs predicted from the source location (L1) over a range of 200 km



5.1.2.2 Potential behavioural effects on marine fauna

The most likely and wide spread behavioural effect resulting from the Taranaki West 3D Seismic Survey is the displacement of animals. While short-term displacement is thought to have very limited or no long-term implications for populations, any long-term displacement can lead to an animal relocating to sub-optimal or high-risk habitats. Long-term displacement can therefore result in negative consequences such as an increase in exposure to predators and decreased foraging or mating opportunities. Should any distributional changes occur as a result of the Taranaki West 3D Seismic Survey, these will be strictly temporary and will only last for the expected 45 day duration of the survey.

The potential behavioural effects for each faunal grouping are discussed in detail below.

Marine mammals

<u>Changes in distribution and related effects:</u>

Avoidance of active seismic operations has been widely documented for marine mammals (Goold, 1996; Stone & Tasker, 2006; Thompson *et al.,* 2013) and can lead to displacement from habitat. A review of 201 seismic surveys within UK waters concluded that most odontocetes were likely to exhibit a clear lateral avoidance response, while mysticetes demonstrated a more moderated lateral response. Noticeable surface behaviours such as breaching have also been recorded when marine mammals are actively avoiding an acoustic source (McCauley *et al.,* 1998; McCauley *et al.,* 2003). These behavioural changes have been interpreted as a means of reducing exposure to acoustic disturbance on account of the 'Lloyd mirror effect' (Carey, 2009) that significantly reduces sound intensity in the upper-most part of the water column. A number of examples of behavioural change in response to seismic surveys are provided below.

- Thompson *et al.* (2013) found that displacement of harbour porpoises was observed when the study animals were exposed to peak-to-peak sound pressure levels of 165-175 dB re 1 µPa (a 470 in^3 acoustic source over ranges of 5 – 10 km). For harbour porpoises, displacement was temporary, with the animals detected again at affected sites within a few hours of exposure and a degree of habituation towards the sound source was also observed, with the level of response declining throughout the 10 day survey period (Thompson *et al.,* 2013). From these observations, Thompson *et al.* (2013) concluded that prolonged seismic surveys did not lead to broad-scale displacement of marine mammals. However it is important to note that the acoustic source in the Thompson *et al*. (2013) study was far smaller than the source proposed by PGS, therefore any displacement of animals during the Taranaki West 3D Seismic Survey is expected to affect a larger area and for a longer duration.
- Humpback whales exposed to 160 – 170 dB re 1 µPa (peak to peak) sounds from seismic surveys consistently changed their course and speed to avoid any close encounters (McCauley *et al.,* 2003).
- The effects of a seismic survey on the migratory behaviour of bowhead whales were documented by Richardson *et al*. (1995), with evidence found for a 20 – 30 km avoidance zone around the seismic vessel. Subsequent to this study further work has been done on bowhead whales to suggest that the rate of response is dependent upon the received sound levels. Blackwell *et al.,* (2015) documented changes in calling rates to demonstrate this; however the authors postulated that this effect was likely to apply to other behavioural changes (e.g. distribution) as well. Displacement of migrating whales is unlikely to have significant energetic consequences for when individuals are travelling in open seas, open seas, but could have a significant effect should displacement occur in confined waterways. With regard to migratory routes in NZ waters, the most obvious confined water body is Cook Strait which provides a corridor for blue and humpback whales, primarily in winter months as they migrate north. As the Taranaki West 3D Seismic Survey will be carried out during summer months, displacement of migratory animals is not expected to occur.

By displaying avoidance behaviours towards an approaching seismic vessel, marine mammals may be forced to leave valuable feeding grounds such as areas with large aggregations of krill or fish. Any deviation from their natural distribution and away from prey aggregations could result in an increase in the energy required to successfully capture prey.

Likewise, in many circumstances the distribution of marine mammals is linked to that of their prey (see Fielder *et al*., 1998). Not only can seismic surveys affect the distribution of marine mammals, but prey distribution may also change. Indirect effects on marine mammals from changes in prey distribution include an increase in energy expenditure during foraging bouts in order to detect and capture prey, or a decrease in foraging success as a prey source in responding to seismic survey noise may no longer be available to marine mammals.

Some disruption to breeding behaviours could also result from displacement effects, although potential reproductive effects are managed to some extent by the mitigation zones imposed around the seismic vessel.

In addition to avoidance behaviours, there is also anecdotal evidence of marine mammals being attracted to operating seismic vessels; common dolphins were observed repeatedly approaching an operating seismic vessel to bow ride as it entered shallow waters off Taranaki. NZ fur seals are also known to occasionally approach operating seismic vessels (Lalas and McConnell, 2015).

This impact assessment notes the following specific risk associated with potential displacement during the Taranaki West 3D Seismic Survey:

- The displacement of pygmy blue whales (particularly mother/calf pairs) from optimal foraging areas - The distribution of this species in the South Taranaki Bight is positively correlated with the distribution of their zooplankton prey (Torres *et al*., 2015). Zooplankton distribution (in particular *Nyctiphanes australis)* depends on characteristics of surface water. Upwelling of cold waters from Kahurangi Shoals (off the northern tip of the South Island) move into the Bight as highly productive eddies of nutrient rich cold water supporting dense aggregations of prey that blue whales are attracted to. Sea surface temperature can therefore act as an indicator for productivity. In El Nino conditions whales tend to be located west of the Bight, but inside the Bight during more typical weather patterns (Torres and Klinck, 2016). The likelihood of feeding aggregations of blue whales being present within the proposed acquisition area during the Taranaki West 3D Seismic Survey is difficult to predict, but sea surface temperature data may be useful to identify upwelling areas that could attract whale aggregations. Pygmy blue whales have been recorded in the Bight during all months of the year. Mother/calf pairs have only recently been documented from the Bight during summer, with a high density of mother/calf pairs (five in total over a three week field season) being observed in February 2016 (Torres and Klinck, 2016). Little is known about the breeding biology of pygmy blue whales, although the observations by Torres and Klink (2016) indicate that the Bight may be used as a nursery ground by this species at least during the summer months. Based on sightings from previous surveys in the general vicinity of the Operational Area, there may be large numbers of blue whales present during the Taranaki West 3D Seismic Survey.

PGS intends to reduce this risk by:

- Compliance with the Code of Conduct; and
- Continuing seismic operations around the clock (as possible) to reduce the overall duration of the survey.

<u>Communication effects:</u>

Marine mammals utilise sound to inform a range of behaviours such as foraging, navigation, communication, reproduction, parental care, and avoidance of predators, and to gain an overall awareness of the surrounding environment (Thomas *et al*., 1992; Johnson *et al.,* 2009). The ability to perceive biologically important sounds is therefore crucial to marine mammals. Anthropogenic sounds produced in the same frequency as biological sounds could interfere with biologically important signals; an effect referred to as 'masking' (Richardson *et al.,* 1995; Di Iorio & Clark, 2009). The frequencies of marine mammal vocalisations (for communication and echolocation) relevant to the Operational Area are presented in **Table 15**.

Table 15: Cetacean Communication and Echolocation Frequencies

Species	Communication Frequency (kHz)	Echolocation Frequency (kHz)
Southern right whale	0.03 – 2.2	N/A
Minke whale	0.06 – 6	N/A
Sei whale	1.5 – 3.5	N/A
Bryde's whales	nd	nd
Blue whale	0.0124 – 0.4	N/A
Fin whale	0.01 – 28	N/A
Humpback whale	0.025 – 10	N/A
Sperm whale	< 9	0.1 – 30
Pygmy sperm whale	nd	60 - 200
Beaked whales*	3 - 16	2 - 26
Hector's/Maui's dolphin	nd	129**
Common dolphin	0.5 - 18	0.2 - 150
Pilot whale	1 – 8	1 – 18
Dusky dolphin	nd	40 - 110***
Killer whale	0.1 – 25	12 – 25
Bottlenose dolphin	0.2 - 24	110 - 150

Source: Summarised from Simmonds *et al.,* 2004

Key:
nd = no data available
* = using the bottlenose whale as an example
** = Kyhn *et al*., 2009
*** = Au and Wursig, 2004

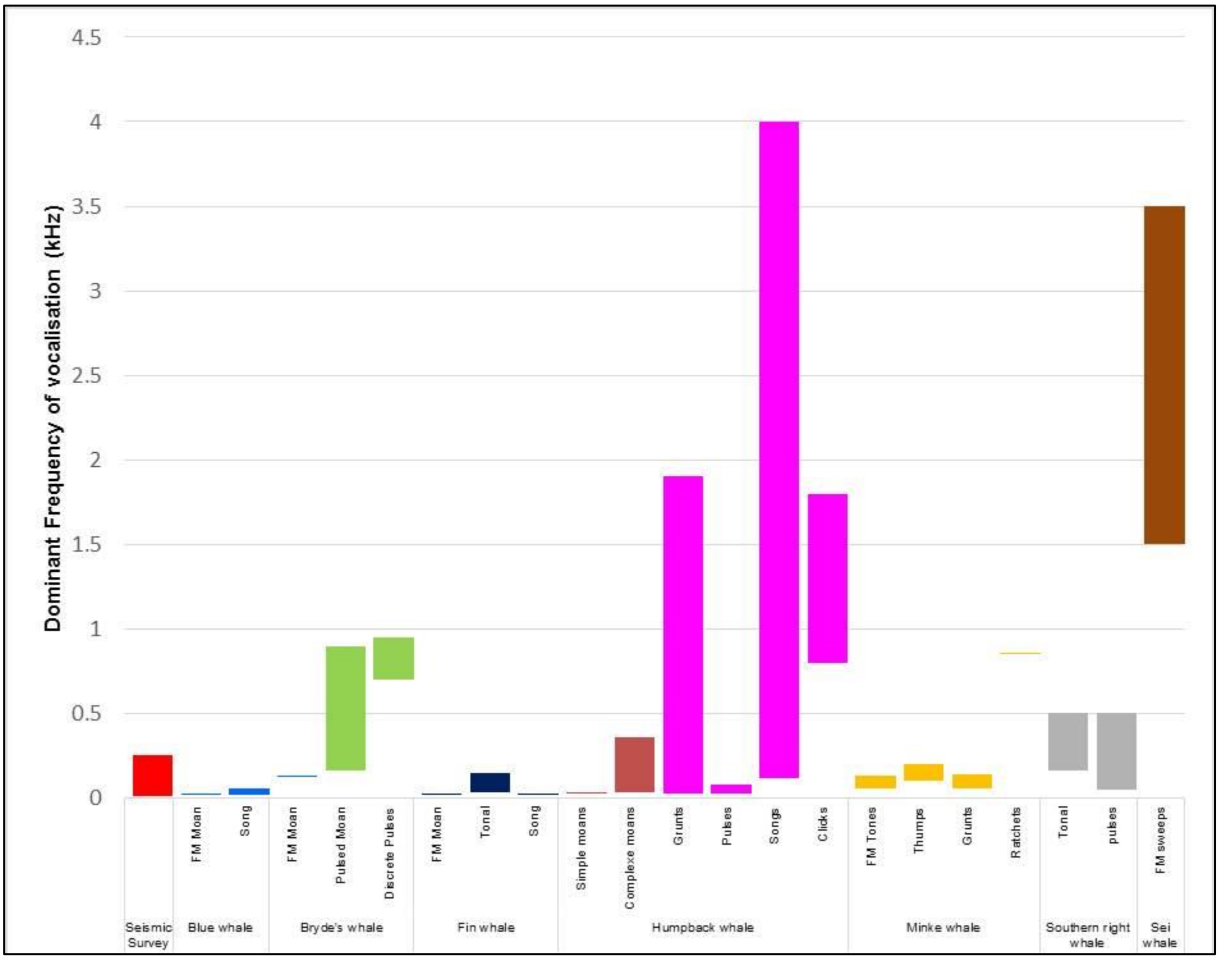
Cetaceans are broadly separated into three functional hearing groups (Southall *et al.,* 2007):

- Low frequency cetaceans have an auditory bandwidth of 0.007 kHz to 22 kHz. Species from this group which could occur in the Operational Area include southern right whales, minke whales, sei whales, humpback whales, blue whales, and fin whales;
- Mid-frequency cetaceans have an auditory bandwidth of 0.15 kHz to 160 kHz. Species from this group which could occur in the Operational Area include bottlenose dolphins, common dolphins, dusky dolphins, Risso's dolphins, false killer whales, killer whales, long-finned pilot whales, sperm whales, and beaked whales; and
- High frequency cetaceans have an auditory bandwidth of 0.2 kHz to 180 kHz. Species from this group which could occur in the Operational Area include the pygmy sperm whale.

The sound frequencies emitted by seismic acoustic sources are broadband, with the majority of energy concentrated between 0.1 kHz and 0.25 kHz. Therefore, the greatest potential for a seismic source to interfere with cetacean vocalisations is at the highest end of the seismic spectrum and the lowest end of the cetacean vocalisation spectrum. This means that the lowest frequency cetaceans (i.e. southern right, minke, sei, humpback, blue and fin whales) are likely to be most affected by 'masking' as the seismic acoustic source has the greatest potential to overlap with these low frequency vocalisations (**Figure 23**). Vocalisations of mid and high frequency cetaceans are less likely to be masked.

Adaptive responses to anthropogenic underwater noises have also been documented, such as changes in vocalisation strength, frequency and timing (McCauley *et al*., 1998; Lesage *et al.,* 1999; McCauley *et al.,* 2003; Nowacek *et al.,* 2007; Di Iorio & Clark, 2009; Parks *et al.,* 2011). For example, the calls emitted by blue whales during social encounters and feeding increased when a seismic survey was operational nearby (Di Iorio & Clark, 2009). Such adaptations are thought to increase the probability that communication calls will be successfully received by reducing the effects of masking. The calling rates of bowhead whales however, were found to vary with changes in received SELs from seismic surveys (Blackwell *et al.,* 2016). In this study, at very low SELs (only just detectable) calling rates increased. As SELs continued to increase, calling rates levelled off (as SELs reached 94 dB re 1µPa^2-s), then began decreasing (at SELs greater than 127 dB re 1µPa^2-s), with whales falling virtually silent once SELs exceeded 160 dB re 1µPa^2-s. Hence adaptations to masking for some species may be limited to circumstances when whales are subject to only moderate SELs.

Figure 23: Low-frequency Cetacean Vocalisations Compared with Seismic Outputs



<u>Summary</u>

Based on the information above, some marine mammal behavioural effects are expected to occur as a result of the Taranaki West 3D Seismic Survey. However, these effects will be strictly temporary due to the short operational period and will cease as soon as the survey ceases. It is considered that acoustic disturbance will confer a ***medium*** risk to marine mammals during the Taranaki West 3D Seismic Survey as displacement and consequent behavioural disruptions will almost certainly occur, as will some masking, particularly with low-frequency cetaceans.

The primary mitigation measure that will be employed to manage behavioural effects on marine mammals will be compliance with the Code of Conduct. The presence of MMOs to visually scan for marine mammals and the use of PAM to detect marine mammals acoustically is mandatory under the Code of Conduct. MMO visual detections and PAM acoustic detections will trigger operational shut-downs and delayed starts. By complying with the Code of Conduct the risk of marine mammals being exposed to excessive levels of noise will be significantly reduced.

During the Taranaki West 3D Seismic Survey a Seiche PAM system will be used to detect marine mammal vocalisations. Full technical specifications of this system are included in **Appendix F**, but to summarise, this system comprises a 250 m array with integral hydrophones and a depth sensor array. The depth sensor array is a 20 m detachable section with four hydrophone elements. Two of these hydrophones monitor a bandwidth of 10 Hz to 200 kHz, but maintain some sensitivity down to 1 Hz. The remaining two hydrophones monitor a bandwidth of 2 kHz to 200 kHz; ensuring that if the other pair of hydrophones is saturated by low frequency vessel noise, the system is still capable of making detections. The specifications of this system have been approved by DOC as being suitable to detect vocalisations from all Species of Concern.

PGS has also undertaken source modelling to ensure that their survey is using the lowest possible acoustic source volume to minimise the effects on marine mammals whilst still achieving the data acquisition objectives of the Taranaki West 3D Seismic Survey.

Based on the information presented above, the potential for disturbance to marine mammal behaviour by the Taranaki West 3D Seismic Survey is considered to be ***medium*** on account of the possibility of localised displacement and some masking of low frequency marine mammal vocalisations.

Seabirds

Feeding activities of seabirds could be interrupted by seismic operations. Birds in the area could be alarmed as the operating seismic vessel passes close-by, causing them to stop diving (MacDuff-Duncan & Davies, 1995). The displacement of bait fish could also lead to a reduction in seabird diving activities and foraging potential.

The potential disruption to seabird behaviour by the Taranaki West 3D Seismic Survey is considered to be ***low*** on account of the potential temporary disturbance to feeding activities.

Marine Turtles

While it is highly unlikely that any turtles will be encountered during the Taranaki West 3D Seismic Survey, patterns of avoidance and behavioural responses have been observed in turtles. When captive sea turtles (a loggerhead and a green turtle) were exposed to an approaching acoustic source, they displayed patterns of avoidance and behavioural responses (McCauley *et al.,* 2000). An increase in swimming speed was observed at a received level of 166 dB re 1 µPa rms, while avoidance through erratic swimming was observed at a received level around 175 dB re 1 µPa rms (McCauley *et al*., 2000). For a 3D seismic survey in 100 – 120 m water, these results suggest a behavioural change at 2 km and avoidance at 1 km from the active source.

In the unlikely event that a turtle is present in close proximity to the operating seismic vessel during the Taranaki West 3D Seismic Survey, some behavioural changes may occur, however no specific mitigation measures are in place. Due to the unlikely occurrence of turtles in the Operational Area and the relatively short-term nature of the survey, it is considered that the risk of seismic operations to marine turtles will be ***low***.

Fish, Cephalopods and Fisheries

Investigations into behavioural impacts from seismic surveys on fish are typically carried out either experimentally whereby caged fish are exposed to an acoustic source, or via studies that assess catch-effort data before and after a seismic survey. Interpretation of such experiments must be done with caution as variability in experimental design (e.g. source level, line spacing, timeframe, geographic area etc) and the subjects (e.g. species, wild or farmed, demersal or pelagic, migrant or site-attached, age etc) often make it difficult to draw overall conclusions and comparisons. In addition, captive studies typically only provide information on behavioural responses of fish during and immediately after the onset of the noise (Popper & Hastings, 2009). Such behavioural observations are also potentially biased by the fact that the subjects are constrained, reducing/removing their ability to exhibit large scale avoidance behaviours that would otherwise be possible in the wild.

In general, there is little indication of long-term behavioural disruptions of fish when exposed to seismic sources. Short-term responses are often observed such as startle responses (Pearson *et al*., 1992; Wardle *et al*., 2001; Hassel *et al*., 2004; Boeger *et al*., 2006), modification in schooling patterns and swimming speed (Pearson *et al*., 1992; McCauley *et al*., 2000; Fewtrell & McCauley, 2012), freezing (Sverdrup *et al.,* 1994), and changes in vertical distribution within the water column (Pearson *et al.,* 1992; Fewtrell & McCauley, 2012). Hassel *et al*. (2004) has also found evidence of habituation through an observed decrease in the degree of startle response.

Seismic surveys often result in the vertical or horizontal displacement of fish away from the acoustic source; pelagic fish tend to dive deeper (McCauley *et al*., 2000), while reef fish return to the reef for shelter as the acoustic source approaches, resuming normal activity once the disturbance has passed (Woodside, 2007; Colman *et al.,* 2008). Pearson *et al*. (1992) also observed vertical displacement of rockfish on exposure to air-gun sounds.

Any change to fish behaviour from a seismic survey can potentially also affect commercial fishing operations (McCauley *et al.,* 2000). Reductions in catch per unit effort for commercial fishing vessels operating close to seismic operations have been demonstrated (Skalski *et al*., 1992; Engas *et al*., 1996; Bendell, 2011; Handegard *et al*., 2013), with effects lasting up to five days following the conclusion of seismic operations. However, there has been no evidence of long-term displacement. These results have been debated, with Gausland (2003) attributing this effect to natural fluctuations in fish stocks or long-term negative population trends that are unrelated to the seismic operations.

Over the last 40 years seismic surveys have become a common feature in the North Sea. Bendell (2011) considered long-line catches off the coast of Norway during the acquisition of a two week seismic survey with a peak source level of 238 dB re 1µPa@1m. Catch rates reduced by 55 – 80% within 5 km from the active source, although these reductions were temporary; catch rates returned to normal within 24 hours of seismic operations ceasing (Bendell, 2011).

Other studies have concluded that seismic surveys do not affect commercial fisheries. In Lyme Bay (UK), the distribution of bass was documented during a long-term seismic survey (three and a half months) operating at a peak source of 202 dB re 1µPa@1m. No long-term changes in distribution were observed, and tagged fish recaptures demonstrated that there were no large scale emigrations from the survey area (Pickett *et al*., 1994). Similarly, a study of fish in the Adriatic Sea reported no observed changes in pelagic biomass following an acoustic disturbance with a peak of 210 dB re 1µPa@1m, indicating that catch rates were unlikely to be affected (Labella *et al.,* 1996). A case study on catch rates around the Faroe Islands also noted that although fishers perceived a decrease in catch during seismic operations, their logbook records during periods both with and without seismic operations revealed no statistically significant effect from acoustic disturbance (Jakupsstovu *et al.,* 2001).

Behavioural changes have also been documented for cephalopods (squid and octopus species) in response to acoustic disturbance. Caged cephalopods exposed to acoustic sources demonstrated a startle response to sources above 151 – 161 dB re 1 µPa and showed behavioural changes towards surface activity in order to avoid acoustic disturbance (McCauley *et al*., 2000). McCauley *et al*. (2000) demonstrated that the use of soft-starts effectively decreases startle responses in cephalopods and Fewtrell & McCauley (2012) confirmed these findings and demonstrated that a source level of 147 dB re 1 µPa was necessary to induce an avoidance response in squid. Other squid reactions observed by Fewtrell & McCauley (2012) were alarm responses (inking and jetting away from the source), increased swimming speed, and aggressive behaviour. The authors noted that the reaction of squid decreased with repeated exposure, suggesting either habituation or hearing loss (Fewtrell & McCauley, 2012).

It is likely that fish and cephalopods will avoid the immediate vicinity of any acoustic disturbance during the Taranaki West 3D Seismic Survey. These predicted distributional changes could in turn result in the short-term displacement of commercially valuable fish stocks from the acquisition area, leading to a potential increase in the effort required to locate viable stocks and maintain catch rates.

A change in prey fish distribution can also lead to indirect effects for marine mammals (as discussed earlier).

Acoustic disturbance to fish and cephalopods is therefore expected during the Taranaki West 3D Seismic Survey and will be minimised through the following mitigation measures:

- The use of soft starts; and
- Operations will occur 24/7 (weather and marine mammal encounters permitting) to ensure the survey will progress as quickly as possible, minimising the duration of any effects.

Commercial fishers have been advised of the Taranaki West 3D Seismic Survey and will be informed of the predicted start date closer to the time. They will also have access to web-based near real-time position information from the seismic vessel to help them avoid on-water conflict associated with spatial overlap. Imagery of the bathymetry will also be provided to fisheries groups following survey completion and data processing.

With these mitigation measures in place it is considered that the risk of behavioural disruptions to fish and cephalopods and the consequences to fisheries during the Taranaki West 3D Seismic Survey is ***medium.***

Crustaceans

Although there is limited information on behavioural responses of crustaceans to acoustic disturbances, the following is a summary of the available literature.

Andriguetto-Filho *et al*. (2005) did not find any effects on catch rates of three species of shrimp (southern white shrimp, southern brown shrimp and Atlantic seabob) during a seismic survey with a peak source level of 196 dB re 1 µPa at 1 m. Similarly, Parry and Gason (2006) documented no effect on catch rates from a lobster fishery spanning 25 years during which 28 seismic surveys (2D and 3D) occurred. In this study, the number of seismic pulses was correlated to catch per unit effort data over 12 depth stratified regions in the Western Rock Lobster Zone (Western Victoria, Australia). The catch per unit effort data detected no significant change in catch rates during the weeks and years following seismic surveys, from which the authors concluded that there were no detectable impacts on rock lobster fisheries (Parry & Gason, 2006).

The red rock lobster (commonly known as crayfish) is the most well-known and commonly harvested crustacean species in NZ and is important from a commercial, cultural and recreational perspective. They are found in coastal waters around NZ where rocky subtidal reefs are present. Commercial fishing for red rock lobster only extends out to the 12 Nm territorial sea and is concentrated on the eastern and southern coast of NZ (MFish, 2015b). As the Taranaki West Seismic Survey will be acquired well outside of the territorial sea, there will be no effects on red rock lobster fisheries.

Scampi and deep-water crabs (red crab, giant spider crab and two species of king crab) are also commercially harvested in NZ. Scampi are targeted by trawlers on grounds to the east of the North Island, the Chatham Rise, and the Auckland Islands, while the deep-water crabs are targeted by pots deployed in water depths up to 1,500 m (MFish, 2015a). As the Taranaki West 3D Seismic Survey is far from the scampi fishing grounds and in water depths shallower than those fished for deep-water crab, the survey will not impact on these fisheries.

Based on the information above, the potential effect of acoustic disturbance on crustaceans and crustacean fisheries is considered to be ***low***.

5.1.2.3 Potential physiological effects on marine fauna

Marine mammals

If a marine mammal is exposed to a high intensity underwater noise at close range, it can suffer physiological effects such as trauma or auditory damage (DOC, 2013). The sound intensities that would elicit such a result are largely unknown, with the current knowledge of traumatic thresholds based on only a few experimental species (Richardson *et al*., 1995; Gordon *et al*., 2003).

The main type of auditory damage documented in marine mammals is a ‘threshold shift’. Threshold shifts essentially refer to hearing loss: when the exposed animal exhibits an elevation in the lower limit of their auditory sensitivity. These shifts can be permanent or temporary; temporary threshold shifts are more common in marine mammals due to their mobile, free-ranging nature which allows them to avoid areas in which SELs would be dangerously high. It is believed that to cause immediate serious permanent physiological damage in marine mammals, SELs would need to be very high (Richardson *et al*., 1995), and although different SELs affect mammal species differently, permanent threshold shifts are thought to occur between 218 – 230 dB re 1 μPa^2-s (Southall *et al*., 2007).

The Code of Conduct sets thresholds that predict the physiological effects on marine mammals in NZ waters during seismic surveys based on those presented in Southall *et al*. (2007). The ‘injury criteria’ is exceeded if marine mammals are subject to SELs greater than 186 dB re 1 μPa^2-s (DOC, 2013). The Code of Conduct requires that seismic operators employ mitigation measures specifically designed to minimise the potential for marine mammals to be subject to SELs that have the potential to cause threshold shifts (both permanent and temporary). Compliance with the Code’s mitigation measures is the fundamental way in which PGS intends to minimise the potential of auditory damage to marine mammals during the Taranaki West 3D Seismic Survey.

STLM results for the Taranaki West 3D Seismic Survey indicate that compliance with the Code of Conduct will sufficiently protect Species of Concern from physiological effects. Even though PGS are not required to undertake ground-truthing to verify the results of the STLM during the survey in accordance with the Code of Conduct requirements, PGS will still undertake this ground-truthing exercise. In order to do this, representative data recorded on the seismic streamers during the seismic survey will be used to compare actual sound exposure levels with STLM predictions and to measure the SELs at each mitigation zone boundary.

If the physiological thresholds for individual marine mammals are exceeded during the Taranaki West 3D Seismic Survey, temporary threshold shifts may result. Permanent threshold shifts are unlikely due to the typical avoidance behaviours exhibited by marine mammals (see **Section 5.1.2.2**) and compliance with the Code of Conduct (i.e. pre-start observations, soft start and shut-down procedures) which serves to minimise the risk to marine mammals to as low as reasonably practicable.

On this basis it is considered that the acoustic effects could put marine mammals at ***medium*** risk of temporary physiological effects.

In addition, if any stranding occurs that results in mortality during or shortly after seismic operations, PGS will, on a case-by-case basis, consider covering the cost of a necropsy in an attempt to determine the cause of death. PGS understand that DOC will be responsible for all logistical aspects associated with the necropsy, including coordination with pathologists at Massey University to undertake the work.

Seabirds

While physiological damage to seabirds could arise if one was to dive in very close proximity to an active acoustic source, it is more likely that birds in the path of the oncoming seismic vessel will move away from the area well before any physiological damage could occur. Seabirds resting on the sea surface are likely to be startled at the approach of the seismic vessel but are unlikely to experience any physiological effects (MacDuff-Duncan & Davies, 1995). On account of this, it is considered that the risk of physiological effects to seabirds form the acoustic source is ***low***.

Fish

Sound can affect fish physiology in a number of ways depending on the source level and species affected. Such effects include an increase in stress levels (Santulli *et al*., 1999; Smith, 2004; Buscaino al, 2010), temporary or permanent threshold shifts (Smith, 2004; Popper *et al*., 2005), or damage to the animal's sensory organs (McCauley *et al*., 2003).

Scholik and Yan (2002) reported that a hearing threshold shift in fathead minnows was directly correlated to the sound frequency and the duration of exposure. A temporary threshold shift was observed after one hour of exposure to white noise at >1 kHz, but no threshold shift occurred at 0.8 kHz. Popper *et al.* (2005) observed varying degrees of threshold shifts in northern pike, broad whitefish, and lake-chub when exposed to a 730 in^3 acoustic source, and although the degree of threshold shift varied, all species recovered within 24 hours of exposure. The Taranaki West 3D Seismic Survey will use a 3,660 in^3 acoustic source with a frequency between 2 and 250 Hz. Emissions will occur approximately every 7 seconds during acquisition.

It is important to consider the species involved. For example, in the Popper *et al.* (2005) study, two species experienced a temporary threshold shift, while the third showed no evidence of an impact. There is no threshold shift data available for the fish species specific to the Operational Area.

Pelagic fish will typically move away from a loud acoustic source (see **Section 5.1.2.2**), minimising their exposure to the sound and the potential for any hearing damage. As a result, the above data can be interpreted as a 'worst case scenario' for the few fish that remain in close proximity to the seismic source.

Woodside (2007) conducted a comprehensive investigation to assess the effects of a seismic survey on reef fish in Western Australia. Water depths within the study area ranged from 20 – 1,100 m and the seismic source had a total capacity of 2,005 in^3. The study assessed a number of parameters including fish diversity and abundance, coral health, and any pathological changes to auditory tissues. Sound loggers and remote underwater video was deployed and fish exposure cages were utilised to contain captive reef fish. No temporary or permanent threshold shifts were documented for any species during this study.

During the Taranaki West 3D Seismic Survey there is potential for the acoustic source to induce temporary physiological effects on fish species that are in close proximity to the acoustic source; however, the risk of any lasting physiological effects are considered to be ***low*** as most pelagic fish are predicted to move away from and avoid the greatest SELs and soft starts are predicted to facilitate this displacement.

Cephalopods

Acoustic trauma has been observed in captive cephalopods. Andre *et al.* (2011) exposed four cephalopod species to low frequency sounds with SEL of 157 ± 5 dB re 1 µPa (peak levels at 175 re 1 µPa). All of the study animals exhibited changes to the sensory hair cells that are responsible for balance. Andre *et al.* (2011) estimated that such trauma effects could occur out to 1.5 – 2 km from the operating acoustic source.

Squid are found over the continental shelf in waters up to 500 m deep, but are most prevalent in water depths less than 300 m (MFish, 2014). Given this pelagic lifestyle, there is the potential for squid to come into close proximity to the acoustic source during the Taranaki West 3D Seismic Survey. Squid can readily move away from the highest SELs; therefore the duration of exposure during the survey is expected to be low. In addition, squid species are generally short-lived, fasting growing, and have high fecundity rates (MFish, 2014); these life history traits indicate that they are well adapted to disturbances. As a result, there are no anticipated long-term risks to squid populations.

Octopuses inhabit primarily coastal waters and are unlikely to be exposed to acoustic disturbances from seismic operations during the Taranaki West 3D Seismic Survey.

Based on the information above, the risk of physiological trauma to cephalopods is considered to be ***low***.

Crustaceans and Molluscs

Research has shown that some species of crustaceans and molluscs (scallop, sea urchin, mussels, periwinkles, crustaceans, shrimp, gastropods) suffer very little mortality below sound levels of 220 dB re 1µPa@1m, while some show no mortality at 230 dB re 1µPa@1m (Royal Society of Canada, 2004). Based on the STLM results for the Taranaki West 3D Seismic Survey, sound levels of this intensity would only be reached in very close proximity to the acoustic source (i.e. within approximately 10 m).

Moriyasu *et al.* (2004) compiled a literature review on the effects of noise on crustaceans and molluscs. One reviewed study used a single acoustic source with source levels of 220 – 240 dB re 1 µPa on mussels and amphipods at distances of 0.5 m or greater. The results showed no detectable effects. Another study from the Wadden Sea exposed brown shrimp to a source level of 190 dB re 1 µPa@1m, in water depths of 2 m. This study found no mortality or evidence of reduced catch rates. It has been suggested that the lack of a swim bladder in these species reduces the likelihood of physiological damage.

Based on these results, it is considered that the risk of physiological effects to crustaceans and molluscs will be ***low***.

Deep-water Benthic Communities

The potential effects of sound on deep-water benthic communities are not well understood and there is a notable lack of literature on the topic. Potential effects on threatened species such as deep-water corals are of primary concern.

With regard to the effects of seismic operations on coral, it has been hypothesised that high SELs could eject or damage polyps on the calcium carbonate skeleton of corals. However, Woodside (2007) detected no lethal or sub-lethal effects of a seismic survey on warm water corals in shallow water. This study represented a world first demonstrating that seismic surveys can be undertaken in sensitive coral reef environments without significant adverse impacts (Colman *et al*., 2008).

In NZ, deep-water corals (e.g. black coral and stylasteroid hydrocorals) are generally found at depths greater than 200 m (see **Section 4.2.2**). Mortality of coral larvae is known to occur within 5 m of an acoustic source (DIR, 2007). However, black coral are protected from such close contact as their larvae are negatively buoyant and do not disperse very far from their parent colony (Parker *et al*., 1997; Consalvey *et al*., 2006).

The information above suggests that deep-water coral communities are unlikely to be significantly affected by seismic surveys. It is therefore predicted that noise from the Taranaki West 3D Seismic Survey will pose a ***low*** risk to deep-water corals.

Planktonic Larvae

The larvae of fish and invertebrates generally have a pelagic planktonic stage during early development. When in close proximity to an operating acoustic source, plankton are vulnerable to physiological damage. A number of studies have indicated that mortality of planktonic communities can occur if they are within 5 m of an active acoustic source (Payne, 2004; DIR, 2007).

During consultation, a concern was raised about the impacts of seismic operations on larval settlement of rock lobsters in the South Taranaki Bight. With regard to this, Payne *et al*. (2007) didn't observe any significant differences between lobsters treated with exposure to seismic sound and control lobsters in terms of delayed mortality, damage to mechanosensory systems, or appendage loss. However, they did observe temporary changes in feeding behaviour and biochemical and histological stress responses. The effects of seismic surveys on rock lobster settlement rates are unknown; however, it is understood that most rock lobster larvae do not settle in the same region from which their larvae originate, indeed most rock lobster larvae from the Taranaki coastline settle in coastal areas further north, and primary settlement phases typically occur in late winter/spring (Forman *et al*., 2014) which does not overlap with the proposed survey operations. In addition the offshore nature of the Operational Area reduces the potential for spatial overlap between rock lobster larvae and seismic operations.

There is limited literature on the effects of seismic surveys on the larvae of NZ species; however Aguilar de Soto *et al.* (2013) has examined how seismic pulses affect the larvae of NZ scallops. In order to assess the effect of noise on early larvae development, scallop larvae were exposed to seismic pulses of 160 dB re 1 µPa@1m in 3 second intervals within one hour after fertilisation. The effects of noise exposure at 24 to 90 hours of development were investigated and compared to a control group (that experienced no anthropogenic noise). Of the experimental larvae, 46% showed abnormalities in the form of malformations, such as localised bulges in soft tissues. No malformations were observed within the control groups. This study provided the first evidence that continual sound exposure causes growth abnormalities in larvae and it is assumed that other larval shellfish and fish may be prone to similar impacts.

Despite indicating larval vulnerability, it is important to put the results of the Aguilar de Soto *et al*. (2013) study into context. The experimental study was restricted to newly fertilised larvae that were exposed to high intensity sounds every 3 seconds for an extended duration (24 – 90 hours). In contrast, the Taranaki West 3D Seismic Survey will emit an acoustic pulse approximately every 7 seconds and exposure time will be much shorter since the source is constantly moving at ~4.5 kts and will pass most acquisition lines only once. Furthermore, this study used pulse duration of 1.5 seconds whereas the pulse duration for a seismic array is typically around 30 milliseconds. For these reasons the population level risk to planktonic larvae is predicted to be **low**.

5.1.3 Waste discharges/emissions

During the Taranaki West 3D Seismic Survey, the survey vessels will produce various types of waste such as sewage, galley waste, garbage, and oily waters. Inappropriate discharges of these wastes have the potential to cause adverse effects on the marine environment. The volume of waste generated is dependent on the number of crew on-board the vessels and the duration of the survey. All wastes produced will be controlled in accordance to PGS's standard environmental practices, MARPOL requirements (as enacted by the Marine Protection Rules for operations in the EEZ).

5.1.3.1 Potential effects from biodegradable waste

The primary forms of biodegradable waste produced during the Taranaki West 3D Seismic Survey will be sewage, greywater, galley waste and oily water. When discharged to the marine environment, such wastes are decomposed by bacteria either in the water column or on the seabed. This decomposition process increases the biochemical oxygen demand in the surrounding area, which can potentially limit the amount of dissolved oxygen available to other marine organisms. This is particularly so in low flow areas where water circulates slowly. Biodegradable wastes can also lead to areas of artificial enrichment of phosphorous and nitrogen which, in extreme cases, can trigger excessive algal growth.

The survey vessels involved in the Taranaki West 3D Seismic Survey contain on-board sewage treatment plants that ensure a high level of treatment before any sewage or grey-water is discharged. Where applicable, vessels involved in the survey will also be required to hold an International Sewage Pollution Prevention Certificate.

Only galley waste in the form of biodegradable food scraps will be discharged at sea during the survey. This discharge will occur in accordance with the NZ Marine Protection Rules; scraps will only be discharged to sea at distances greater than 12 Nm from land, or, between 3 and 12 Nm, and only comminuted wastes (<25 mm) will be discharged.

Oily waters are generally derived from the bilges; the survey vessels will have a bilge water treatment plant that ensures any discharge is below the required 15 ppm.

MARPOL Annex V requirements will be followed for all aspects of waste disposal. In particular, records will be kept detailing type, quantity, and disposal route, with the records made available for inspection on request.

The risk from routine discharges of biodegradable waste during the Taranaki West 3D Seismic Survey is considered to be ***low***.

5.1.3.2 Potential effects from non-biodegradable waste

Discharges of solid non-biodegradable wastes to the marine environment can have severe detrimental effects on marine fauna. Such effects include entanglement, injury, and ingestion of foreign objects. All non-biodegradable wastes produced during the Taranaki West 3D Seismic Survey will be returned to shore and disposed of in adherence to local waste management requirements, with all chain of custody records retained.

The environmental risk from discharges of non-biodegradable wastes to the marine environment is considered to be ***low***.

5.1.3.3 Potential effects from atmospheric emissions

The principle sources of atmospheric emissions during the Taranaki West 3D Seismic Survey are combusted exhaust gasses. Most of these emissions will be in the form of carbon dioxide, although smaller quantities of other gasses such as oxides of nitrogen, carbon monoxide, and sulphur dioxide may be emitted. These types of emissions are classed as greenhouse gas emissions and are linked to climate change. Combusted exhaust gasses can also reduce ambient air quality, leading to human health issues (usually in populated areas).

The survey vessels will hold International Air Pollution Prevention Certificates, which ensure that all engines and equipment are regularly serviced and maintained; this minimises emissions. Low sulphur fuel is also common place on seismic vessels, which also serves to reduce atmospheric emissions.

Given the offshore nature of the survey and the proactive management of emissions, the environmental risk is considered to be ***low***.

5.1.4 Cumulative Effects

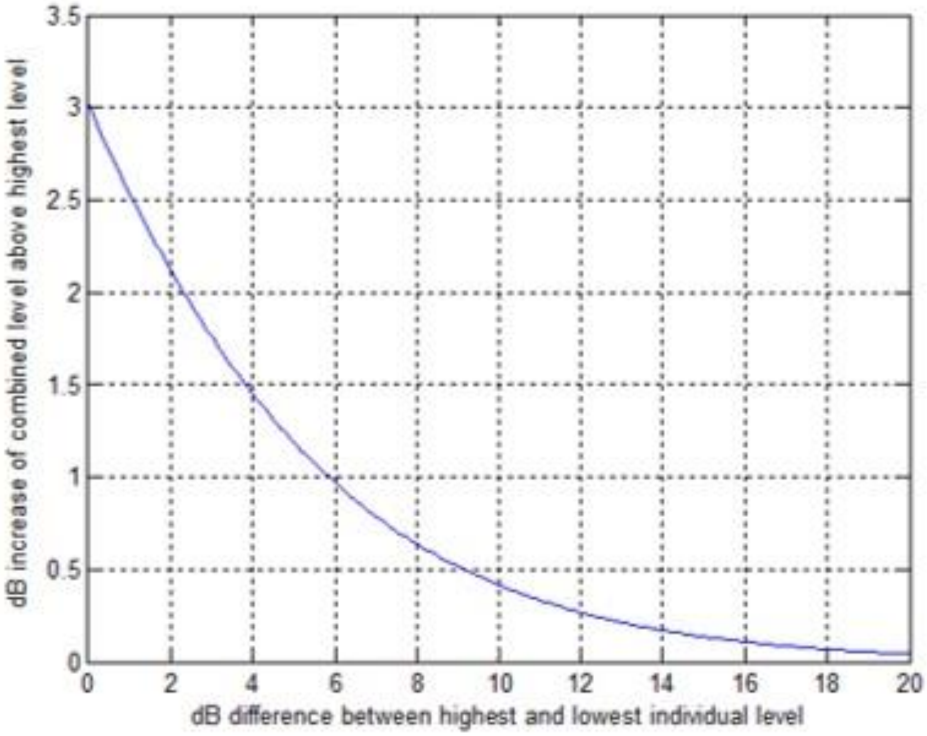
'Cumulative effects' refer to the interaction of the potential effects from the Taranaki West 3D seismic Survey with environmental effects that arise from other marine activities (e.g. other seismic surveys, marine traffic, fishing operations, etc.). The primary concern for seismic surveys is the potential for cumulative acoustic effects that could result when multiple sources of underwater noise combine to significantly increase the underwater sound profile. In particular, cumulative effects associated with other seismic surveys and shipping traffic are discussed below.

Assessing cumulative effects in a quantitative manner is fraught with difficulties and as a result few studies have broached this topic in relation to seismic surveys. Di Iorio & Clark (2009) assessed the calling rate of blue whales during a seismic survey. They concluded that shipping noise in the operational area did not account for any of the observed changes in the acoustic behaviour of blue whales, and that the seismic survey was solely responsible for the observed changes. Such results are relevant in an environment where heavy levels of shipping existed prior to any seismic operations, but in areas where shipping levels are historically lower, the combinations of a seismic survey with shipping noise could result in greater disturbance to marine mammals than from either activity in isolation. In such circumstances, it is probable that some masking of marine mammal vocalisations, especially the low frequency calls of baleen whales, could occur. The zone of impact of masking effects could be relatively large given the low frequency nature of shipping and seismic noises which propagate over long distances.

Recent studies have provided evidence to suggest that in the presence of consistent noise, marine mammals do adapt their vocalisations, presumably to mitigate against the effects of masking (e.g. McGregor *et al.,* 2013) (see **Section 5.1.2.2**). These studies support the notion that the most significant masking effects can be expected in areas where baseline noise levels are typically low.

When the acoustic outputs from two difference seismic surveys combine, the outcome is counter-intuitive; the largest difference between the combined and individual SELs will be 3 dB re 1µP^{2-}s, however this will only occur when both surveys produce the same SEL's. To put this into context, if at a given location Survey A by itself would produce a SEL of 160 dB re 1µP^{2-}s, and Survey B by itself would also produce an SEL of 160 dB re 1µP^{2-}s, then the two surveys combined will produce an SEL of 163 dB re 1µP^{2-}s (Alec Duncan pers. comm.). However, if one survey produced a higher SEL, then the higher SEL would dominate to the point where if Survey A produces an SEL of 6 dB re 1µP^{2-}s higher than Survey B, then the combined level is 1 dB re 1µP^{2-}s higher than the higher of the individual SELs (i.e. Survey A) (**Figure 24**).

Figure 24: Combined Sound Exposure from Two Seismic Sources



Cumulative effects are much more likely to occur when two surveys are operating close together in both time and space. It is hypothesised that a cetacean may be able to reorient and cope with a single sound source emitted from a seismic survey, but may be less able to cope with multiple sources.

The potential for cumulative effects from interactions with other seismic operations is also likely to be related to physical features such as depth, bathymetry and coastline shape. A higher risk is present in shallow waters and enclosed bays or areas, where the attenuation potential is lower. Resident populations (such as Hector's dolphins) will be more sensitive to cumulative effects than will migratory or non-resident populations (for example humpback whales).

The only other seismic surveys that will occur concurrently with the Taranaki West 3D Seismic Survey is the Schlumberger East Coast Basin 3D Seismic Survey. However, these surveys will be acquired on opposite sides of Cook Strait; hence cumulative effects are likely to be limited. In addition, two surveys will occur in Taranaki prior to the Taranaki West 3D Seismic Survey; hence, the regional effects from seismic surveys may persist off the Taranaki coast for longer than the duration of a single survey.

The low frequency nature of shipping noise is not unlike that of seismic, in that it travels long distances underwater. Offshore Taranaki and the West Taranaki Bight are frequently used by large ships in transit. Hence background shipping noise is likely to be a constant in the Operational Area and both alone and in conjunction with the Taranaki West 3D Seismic Survey could cause some masking of marine mammal vocalisations.

Despite the potential for cumulative effects to occur, no specific additional mitigation measures are recommended to address these effects.

5.2 Unplanned Event – Potential Effects and Mitigations

The unplanned events associated with seismic operations include the introduction of invasive marine species, streamer loss, hydrocarbons spills, or a vessel collision/sinking. Although such unplanned events are rare during seismic operations, the potential effects of any unplanned incident must be given serious consideration as the consequences of such events can be high. The potential incidents are discussed below.

5.2.1.1 Potential effects of invasive marine species

The introduction of and spread of marine pests or invasive species to NZ waters can occur through ballast water discharges, sea chests and hull fouling on vessels.

As part of the environmental management commitments for the proposed Taranaki West 3D Seismic Survey, PGS have committed to mitigate the risk of introducing invasive marine species by requiring that the survey and support vessels are inspected by qualified invasive marine species inspectors prior to the vessels entering the country. Based on the outcomes of the inspections, management measures will be implemented to ensure the vessels meet the Part 2.1 'clean hull requirement of the Craft Risk Management Standard – Biofouling on Vessels Arriving to NZ'. All survey vessels brought into the country will also adhere to the 'Import Standard for Ballast Water Exchange'. The potential risk of introducing invasive marine species during the survey is therefore considered to be ***low.***

5.2.2 Potential effects from streamer loss

Potential damage or loss, of streamers could occur in the event that they become snagged on floating debris, rupture from abrasions or shark bites, or are severed (e.g. if another vessel accidentally crossed the streamer). As solid streamers are negatively buoyant they would sink if severed; therefore, if a streamer is lost there is potential for the severed portion to make contact with the seabed.

Solid streamers fitted with self-recovery devices will be used during the Taranaki West 3D Seismic Survey. The self-recovery devices are programmed to activate at depth (~50 m), bringing the severed streamer back to the surface for retrieval. The use of self-recovery devices will minimise the potential for damage to the seabed and benthic communities in the event of streamer loss.

The Taranaki West 3D Seismic Survey will also be undertaken by experienced personnel, therefore the environmental risk from streamer loss is considered to be ***low***.

5.2.3 Potential effects from hydrocarbon spills

A hydrocarbon spill has the potential to arise from a number of causes; a refuelling incident, leaking equipment or storage facilities, or hull/fuel tank failure due to a collision or sinking.

A refuelling incident at sea is the most likely to cause of a hydrocarbon spill into the marine environment during the Taranaki West 3D Seismic Survey. Refuelling of the seismic vessel will be undertaken at sea every 5 weeks from the support vessel. Potential causes of a fuel spill during refuelling include hose rupture, coupling failures or tank overflow. The seismic vessel will have a detailed refuelling protocol and procedures will be in place to prevent any incidents. Spills caused by fuel handling mishaps are rare due to well-tested monitoring and management systems.

If a spill from the fuel tank of the seismic vessel did occur, the maximum possible volume spilt would be 2,092 m^3. For this to occur there would have to be a complete failure of the vessel's fuel containment systems, or a catastrophic failure of hull integrity. The high-tech navigational systems on-board, adherence of the COLREGS and operational procedures aligned with international best practice will ensure that such risks are minimised.

Where applicable, all vessels involved in survey operations will have an approved and certified Shipboard Oil Pollution Emergency Plan and an International Oil Pollution Prevention Certificate, as per MARPOL 73/78 and Marine Protection Rules Part 130A and 123A.

During refuelling operations, the following mitigation actions will be adhered to in order to prevent a hydrocarbon spill:

- Refuelling will only be undertaken during daylight and when sea conditions are appropriate as determined by the vessel master;
- A job hazard analysis (or equivalent) will be in place and reviewed before each fuel transfer;
- Transfer hoses will be fitted with ‘dry-break’ couplings (or similar and checked for integrity);
- Spill response kits will be maintained and located in close proximity to hydrocarbon bunkering areas;
- Refuelling operations will be manned to ensure constant visual monitoring of gauges, hoses, fittings and the sea surface; and
- Radio communications will be maintained between the seismic vessel and support vessel.

In the event that a spill occurs during refuelling, a spill response will initially be undertaken in accordance with the Shipboard Oil Pollution Emergency Plan, and notification will be provided to Maritime NZ as required.

Based on the information presented above and the mitigation actions in place, it is considered that the risk of effects from a hydrocarbon spill is ***low***.

5.2.4 Potential effects from vessel collision or sinking

If a collision occurred during the seismic operations, the biggest threats to the environmental would be the vessel reaching the sea floor and/or the release of any hazardous substances or hydrocarbons. An incident of this nature is extremely unlikely and risks are mitigated through the constant presence of a support vessel and adherence to the COLREGS. As a result, the risk of a vessel collision or sinking incident is considered to be ***low***.

5.3 Environmental Risk Assessment Summary

A summary of the ERA results is presented in **Table 16**.

Table 16: Summary of ERA Results for the Taranaki West 3D Seismic Survey

Effects from Planned Activities	Consequence	Likelihood	Risk Ranking
Physical presence of seismic vessel and towed equipment – marine mammal effects	Minor	Possible	Medium
Physical presence of seismic vessel and towed equipment – seabird effects	Negligible	Possible	Low
Physical presence of seismic vessel and towed equipment – fisheries/marine traffic effects	Moderate	Possible	Medium
Physical presence of seismic vessel and towed equipment – marine archaeology effects	Negligible	Unlikely	Low
Acoustic disturbance – behavioural effects on marine mammals	Minor	Likely	Medium
Acoustic disturbance – behavioural effects on seabirds	Negligible	Possible	Low
Acoustic disturbance – behavioural effects on turtles	Minor	Unlikely	Low
Acoustic disturbance – behavioural effects on fish and cephalopods	Minor	Likely	Medium
Acoustic disturbance – impacts on fisheries	Minor	Likely	Medium
Acoustic disturbance – behavioural effects on crustaceans	Negligible	Possible	Low
Acoustic disturbance – physiological effects on marine mammals	Minor	Possible	Medium
Acoustic disturbance – physiological effects on seabirds	Negligible	Unlikely	Low
Acoustic disturbance – physiological effects on fish	Negligible	Possible	Low
Acoustic disturbance – physiological effects on cephalopods	Negligible	Possible	Low
Acoustic disturbance – physiological effects on crustaceans and molluscs	Negligible	Unlikely	Low
Acoustic disturbance – physiological effects on deep water benthic communities	Negligible	Unlikely	Low
Acoustic disturbance – physiological effects on planktonic larvae	Negligible	Possible	Low
Effects from the discharge of biodegradable waste	Negligible	Possible	Low
Effects from the discharge of galley non-biodegradable waste	Negligible	Unlikely	Low
Effects from atmospheric emissions	Negligible	Unlikely	Low
Effects from Unplanned Events	**Consequence**	**Likelihood**	**Risk Ranking**
Effects from invasive marine species	Minor	Unlikely	Low
Effects from streamer loss	Negligible	Unlikely	Low
Effects from hydrocarbon spills	Minor	Unlikely	Low
Effects from vessel collision or sinking	Minor	Unlikely	Low

6 ENVIRONMENTAL MANAGEMENT PLAN

The management of environmental risks is fundamental to PGS's operating philosophy. The protocols outlined in the MMMP (**Appendix E**) are the primary measures by which PGS proposes to manage environmental risks during the Taranaki West 3D Seismic Survey. The MMMP is the operating procedure that is followed by MMOs and the seismic vessel crew while at sea in order to ensure compliance with the Code of Conduct.

Some additional measures over and above the requirements of the Code of Conduct will also be in place during the Taranaki West 3D Seismic Survey. As well as being reflected in the MMMP, these measures are summarised in the Environmental Management Plan (EMP) presented in **Table 17**.

The EMP is essential for the successful implementation of the Taranaki West 3D Seismic Survey. It summarises the key environmental objectives, the full suite of mitigation measures, and the regulatory and reporting requirements and commitments outlined in this MMIA.

Table 17: Taranaki West 3D Seismic Survey Environmental Management Plan

Environmental Objectives	Proposed Controls	Relevant Legislation or Procedure
Minimise behavioural and physiological effects to marine fauna	• The limited duration of operational activities serves to reduce the temporal scale of effects to an anticipated 45 days • Seismic operations will continue around the clock (as possible) to reduce the overall duration of the survey • The slow speed (4-5 knots) of the seismic vessel will reduce the potential for collisions with marine fauna • Timing of the survey (summer months) is not predicted to affect whale migration behaviours • All seismic acquisition outside 12 nm, hence effects on Farewell Spit, coastal species & larvae will be minimised • PGS has undertaken source modelling to ensure that their survey is using the lowest possible acoustic source volume • Compliance with the Code of Conduct, including: ➢ Visual and acoustic detections of marine mammals to prompt required delayed starts and shut-downs ➢ Soft starts to ensure that mobile fauna can avoid the highest SELs ➢ Adherence to an approved Marine Mammal Mitigation Plan ➢ Ground-truthing of STLM results will occur during the survey ➢ PAM equipment has been approved as suitable for high frequency NZ Species of Concern • Although not strictly required, STLM was conducted to verify that the standard mitigation zones are appropriate • Marine mammal sightings will be collected whilst in transit to the Operational Area • MMOs will be vigilant for entanglement incidents and will report any dead marine mammals observed at sea • MMOs to notify DOC immediately of any Hector's/Maui's dolphin sightings; humpback and southern right whales in the territorial sea will also be reported immediately to DOC & Weekly MMO reports to be provided to DOC and EPA • PGS will consider covering the cost of necropsies on a case-by-case basis in the event of marine mammal strandings	Code of Conduct EEZ Act 2012 MMMP
Minimise disruption to fisheries and other marine traffic	• The limited duration of operational activities serves to reduce the temporal scale of effects to an anticipated 45 days • Seismic operations will continue around the clock (as possible) to reduce the overall duration of the survey • Comply with the COLREGS and have a support vessel present at all times • Notify commercial fishers of the proposed survey and provide web-based near real-time position information/scheduling • Issue a Notice to Mariners and a coastal navigation warning • Display a tail buoy at the end of each streamer to mark the overall extent of the towed equipment • All seismic acquisition outside 12 nm, hence effects on recreational fish stocks species will be minimised	COLREGS International best practice
Minimise effects on marine archaeology, cultural heritage, submarine infrastructure	• No planned activity will impact the seabed • No operations within the CMA where most sites of cultural significance are located	RMA 1991
Minimise potential of invasive species	• Survey vessels to be inspected by qualified invasive marine species inspectors • Adherence to Craft Risk Management Standard for Vessel Biofouling (CRMS) • Adherence to Import Health Standard for Ships Ballast Water (IHS)	Biosecurity Act 1993 IHS CRMS
Minimise effects on water quality	• All discharges to sea will occur in accordance with MARPOL and relevant NZ legislation • On-board sewage treatment plant and approved ISPPC as applicable • On-board bilge water treatment plant to ensure oily water discharge does not exceed 15 ppm • All non-biodegradable waste to be returned to shore for disposed at an approved shore reception facility • PGS will ensure that a waste disposal log is maintained on all survey vessels	MARPOL Annex V and IV Maritime Transport Act 1994 Marine Protection Rules Part 170 Resource Management (Mar Pol) Regulations 1998
Minimise effects on air quality	• Regular maintenance of machinery • Approved IAPPC where applicable to vessel class and regular monitoring of fuel consumption	International best practice
Minimise the likelihood of unplanned events	• Seismic operations will continue around the clock (as possible) to reduce the overall duration of the survey • Comply with the COLREGS and have a support vessel present at all times • Approved SOPEP and IOPPC where applicable to vessel class • Refuelling will only occur during daylight and in good sea conditions, and will be constantly monitored • Transfer hoses will be fitted with 'dry-break' couplings • Spill response kits will be maintained and located in close proximity to hydrocarbon bunkering areas • Radio communications will be maintained between the seismic vessel and support vessel during refuelling • Solid streamers used in conjunction with self-recovery devices	International best practice COLREGS Maritime Protection Rules Part 130A and 123A JHA for refuelling

7 CONCLUSION

Marine seismic surveys are considered to be routine activities within the oil and gas industry and are a prerequisite for the discovery of hydrocarbons beneath the seabed. During the proposed Taranaki West 3D Seismic Survey, PGS will comply with the Code of Conduct as the primary means of mitigating environmental effects. By committing to the mitigation measures required by the Code of Conduct, the potential physiological and behavioural effects of acoustic disturbance on marine mammals will be minimised to a level that is deemed acceptable by DOC. In addition to the requirements of the Code of Conduct, STLM has been conducted to verify that the standard mitigation zones specified in the Code of Conduct will sufficiently protect marine mammals during the Taranaki West 3D Seismic Survey.

In compliance with the Code of Conduct, PGS will have two MMO's and two PAM operators on-board the seismic vessel. These personnel will be independent and qualified through DOC-recognised training programmes. Visual observations will occur through daylight hours when the source is active and PAM operations to acoustically detect marine mammals will occur around the clock to enable detections of marine mammals at night. Depending on the circumstance and in keeping with the Code of Conduct, marine mammal detections will trigger the required mitigation actions, e.g. delayed start or shut downs of the source. In addition to the four qualified MMOs, PGS has also made a commitment to local iwi groups to engage a trainee iwi MMO as a way of assisting these trainees towards becoming qualified.

In addition to the measures outlined in the Code of Conduct, PGS will comply with all other relevant NZ legislation and international conventions (in relation to navigational safety, waste discharge, biosecurity etc). PGS has also proposed a number of extra management actions to further reduce the likelihood of environmental effects and to contribute to the knowledge of marine mammals in the proposed Operational Area. Other management actions have also been proposed to minimise potential effects on cultural and commercial sensitivities.

This MMIA identifies all potential environmental effects from the Taranaki West 3D Seismic Survey and describes all proposed mitigation measures that will be implemented to ensure that any potential effects are reduced to levels as low as reasonably practicable.

With regards to marine mammals, displacement of whales into suboptimal habitat was identified as the primary environmental risk. This was particularly noteworthy for pygmy blue whales that associate with dense prey aggregations in the South Taranaki Bight region. However it is considered that compliance with the Code of Conduct should provide appropriate protection to this species.

Although the MMIA focusses largely on potential marine mammal effects, potential effects on other components of the marine ecosystem and existing maritime activities are also considered and assessed through well-established ERA methodologies. In summary, the predicted effects of the Taranaki West 3D Seismic Survey are considered to be ***low to medium***, with medium effects representing a small environmental effect that is sufficiently managed by mitigation measures proposed in this MMIA.

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LETTER TO IWI

7 October 2015

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[Address line 1]
[Address line 2]
[Address line 3]

Attention: [name]

Tena Koe [first name],

Information to Iwi regarding the PGS PPP Area

This letter is to inform you that PGS Australia Pty Ltd (PGS), a multi-client seismic provider has lodged an application for a Petroleum Prospecting Permit (PPP) off the west coast of the North Island in the Taranaki Basin. If the PPP application is approved, this will allow PGS to undertake a marine seismic survey as well as reprocess previously acquired seismic data within the PPP area.

New Zealand Petroleum and Minerals will contact you shortly as part of their statutory notification process (as required by the Crown Minerals Act 1991) to provide you with:

- more information about PGS's PPP application;
- an opportunity to comment on the application, and
- a map of the proposed PPP Area

We are contacting you on behalf of PGS, as an overlap has been identified between your rohe and the proposed PPP Area that will soon be circulated. This letter is to inform you that despite this overlap, no new seismic acquisition is planned within your rohe. Instead, the reprocessing of previously acquired seismic data is intended. The size of the proposed PPP Area is sufficiently broad to cover all new acquisition operations and all reprocessing.

Reprocessing of previously acquired seismic data with new technology (i.e. more powerful computers and software) facilitates a better understanding of the underlying geology in the area. If granted, the PPP will give PGS the exclusive rights to the resulting seismic data for 15 years.

If PGS are awarded a PPP, there are still further regulatory requirements that have to be adhered to prior to commencing seismic acquisition. This will involve adhering to the Exclusive Economic Zone & Continental Shelf (Environmental Effects) Act 2012 and complying with the Department of Conservation (DOC) Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations. Regulatory approval from the Director General of DOC is required before seismic survey activities can commence.

Please feel free to contact me with any further questions.

Yours sincerely

HELEN MCCONNELL

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SLR
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PGS Australia Pty Ltd
Taranaki Basin 3D Marine Seismic Surveys
Information Sheet

Introduction

SLR New Zealand Limited (SLR) has been engaged by PGS Australia Pty Ltd (PGS) to prepare Marine Mammal Impact Assessments for two upcoming marine seismic survey operations in the South Taranaki Bight. The proposed Operational Areas for 3D seismic acquisition are illustrated in **Figure 1**.

The purpose of the proposed surveys is to gain a better understanding of the regional underlying geology in the Taranaki Basin in relation to oil and gas exploration. PGS have been granted a Petroleum Prospecting Permit from New Zealand Petroleum and Minerals. The permit area is depicted by the blue outline in **Figure 1.**

Within the South Taranaki Bight, seismic surveys will be restricted to the defined Operational Areas that are located within New Zealand's Exclusive Economic Zone. The actual acquisition areas are likely to be smaller still. No survey operations will occur within the territorial sea (i.e. within 12 nautical miles of the New Zealand coast).

PGS will operate in accordance with the Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012 (EEZ Act) which classifies Seismic Surveys as Permitted Activities as long as they comply with the Department of Conservation's *2013 Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Operations* (Code of Conduct).

The proposed surveys are scheduled to commence in mid-October 2016, with an estimated total duration of up to 120 days.

Operational Summary

Seismic surveying is commonly used in the oil and gas industry to improve the understanding of subsurface geology. The proposed surveys will use a purpose-built seismic survey vessel to collect seismic data derived from towed acoustic source arrays and hydrophone cables, also known as streamers.

The vessel will tow 10 streamers that are up to 8.1 km in length. The streamers are placed at 150 m spacings which results in an overall span of 1,350 m. This broad span of towed gear significantly restricts the manoeuvrability of the vessel (**Figure 2**). The end of each streamer is marked with a tail buoy equipped with a flashing light and radar reflector, allowing the streamers to be visible day and night. The vessel will traverse a series of pre-determined survey lines within each of the Operational Areas at a speed of approximately 4–5 knots (7–9 km/hr) and will operate 24 hours per day.

The source array produces acoustic emissions that are reflected off the subsurface geology and detected by the streamers on their return (**Figure 3**). These acoustic reflections are recorded as seismic data that is transferred back to the seismic vessel. The data is subsequently processed to provide information about the structure and composition of the geological formations below the seabed.

A support vessel will accompany the seismic vessel to ensure the survey area is clear of obstructions and to inform other marine users of the presence of the seismic vessel and its restricted ability to manoeuvre. A Notice to Mariners will be issued and a coastal navigation warning will be broadcast daily on maritime radio advising others that a seismic survey is underway. These notices will be in place for the duration of the surveys.

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Company Number 2443058

Environmental Management and Approvals

PGS has a recognised track record of technological leadership in the science of geophysics and a history of successfully conducting similar marine seismic surveys worldwide. PGS conduct their business with integrity and strong environmental ethics and are committed to a high level of corporate accountability.

The proposed Taranaki Basin 3D Seismic Surveys are undergoing rigorous environmental risk assessments and risk mitigation planning. PGS will operate their proposed surveys in accordance with the Code of Conduct as per the requirements of the EEZ Act. This requires a Marine Mammal Impact Assessment to be prepared for each Operational Area and for the mitigation measures outlined in the Code of Conduct to be adhered to at all times to reduce the potential for any adverse effects on the marine environment, in particular marine mammals. The Director-General of Conservation is required to review all Marine Mammal Impact Assessments before seismic survey operations can commence.

Furthermore, PGS are leaders in Health and Safety and consider personnel health, operational safety and protection of the environment as key building blocks of their organisation.

Contact Details

If you have any further questions or matters you would like to discuss or you would like any further information in regard to the proposed surveys, please contact Helen McConnell of SLR.

Helen McConnell
Associate Consultant
SLR Consulting New Zealand Ltd

Mobile: 0275 267 123
Email: hmcconnell@slrconsulting.com
PO Box 5061
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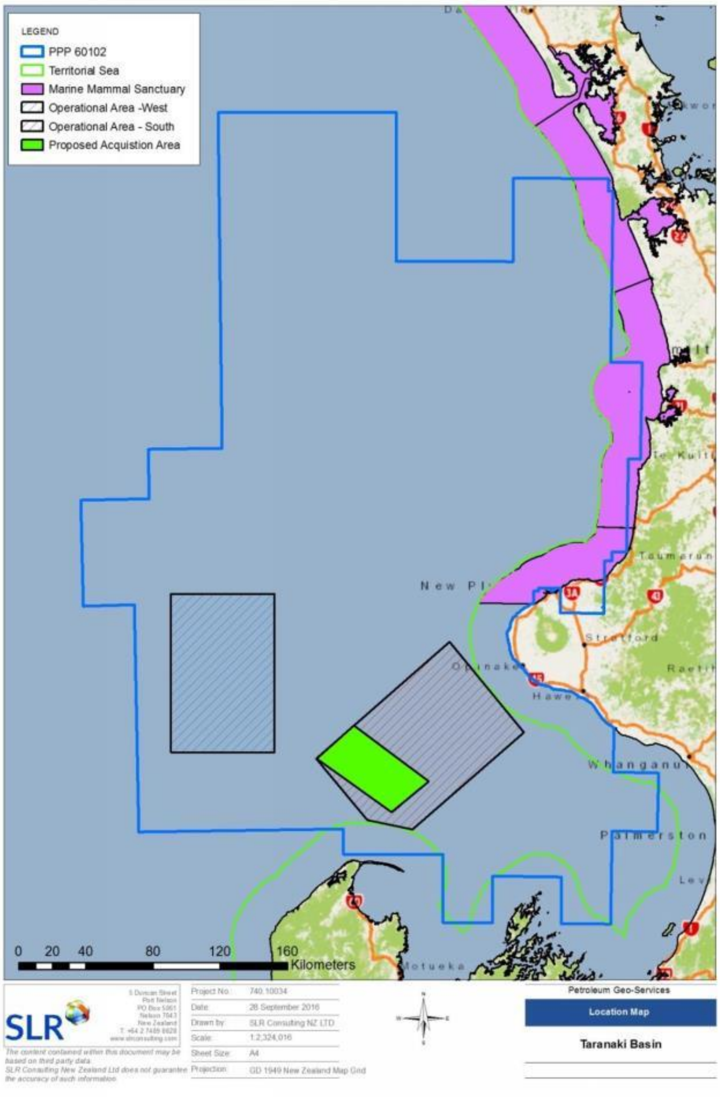
SLR global environmental solutions

Figure 1: Taranaki Basin 3D Marine Seismic Surveys

(The Petroleum Prospecting Permit Area is defined by the blue outline, Operational Areas are defined by black outlines, and an acquisition area has been defined for one of the surveys and is depicted in green)



SLR Consulting NZ Limited

Figure 2: Schematic of a 3D seismic survey layout

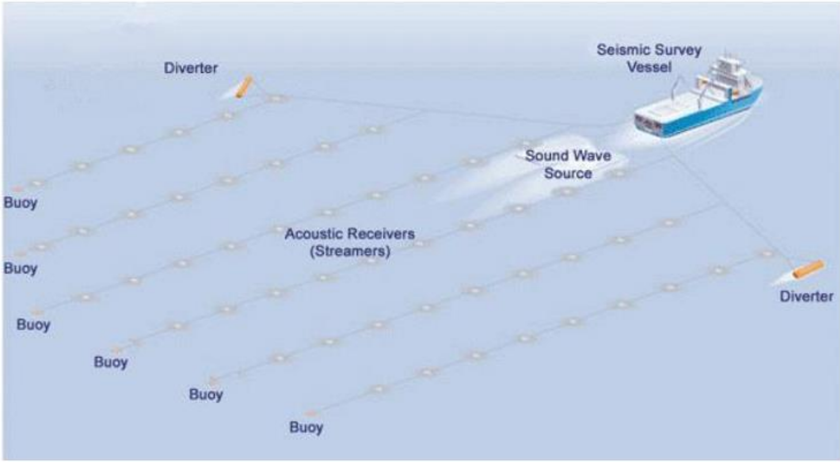
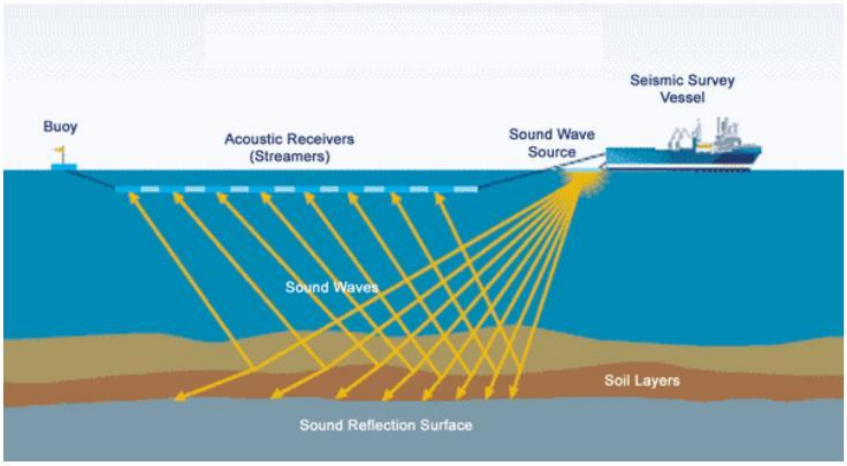


Figure 3: Schematic of acoustic sound waves being reflected from subsurface layers



SLR Consulting NZ Limited

Stakeholder	Means	Date	Stakeholder Feedback	PGS Commitments
Te Atiawa ki Whakarongotai	Letter	9.10.15	-	-
Taranaki Whānui ki te Upoko o te Ika	Letter	9.10.15	-	-
Te Atiawa (Wellington)	Letter	9.10.15	-	-
Ngāti Toa Rangatira	Letter	9.10.15	-	-
Te Atiawa o Te Waka-a-Māui	Letter	9.10.15	-	-
Ngāti Apa ki te Rā Tō	Letter	9.10.15	-	-
Rangitāne o Wairau	Letter	9.10.15	-	-
Ngāti Kuia	Letter	9.10.15	-	-
Ngāti Rarua	Letter	9.10.15	-	-
Ngāti Kōata	Letter	9.10.15	-	-
Ngāti Tama ki Te Tau Ihu	Letter	9.10.15	-	-
Te Atiawa – Top of the South	Letter	9.10.15	-	-
Tainui	Letter	9.10.15	-	-
Ngati Maru (Hauraki)	Letter	9.10.15	-	-
Ngati Paoa	Letter	9.10.15	-	-
Ngati Tamatera	Letter	9.10.15	-	-
Ngati Hako	Letter	9.10.15	-	-
Ngāti Whātua o Ōrākei	Letter	9.10.15	-	-
Te Kawerau a Maki	Letter	9.10.15	-	-
Ngāti Tamaoho	Letter	9.10.15	-	-
Te Ākitai Waiohua	Letter	9.10.15	-	-

Ngāti Whanaunga	Letter	9.10.15	-	-
Ngāti Whātua o Kaipara	Letter	9.10.15	-	-
Ngāti Te Ata	Letter	9.10.15	-	-
Ngati Maniapoto	Info sheet	16.12.15, 27.09.16	-	-
Ngati Mutunga	Meeting, Email update	16.12.15, 5.10.16	Ngati Mutunga have an iwi member who has attended the PEPANZ MMO training course. Key interest was to ensure that fishing fleets are well aware of the proposal.	- Trainee Iwi MMO to be on board seismic vessel
Ngati Tama	Meeting, Email update	16.12.15, 5.10.16	Key interest was to ensure that fishing fleets are well aware of the proposal.	- Trainee Iwi MMO to be on board seismic vessel
Ngati Rahiri Hapu (Te Atiawa)	Meeting, Email update	14.12.15, 5.10.16	Have a strong preference for the 4 trained iwi MMOs in Taranaki to be used first before other MMOs from other regions are considered. Identified concerns about whale stranding risks at Farewell Spit.	- Trainee Iwi MMO to be on board seismic vessel - Post survey visit to present relevant findings and summary for MMO data
Otaraua Hapu (Te Atiawa)	Info sheet, Email update	16.12.15, 5.10.16	-	-
Manukorihi Hapu (Te Atiawa)	Meeting, Email update	14.12.15, 5.10.16	Queried how iwi could stop operations; seismic operations are not in themselves concerning, but the exploration/production activities that follow are of greater concern so would rather stop future drilling by not allowing seismic . Philosophically opposed to Oil & Gas development. Concerned about coastal archaeological sensitivities.	- Trainee Iwi MMO to be on board seismic vessel

Taranaki iwi	Info sheet	17.12.15, 29.09.16	-	-
Manawhenua ki Mohua	Meeting	18.12.15 & 6.10.16	Particular concerns about pilot whales, blue whales, impacts on Farewell Spit, strandings on the Spit (iwi have a spiritual connection to stranded whales), and the harvest of customary foods within Mataitai areas. Are very strongly opposed to all seismic operations in the territorial sea on account of stranding concerns. Keen to see the MMO report after the survey. Are generally opposed to Oil & Gas activities, not seismic specifically, but the exploration and production activities that could follow.	- Send through information sheet, MMIA, seismic survey information presentation from PEPANZ, Code of Conduct, Oceans of Noise - Mataitai to be discussed in MMIA - Trainee Iwi MMO to be on board seismic vessel - Post survey vist to present relevant findings and continue the relationship - Provide MMO report after survey
Nga Ruahine	Meeting	15.12.15 & 4.10.16	The south Operational Area is of primary interest due to their mana moana over the area, but all Operational Areas are of interest due to migratory species. Would prefer to have a Nga Ruahine/Ngati Ruanui trainee MMO on the survey and asked for the allocation process to be stated in the MMIA for transparency. Key environmental concerns were seabirds, cumulative impacts and lack of a more holistic long-term perspective when it comes to preserving mana moana.	- Trainee Iwi MMO to be on board seismic vessel - Iwi MMO allocation process to be stated in MMIA - Post survey visit to present relevant findings - Key environmental concerns to be thoroughly addressed in MMIA - seabirds, cumulative impacts and lack of a more holistic long-term perspective when it comes to preserving mana moana - Provide finalised MMIA - Provide detailed bathymetry image - Provide login for web-based vessel positioning information
Ngati Ruanui	Meeting	15.12.15 & 4.10.16	The south Operational Area is of greatest interest and relevance to Ngati Ruanui. They are reasonably comfortable with seismic operations provided operators	- Taonga species list to be included in MMIA - MMIA to be provided to Ngati Ruanui - Iwi MMOs to be on board seismic vessel

			demonstrate best practice and share information post-survey. Would like to review/see the full MMIA to ensure their cultural sensitivities were addressed properly. Keen to see a local connection between the MMO and the area being acquired – important for iwi/Oil & Gas relations. Two Ngati Ruanui have just received training. Want the seismic vessel to be blessed before operating in NZ.	- Vessel blessing to be conducted
Nga Rauru Kitahi	Info sheet	16.12.15, 26.09.16	-	-
Whanganui Iwi fisheries/Te Atihaunui	Meeting	15.12.15 & 3.10.12	Considers the key thing with regard to potential impacts on fisheries is good communication between fisheries groups and the seismic company. Raised the issue of impacts on migrating eels across South Taranaki Basin.	- Include description of the fisheries likely to be most affected in MMIA - Provide details of forward scheduling and real-time maps - Provide detailed bathymetry image - Provide copy of finalised MMIA - Post survey visit to present relevant findings
Ngati Apa	Info sheet, Meeting	16.12.15, 3.10.12	-	- Provide copy of finalised MMIA
Department of Conservation – Wellington	Meeting	27.11.15 & 3.10.16	Advised that operating in the MMS is technically possible, but would increase the social risks. Requested separate MMIAs to be submitted for each area with its own STLM. Confirmed they are happy to accept modelling on the larger of the possible arrays (3090 or 4130) but noted potential problems with ground truthing. Mentioned that it is the first season in which qualified PAMOs were available and that these must be engaged first before	- Address all DOC feedback in draft MMIA - Provide weekly MMO reports

			trained PAMOs are engaged. DOC are happy to review the MMIA in stages.	
Department of Conservation – Taranaki	Meeting	26.11.15 & 5.10.16	Voiced concern at how consultation with iwi could be achieved before Christmas due to the short time frame and number of iwi. No further concerns were raised.	- Provide weekly MMO reports - Immediately report Hector's/Maui's dolphin sightings (in all areas), and humpback and southern right whales (in territorial sea)
Department of Conservation - Takaka	Meeting	18.12.15 & 6.10.16	Did not raise any concerns, but lengthy discussions had around whale strandings on Farewell Spit.	- Provide information sheet, MMIA, seismic survey information presentation from PEPANZ, Code of Conduct, Oceans of Noise
Environmental Protection Authority	Meeting	27.11.15 & 3.10.16	Would appreciate weekly reports and an opportunity to audit the vessel before the survey begins but did not raise any concerns.	- Provide weekly MMO reports - Liaise regarding vessel audits
Taranaki Regional Council	Meeting, Info sheet	26.11.15, 30.09.16	As all operations were planned for outside TRC's jurisdiction, they have no problem with the proposed survey.	- Provide copy of final MMIA - Provide basic information on seismic surveying to the council
Deepwater Group, Talleys & Sealords	Meeting	18.12.15 & 7.10.12	Generally the fishing industry is supportive of the Oil & Gas industry but conflict on water, decreased catch per unit effort, scampi effects and impacts on fisheries surveys are the key concerns which can all be managed through communications. Primary concern with Oil & Gas is not seismic but abandonment of wells and structures left behind.	- Provide web-based real-time locational update during survey and forward scheduling - Provide detailed bathymetry image - Provide coordinates for Operational Area
Auckland University	Info sheet	Dec 2015	-	-
Egmont Seafoods	Meeting	16.12.15 & 5.10.16	The main issue for Egmont Seafoods is communication; knowing when and where to operations will occur. Most of their vessels are set net boats and this static gear is at greater risk than trawlers.	- Provide web-based real-time locational update during survey and forward scheduling - Provide detailed bathymetry image

New Plymouth Sport Fishing Club	Meeting	17.12.15	Previous conflicts on account of seismic season overlapping with Marlin season, however little overlap with the survey and Operational Areas was predicted. Communication would be appreciated.	- Provide web-based real-time locational update during survey and forward scheduling
Port Taranaki	Meeting	17.12.15 & 4.10.16	Noted there would not be any problems with either of the proposed vessels using Port Taranaki berths. Suggested that although there were other Oil & Gas operations that may overlap with the proposed timeframe, there should be no problems with PGS vessels operating from the port at the same time.	- Clarification of bunkering requirements provided in MMIA - Forward warning of the arrival of survey vessel
Project Jonah	Info sheet	22.12.15 & 7.10.16	-	-
Massey University	Info sheet	21.12.15	Happy to conduct any necropsies as required	-
NIWA	Info sheet	21.12.15, 30.09.16	-	-
Oregon State University	Info sheet	21.12.15, 30.09.16	Thanks for the notification and keen to develop a communication protocol between the seismic vessel and the research boat	Communication protocol to be developed as relevant
NZ Rock lobster Industry Council	Info sheet	21.12.15	Concerns re impacts on lobster larval settlement disruption	Include comment on rock lobster settlement in MMIA

SOUND TRANSMISSION LOSS MODELLING RESULTS

Petroleum Geo-Services

Taranaki West 3D Seismic Survey

Sound Transmission Loss Modelling

Report Number 740.10034

28 January 2016

PGS Australia Pty Ltd

Level 4, IBM Building

106 Hay Street

Western Australia 6005

Version: Draft 1

Petroleum Geo-Services

Taranaki West 3D Seismic Survey

Sound Transmission Loss Modelling

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Executive Summary

PGS Australia Pty Ltd (PGS) is proposing to acquire a three dimensional (3D) marine seismic survey in the Taranaki Basin. The Operational Area lies to the northwest of Cape Farewell in water depths of over 200 m. The seismic survey is predicted to be a 60 day operational programme that is scheduled to be acquired between 1 November 2016 and 30 April 2017.

SLR Consulting Australia Pty Ltd (SLR) has been engaged by PGS to provide Sound Transmission Loss Modelling (STLM) service for the proposed seismic survey, to assist PGS in achieving relevant regulatory approval for the completion of the survey.

This report details the sound transmission loss modelling study that has been carried out for the proposed survey, which includes the following three modelling components:

- Array source modelling, i.e. modelling the sound energy emissions from the array source, including its directivity characteristics;
- Short range modelling, i.e. prediction of the received sound exposure level (SEL) over a range of a few kilometres from the array source location, in order to assess whether the proposed survey complies with the regulatory mitigation zone requirements, and
- Long range modelling, i.e. prediction of the received sound exposure level over a range of tens to hundreds of kilometres from the array source location, in order to assess the noise impact from the survey on the relevant farfield marine mammal sanctuaries or other areas of marine importance.

The detailed modelling methodologies and procedures for the above components are described in **Section 2** and **Section 3** of the report.

The proposed source array configuration for this survey is the PGS 4,130 cubic inch source array. This source array consists of three sub-arrays, with 11-9-11 individual source components of varying sizes, which combine to create an effective sound source for geophysical surveying. The source type is the Bolt Long-Life Source (1900 LLXT). The proposed array has an average towing depth of 7.0 m and an operating pressure of 2000 pounds per square inch (PSI). The array source modelling illustrates strong array directivity which has significant angle and frequency dependence for the energy radiation from the array, as a result of interference between signals from different array elements, particularly the three sub-arrays.

The short range modelling prediction demonstrates that the highest SELs occur in the in-line and cross-line directions, as a result of the directivity of the source array. The maximum received SELs over all azimuths are predicted to be below 186 dB re 1µPa^2·s at 200 m and below 171 dB re 1µPa^2·s at 1.0 km.

The long range modelling shows that the received SELs at long range vary significantly at different angles and distances from the source. This directivity of received levels is due to a combination of the directivity of the source array, and propagation effects caused by bathymetry and sound speed profile variations. The West Coast North Island Marine Mammal Sanctuary is over 120 km to the source location. The maximum SELs received from the chosen source location at the sanctuary boundary are predicted to be slightly greater than 90 dB re 1µPa^2·S.

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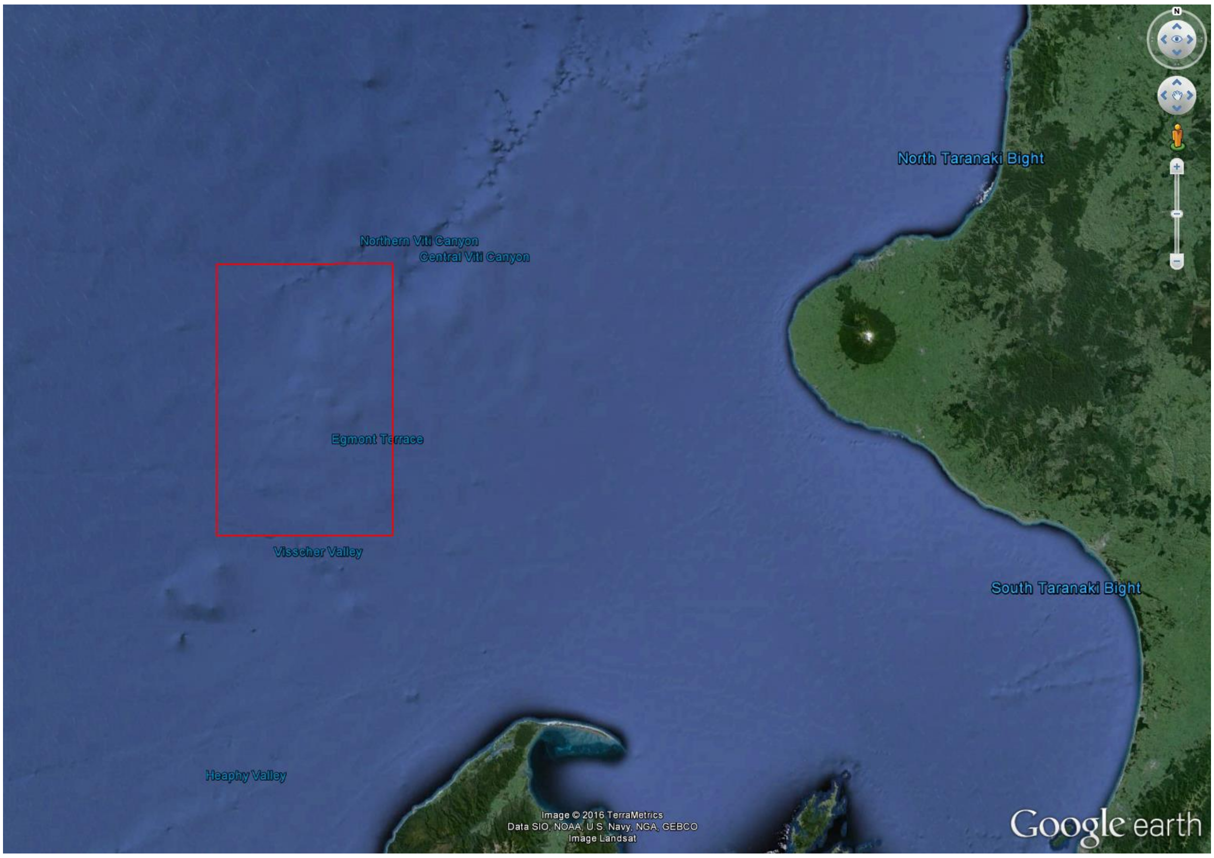
1 INTRODUCTION

1.1 Project description

PGS Australia Pty Ltd (PGS) is proposing to acquire a three dimensional (3D) marine seismic survey in the Taranaki Basin. The Operational Area, within which all seismic operations will be restricted, is illustrated in **Figure 1** and lies to the northwest of Cape Farewell in water depths of over 200 m. This survey is referred to as the 'Taranaki West 3D Seismic Survey'.

SLR Consulting NZ Ltd (SLR) has been engaged by PGS to undertake sound transmission loss modelling for the proposed survey, in order to predict the received sound exposure levels from the survey, and to demonstrate whether the survey complies with the sound exposure level statutory requirements within the *2013 Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations* (the Code).

Figure 1 The proposed PGS Taranaki West 3D Seismic Survey in red overlaying Google Earth images



1.2 Statutory requirements for sound transmission loss modelling (STLM)

In New Zealand, the *2013 Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations* (the Code) was developed by the Department of Conservation (DOC) in consultation with a broad range of stakeholders in marine seismic survey operations. The Code came into effect on 29 November 2013.

The Code requires sound transmission loss modelling to be undertaken to determine whether received sound exposure levels (SELs) exceed 171 dB re 1µPa^2.s (behaviour criteria) at ranges of 1.0 km and 1.5 km from the source or 186 dB re 1µPa^2.s (injury criteria) at a range of 200 m from the source.

1.3 Structure of the report

This sound transmission loss modelling study includes the following three modelling components:

- Array source modelling, i.e. modelling the sound energy emissions from the array source, including its directivity characteristics;
- Short range modelling, i.e. prediction of the received sound exposure level over a range of a few kilometres from the array source location, in order to assess whether the proposed survey complies with the near-field mitigation zone requirements imposed by the Code, and
- Long range modelling, i.e. prediction of the received sound exposure level over a range of tens to hundreds of kilometres from the array source location, in order to assess the noise impact from the survey on the relevant farfield marine mammal sanctuaries.

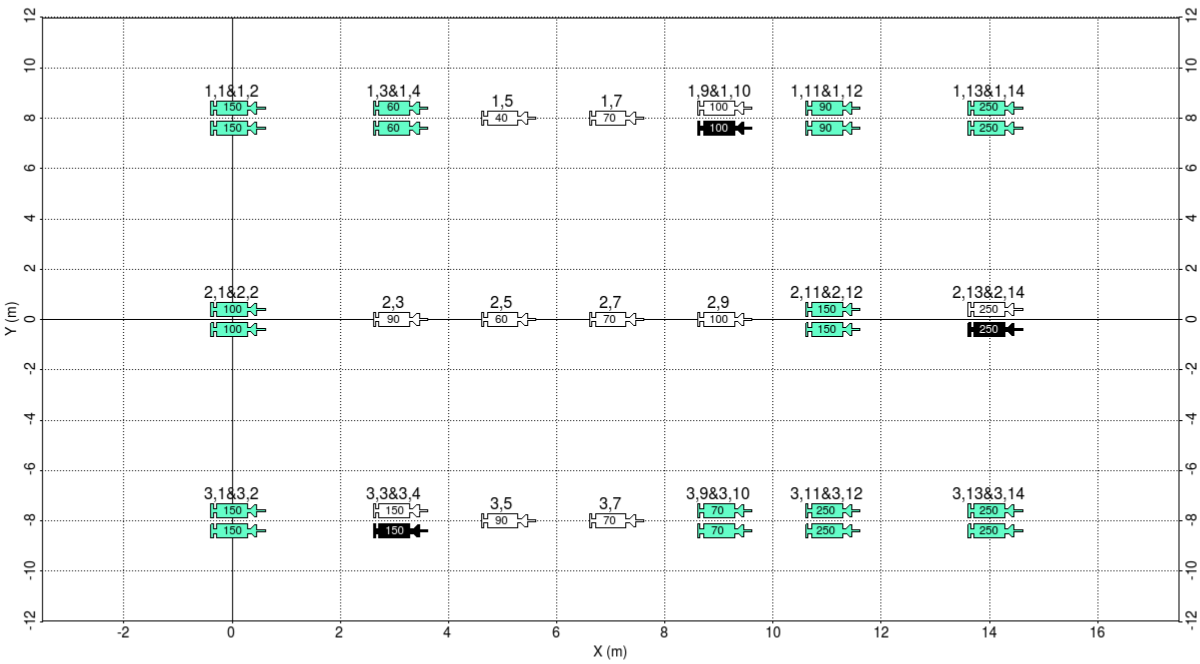
Section 2 of this report details the modelling methodology, procedure and results for the array source modelling. **Section 3** of the report outlines the methodologies and procedures associated with the short and long range transmission loss modelling, with the major modelling results presented in **Section 4**. Relevant acoustic terminologies throughout the report are presented in **Appendix A**.

2 SOURCE ARRAY MODELLING

2.1 Source array configuration

The source array proposed for this survey is the PGS 4,130 cubic inch array. The array configuration is shown in **Figure 2**. The array comprises 3 subarrays, with 12-10-12 (effective 11-9-11) individual source components of varying sizes, arranged as single sources or in clusters. 31 sources are active and 3 sources are spare (one in each subarrays). The source type for all 34 sources is the Bolt Long-Life Source (1900 LLXT).

Figure 2 The configuration of the PGS 4,130 cubic inch array (total volume of 4630 with effective volume of 4,130 cubic inches). Single sources indicated as blank fill, cluster sources as blue fill and spare sources as black fill.



2.2 Modelling methodology

The outputs of the source array modelling required for the subsequent sound modelling predictions include:

- A set of “notional” signatures for each of the array elements;
- The farfield signature of the source array and its directivity/beam patterns.

2.2.1 Notional signatures

The notional signatures are the pressure waveforms of each individual source, accounting for its interaction with other sources in the array, at a standard reference distance of 1 m.

Notional signatures are modelled using the Gundalf Designer software package (2015). The Gundalf source array model is developed based on the fundamental physics of the oscillation and radiation of bubbles as described by Ziolkowski (1970), taking into account non-linear pressure interactions between sources (Ziolkowski et al, 1982; Dragoset, 1984; Parkes et al, 1984; Vaages et al, 1984; Laws et al, 1988 & 1990).

The model solves a complex set of differential equations combining both heat transfer and dynamics, and has been calibrated against multiple measurements of both non-interacting sources and interacting cluster sources for all common source types at a wide range of deployment depths.

2.2.2 Farfield signatures

The notional signatures from all sources in the array are combined using appropriate phase delays in three dimensions to obtain the farfield source signature of the array in all directions from the source. This procedure, to combine the notional signatures to generate the farfield source signature, is summarised as follows:

- The distances from each individual source to nominal farfield receiving location are calculated. A 9 km receiver set is used for the current study;
- The time delays between the individual sources and the receiving locations are calculated from these distances with reference to the speed of sound;
- The signal at each receiver location from each individual source is calculated with the appropriate time delay. These received signals are summed to obtain the overall array farfield signature for the direction of interest.
- The farfield signature also accounts for ocean surface reflection effects by inclusion of the “surface ghost”. An additional ghost source is added for each source element using a sea surface reflection coefficient of -1.

2.2.3 Beam patterns

The beam patterns of the array are obtained as follows:

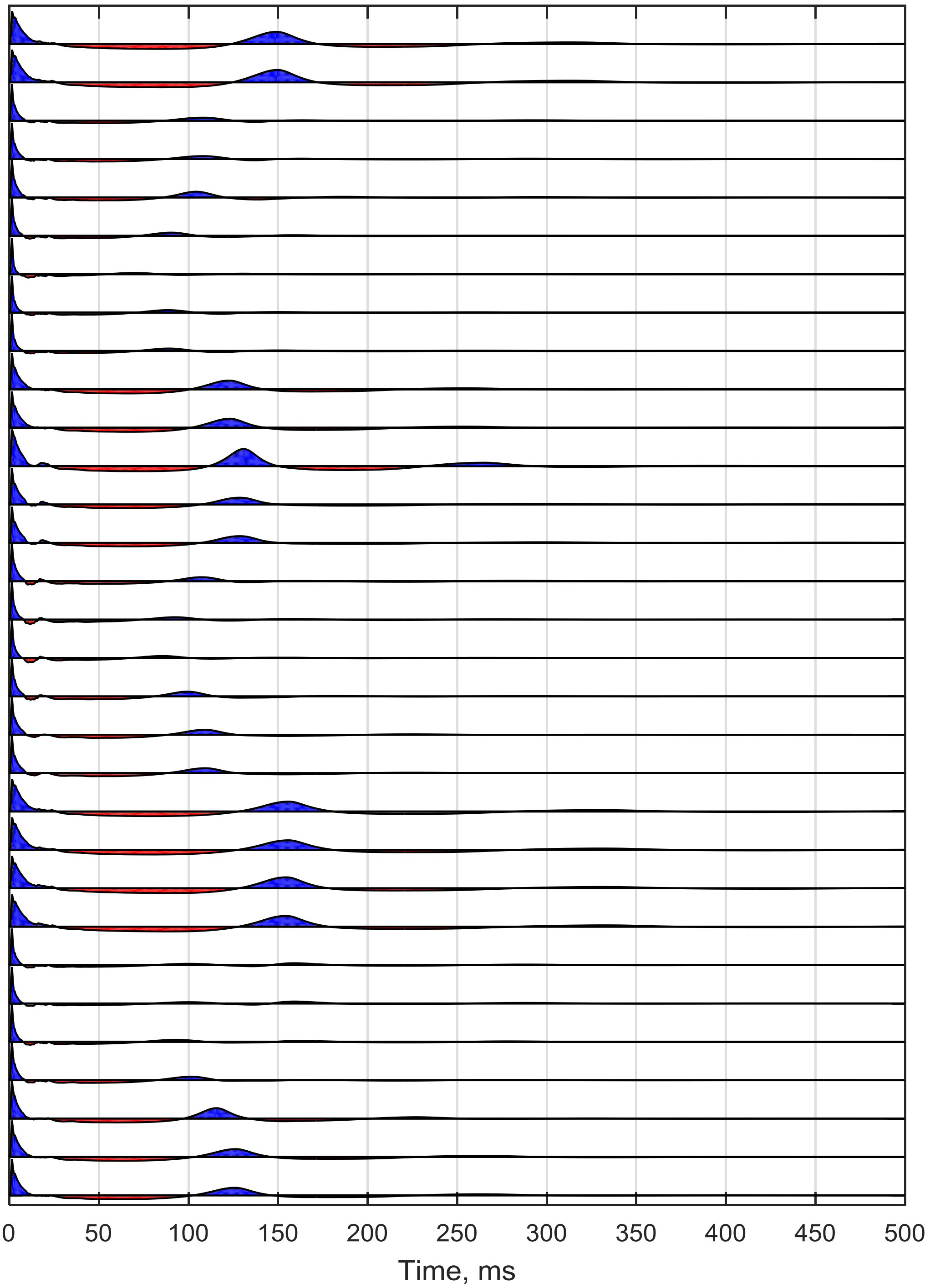
- The farfield signatures are calculated for all directions from the source using azimuthal and dip angle increments of 1-degree;
- The power spectral density (PSD) (dB re 1 $\mu Pa^2 s/Hz$ @ 1m) for each pressure signature waveform is calculated using a Fourier transform technique.
- The PSDs of all resulting signature waveforms are combined to form the frequency-dependent beam pattern for the array.

2.3 Modelling results

2.3.1 Notional signatures

Figure 3 shows the notional signatures for the 31 active sources (9 or 11 sources per subarray) of the PGS 4,130 cubic inch array.

Figure 3 **Notional signatures for the 31 active individual sources of the PGS 4,130 cubic inch array. Time series of positive pressure and negative pressure indicated by blue fill and red fill respectively. The scale is the same for the signatures from all sources.**

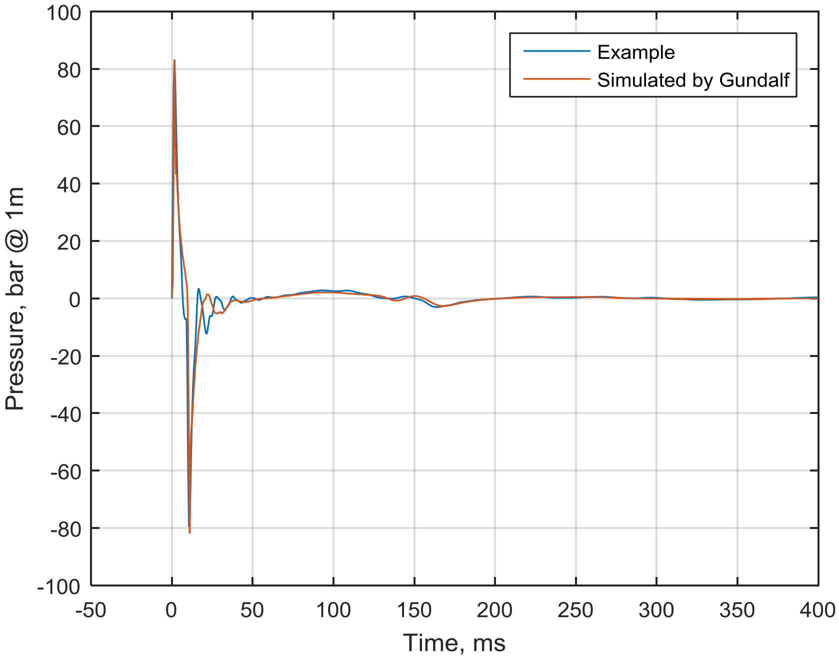


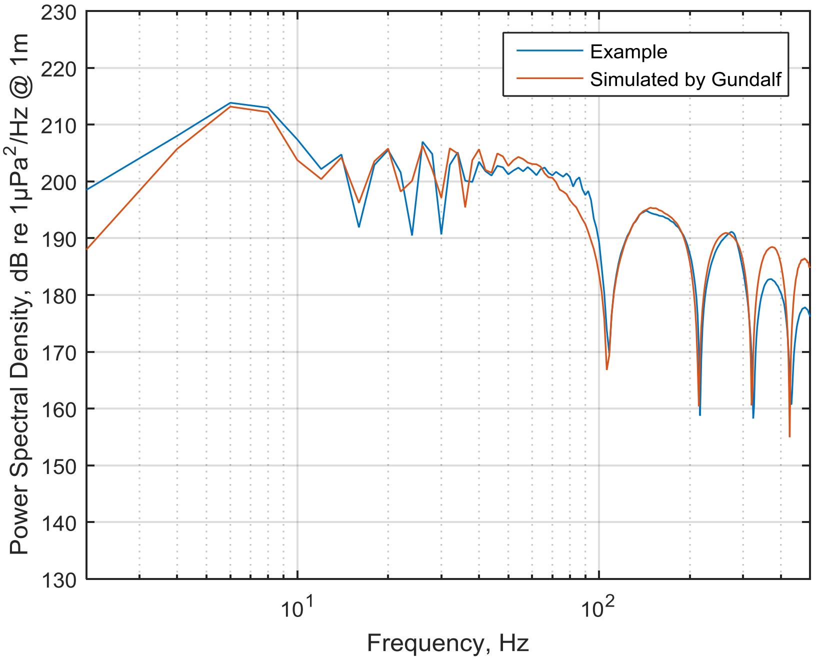
2.3.2 Farfield signatures

Figure 4 shows the comparison between the example case provided by the client and the simulated case based on Gundalf Designer software for both signature waveform and its power spectral density. The signatures are for the vertically downward direction with surface ghost included.

It can be seen from the figure that the two cases are generally in good agreement, differing only in minor details.

Figure 4 Comparison between the farfield signature of vertically downward direction (top) and the power spectral density (bottom) for the PGS 4,130 cubic inch array.





2.3.3 Beam patterns

Array farfield beam patterns of the following three cross sections are presented in **Figure 5**:

a) The horizontal plane (i.e. dip angle of 90 degrees) with azimuthal angle of 0 degree corresponding to the in-line direction;

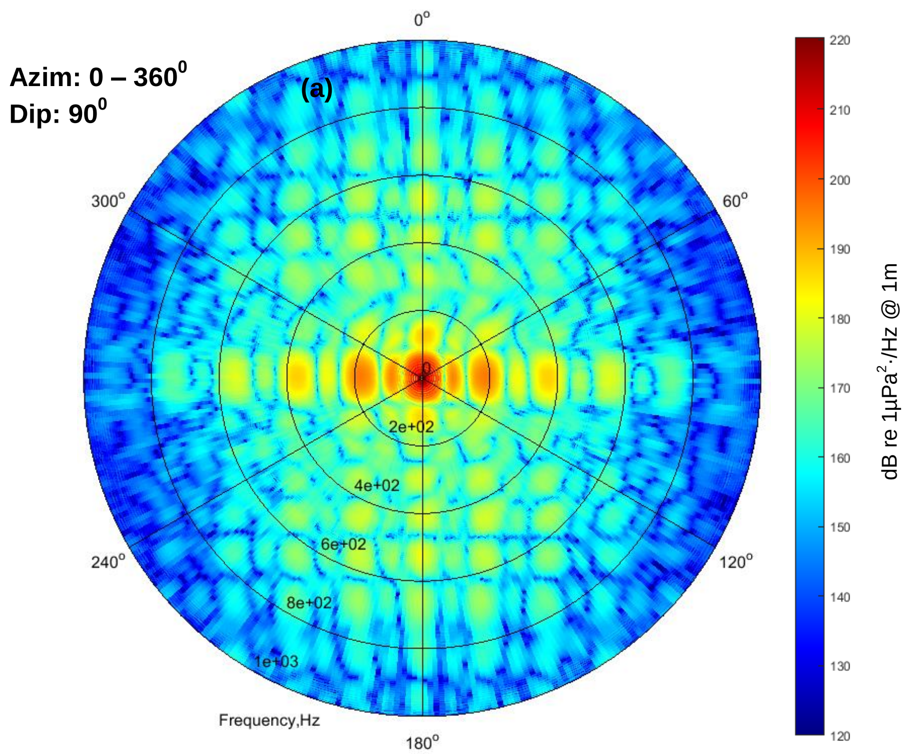
b) The vertical plane for the in-line direction (i.e. azimuthal angle of 0 degree) with dip angle of 0 degree corresponding to the vertically downward direction;

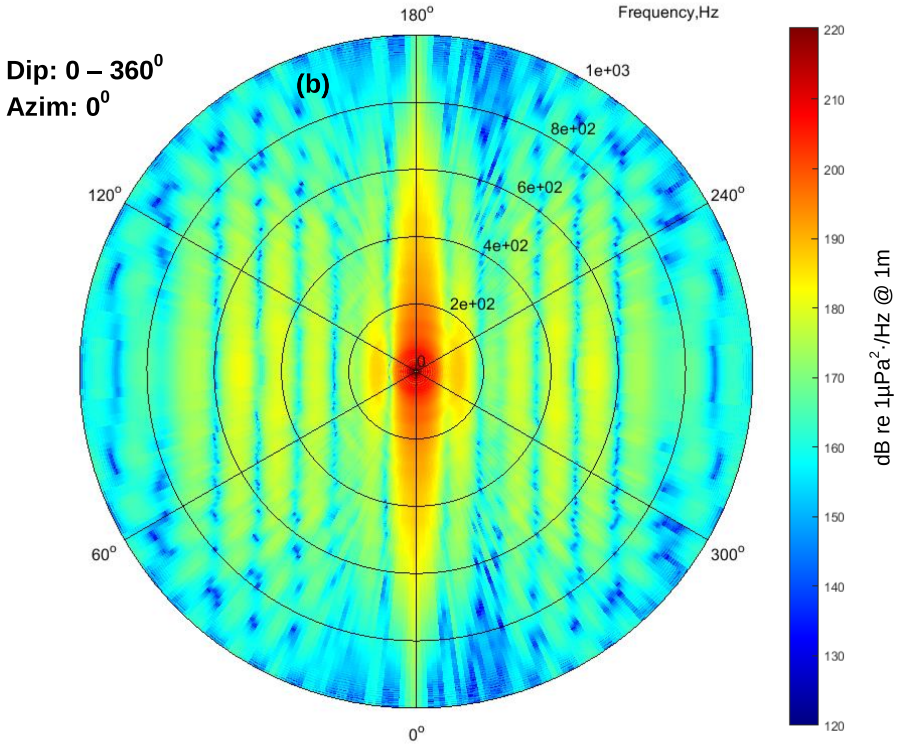
c) The vertical plane for the cross-line direction (i.e. azimuthal angle of 90 degrees) with dip angle of 0 degree corresponding to the vertically downward direction.

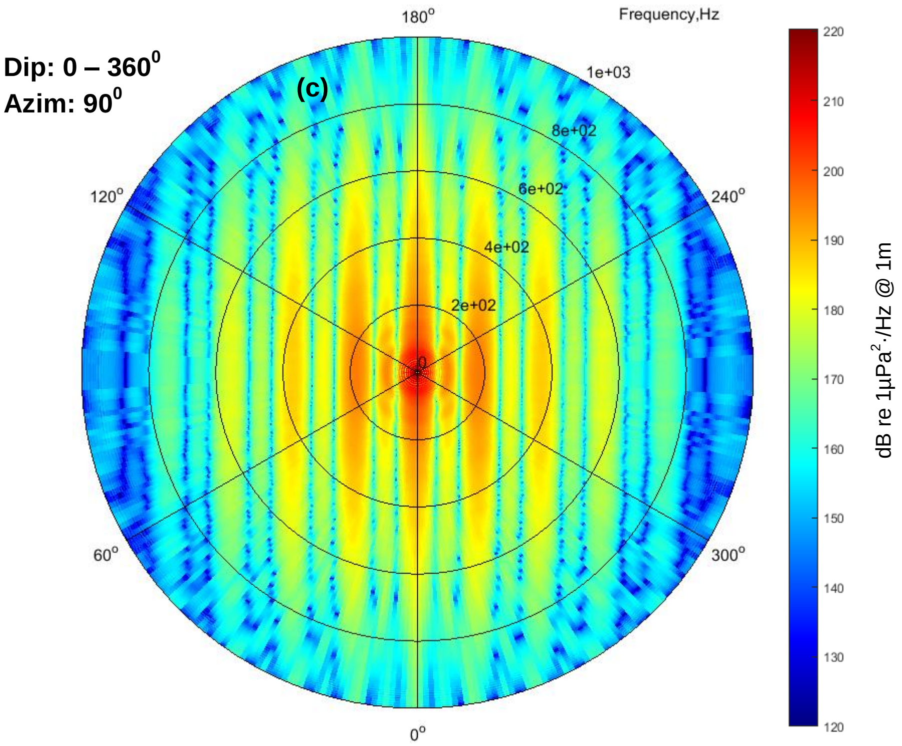
These beam patterns illustrate the strong angle and frequency dependence of the energy radiation from the array. The beam pattern of the horizontal plane shows stronger energy radiation in the cross-line direction than in the in-line direction. The beam pattern of in-line vertical plane has the strongest radiation in the vertical direction, and that of the cross-line vertical plane has strong radiation in both the vertical and horizontal directions.

The predominant frequency variation characteristics of these beam patterns are a result of interference between signals from different array elements, particularly from the three sub-array elements.

Figure 5 Array farfield beam patterns as a function of orientation and frequency. (a) - The horizontal plane with 0 degree corresponding to the in-line direction; (b) – The vertical plane for the in-line direction; (c) – The vertical plane for the cross-line direction. 0 degree dip angle corresponds to vertically downward direction.




Dip: 0 – 360°
Azim: 0°
(b)
180°
Frequency,Hz
1e+03
8e+02
6e+02
4e+02
2e+02
0
120°
240°
60°
300°
0°
220
210
200
190
180
170
160
150
140
130
120
dB re 1µPa²·/Hz @ 1m


Dip: 0 – 360°
Azim: 90°
(c)
180°
Frequency,Hz
1e+03
8e+02
6e+02
4e+02
2e+02
0
120°
240°
60°
300°
0°
220
210
200
190
180
170
160
150
140
130
120
dB re 1µPa²·/Hz @ 1m

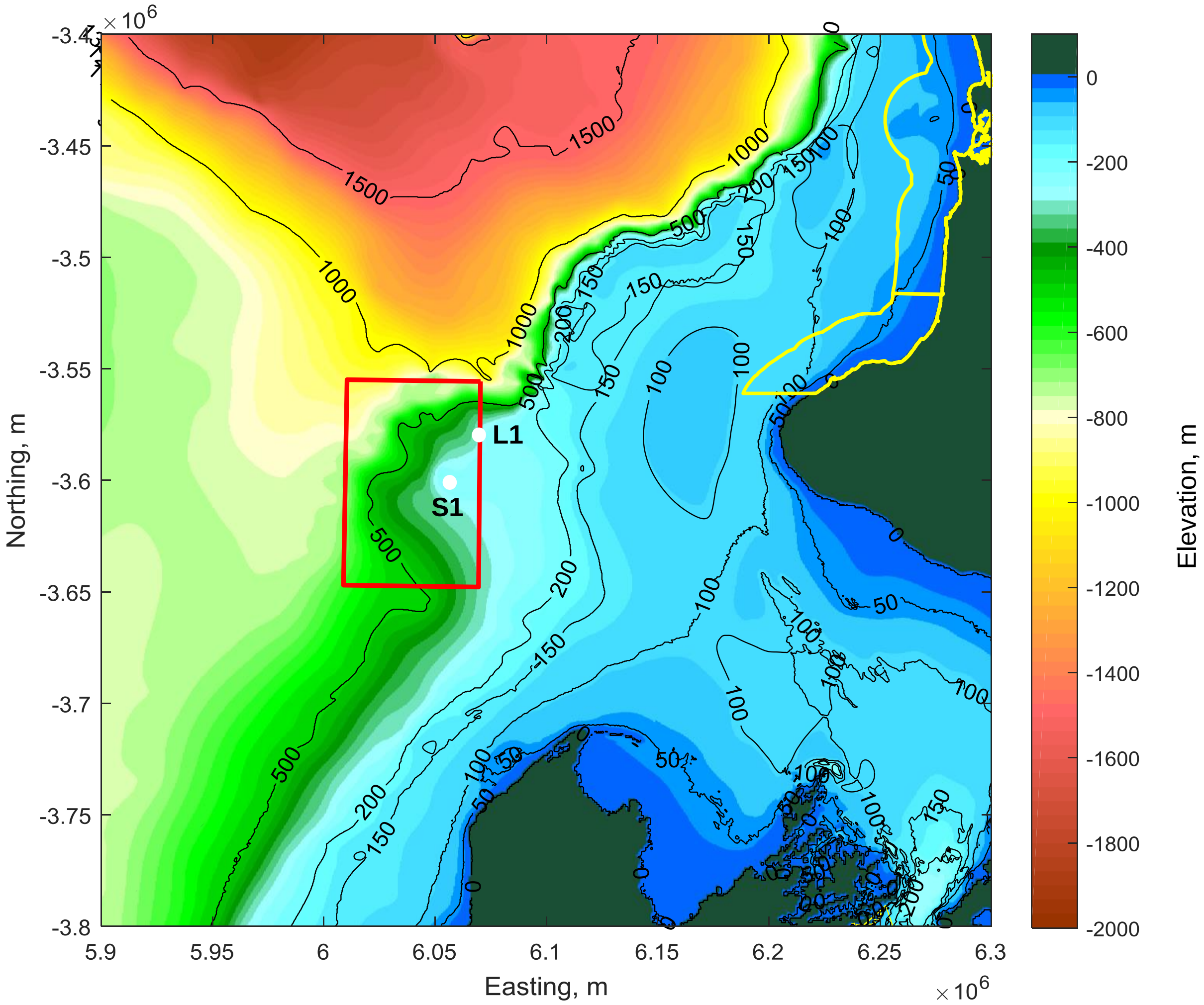
3 TRANSMISSION LOSS MODELLING

3.1 Modelling input parameters

3.1.1 Bathymetry

The bathymetry data used for the sound propagation modelling are obtained from the National Institute of Water and Atmospheric Research (NIWA) NZ Region 250 m gridded bathymetric dataset (CANZ, 2008). The corresponding project area bathymetric imagery with a resolution of 250 m is presented in **Figure 6**.

Figure 6 The bathymetric imagery in a resolution of 250 m covering the proposed survey area. Yellow polygons show the marine mammal sanctuaries and red polygons show the 3D survey area boundaries. The coordinate system is based on WGS84 Web Mercator Map Projection. White dots S1 and L1 are the nominated source locations for the short range and long range modelling cases respectively.



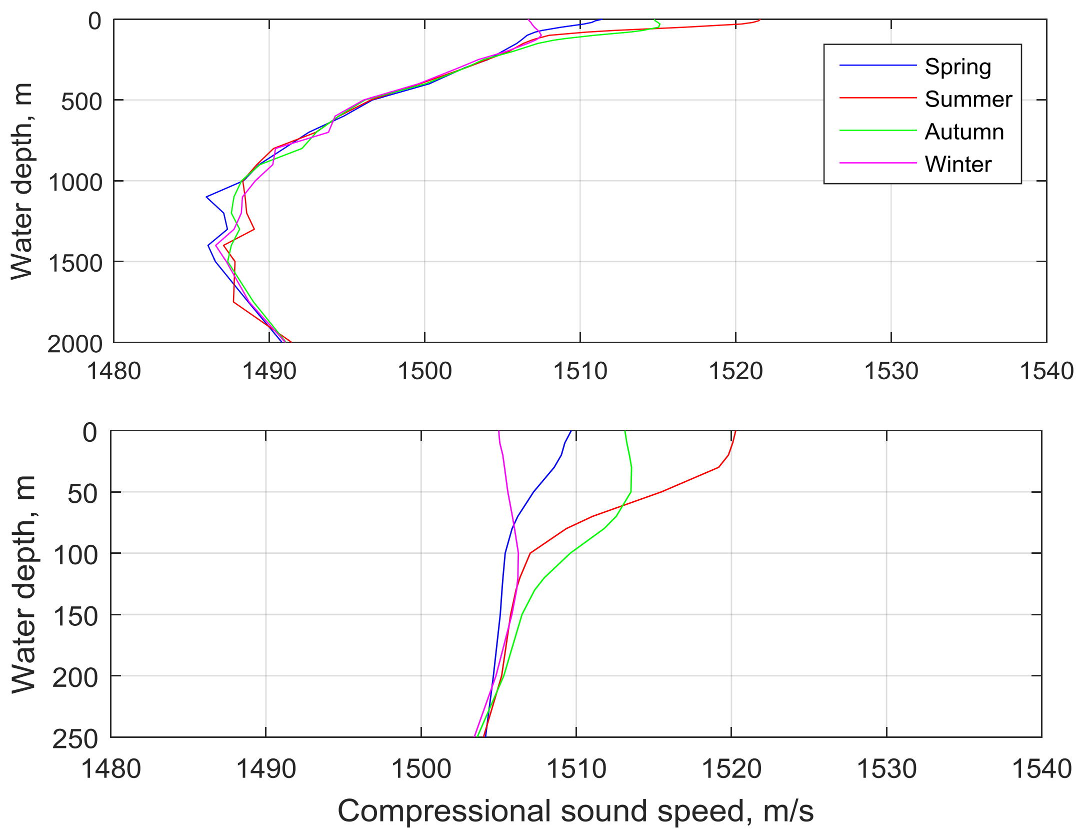
3.1.2 Sound speed profiles

Temperature and salinity data required to derive the sound speed profiles were obtained from the World Ocean Atlas 2009 (WOA09) (Locarnini et al, 2010; Antonov et al, 2010). The hydrostatic pressure needed for calculation of the sound speed based on depth and latitude of each particular sample was obtained using Sanders and Fofonoff's formula (Sanders and Fofonoff, 1976). The sound speed profiles were derived based on Del Grosso's equation (Del Grosso, 1974).

Figure 7 demonstrates typical sound speed profiles west of the North Island for four southern atmosphere seasons. The most significant distinctions for the four profiles occur within the mixed layer near the surface. The spring and summer seasons have downwardly refracting near-surface profiles, with the summer profile having the stronger downwardly refracting feature. Both the autumn and winter seasons exhibit a surface duct, with the profile in the winter season having a stronger and deeper surface duct than that in the autumn season. Due to the stronger surface duct within the profile, it is expected that the winter season will favour the propagation of sound from an array as it is a near-surface acoustic source. In a descending order, the autumn, spring and summer seasons are expected to have relatively weaker sound propagation for a near-surface source array.

The PGS survey is scheduled to occur during November 2016 - April 2017. Therefore, the autumn sound speed profile is selected as the worst case condition for all sound propagation modelling scenarios.

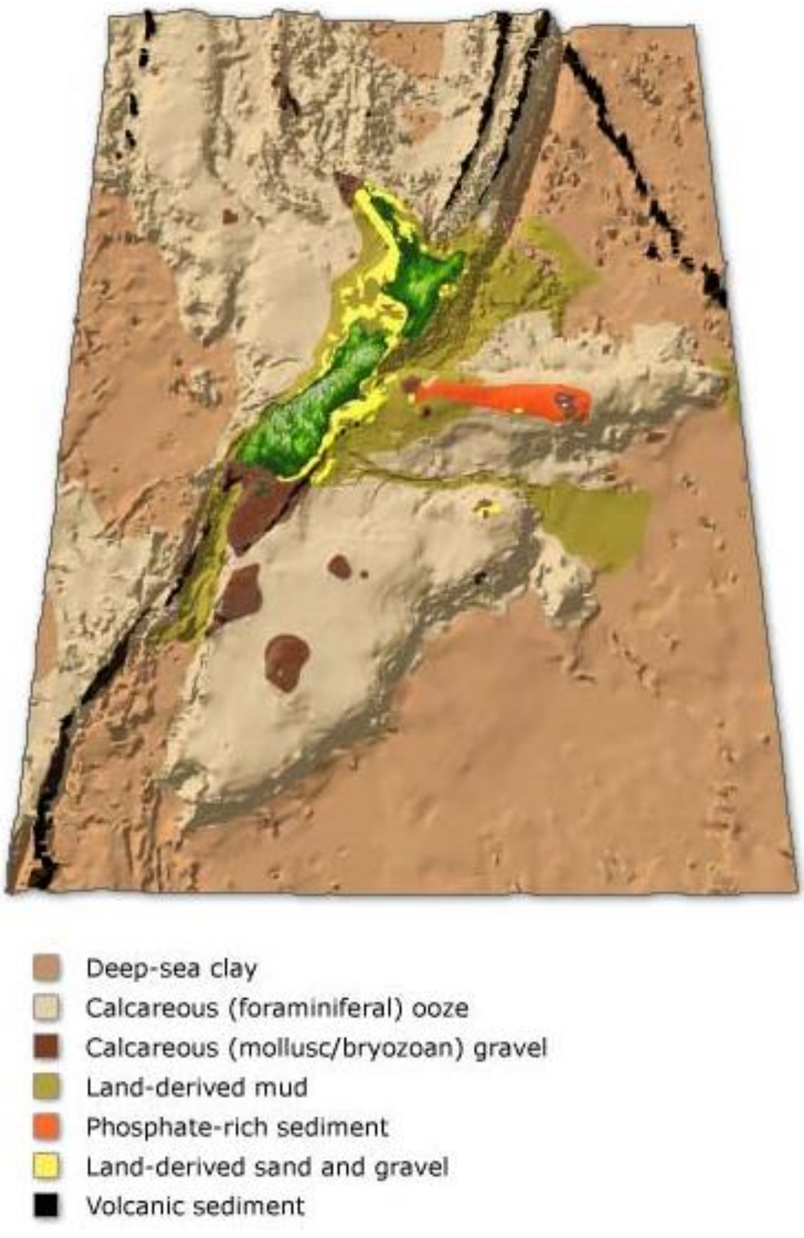
Figure 7 Typical sound speed profiles west of the North Island for different southern atmosphere seasons. Top panel shows profiles in deep water region, bottom panel shows profiles in continental shelf region near the proposed survey area.



3.1.3 Seafloor geo-acoustic models

New Zealand has diverse seafloor sediments thanks to its variable and dynamic marine and terrestrial environments. NIWA has over many years produced a variety of marine sediment charts illustrating the ocean bottom types around coastal New Zealand and some offshore areas. The map in **Figure 8** extracted from NIWA illustrates the distribution of the main types of marine sediments found on the ocean floor around New Zealand (Lewis et al, 2012 & 2013).

Figure 8 The distribution of the main types of marine sediment on the seafloor within coastal and offshore regions around New Zealand



The Continental shelf is covered mainly with land-derived sand, gravel and mud sediment, except at the northern and southern extremities where the shelly sediment from once-living sea creatures prevails due to the lack of major rivers. Within the project area, off the eastern North Island, the seafloor is overlaid with land-derived mud as in this area the supply of sediment from land is the largest in New Zealand.

The detailed sediment types for various relevant coastal and offshore regions are referred to the NZ marine sediment charts and some technical reports (e.g. such as Matthew et al (2014) and Galindo-Romero et al (2014)). A summary of sediment types in and around the Taranaki Basin is provided in **Table 1**.

Table 1 Detailed sediment types within the coastal and offshore regions covering the survey area.

Region - West NZ	Sediment Type
Taranaki – Northland Continental Shelf	Dominant fine sand sediment with coarse sand sparsely scattered
Taranaki – Northland Continental Slope	Silt - clay
Southern New Caledonia Basin, Reinga Basin and Challenger Plateau	Pelagic sediments (mud – oozes, equivalent to silty clay)
Cook Strait	Fine sand

The geoacoustic properties for the various possible sediment types within the coastal and offshore regions around the survey area are presented in **Table 2**. The geoacoustic properties for sand, silt and clay are as described in Hamilton (1980), with attenuations referred to Jensen et al (2011). The elastic properties of sand, silt and clay are treated as negligible.

Table 2 Geoacoustic properties for various possible sediment types within the coastal and offshore regions in the Taranaki Basin.

Sediment Type	Density, ρ, ($kg.m^{-3}$)	Compressional Wave Speed, c_p, ($m.s^{-1}$)	Compressional Wave attenuation, α_p, (dB/λ)
Sand			
Coarse Sand	2035	1835	0.8
Fine Sand	1940	1750	0.8
Very Fine Sand	1855	1700	0.8
Silt - Clay			
Silt	1740	1615	1.0
Sand-Silt-Clay	1595	1580	0.4
Clayey Silt	1490	1550	0.2
Silty Clay	1420	1520	0.2

The reflection coefficients for sediments of sand, silt and clay are presented in **Figure 9** and **Figure 10** respectively. As can be seen, the sandy seafloor sediments are more reflective than the silt and clay sediments, particularly at low grazing angles.

Figure 9 **The reflection coefficients (magnitude - top panel and phase – bottom panel) for sand sediments (coarse sand, fine sand and very fine sand)**

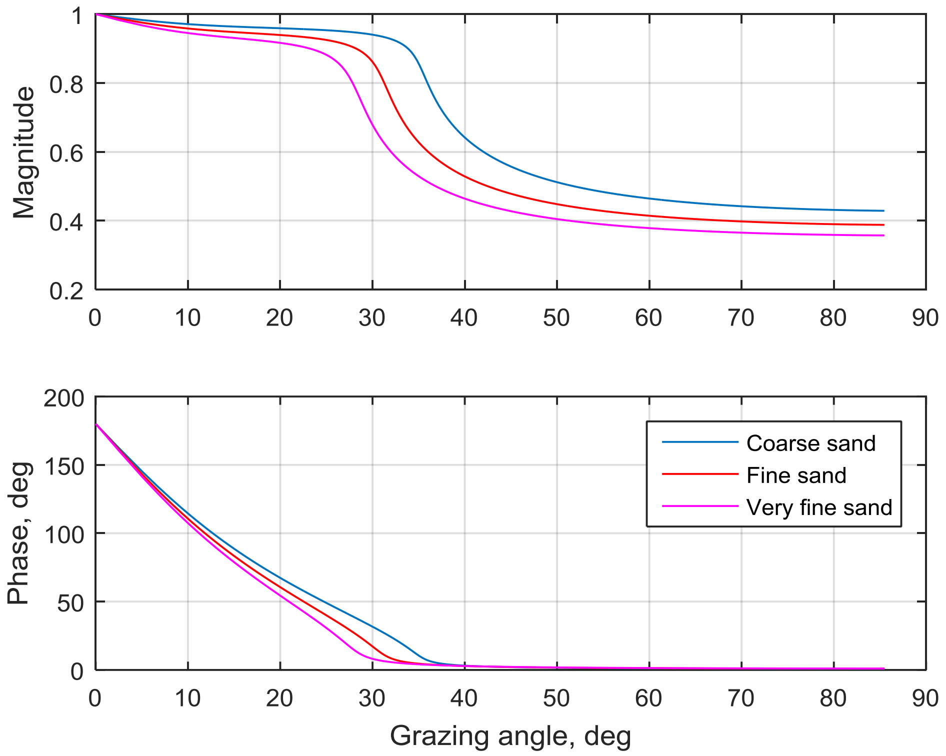
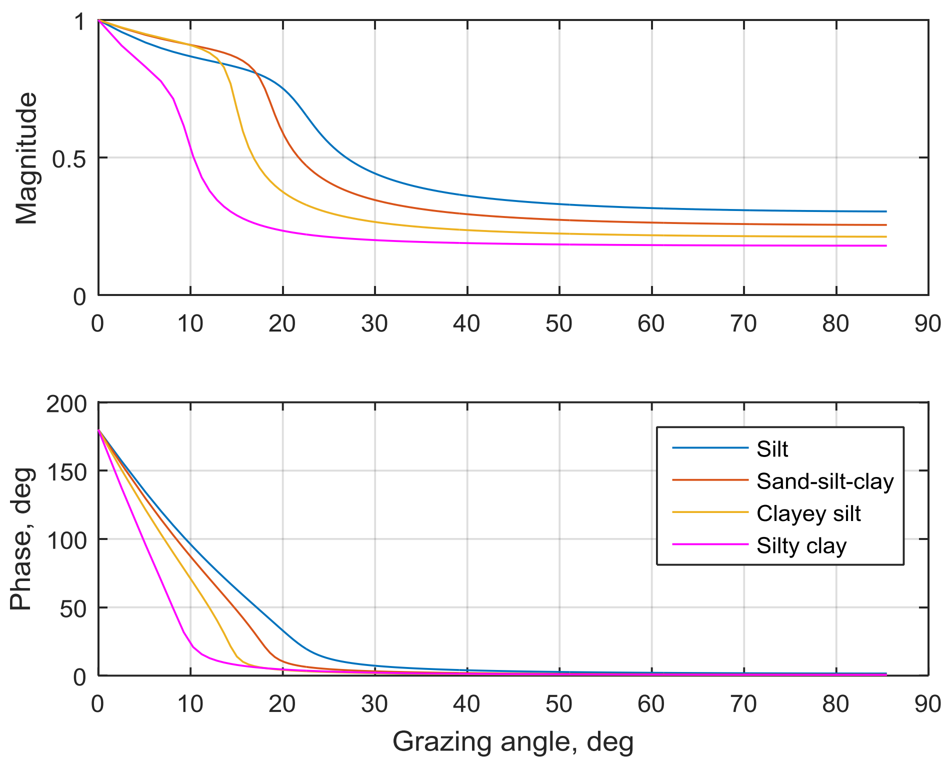


Figure 10 **The reflection coefficient (magnitude - top panel and phase – bottom panel) for silt-clay sediments (silt, sand-silt-clay, clayey silt, silty clay)**



3.2 Detailed modelling methodologies and procedures

The modelling accuracy requirements, source directivity characteristics and computational cost of the short range and long range modelling cases are different. The following sections describe the different modelling methodologies and procedures employed for the short range and long range modelling cases.

3.2.1 Short range modelling

3.2.1.1 Modelling methodology and procedure

The short range modelling is used to verify mitigation zones in relatively close proximity to the array source, and requires modelling predictions with high accuracy. In addition, interference between the signals arriving at any receiving location from different sources in the array is expected to be significant and complex for such a near-field scenario. To account for these considerations, the predictions for the short range case are modelled by simulating the received signal waveforms from individual source units within the array.

The wavenumber integration modelling algorithm SCOOTER (Porter, 2010) is used to calculate the transfer functions (both amplitudes and phases) between sources and receivers. SCOOTER is a finite element code for computing acoustic fields in range-independent environments. The method is based on direct computation of the spectral integral, and is capable of dealing with an arbitrary layered seabed with both fluid and elastic characteristics.

The following procedure is followed to calculate received sound exposure levels:

1) The modelling algorithm SCOOTER is executed for frequencies from 1 Hz to 1 kHz, in 1 Hz increments. The source depth is taken to be 7.0 m. A 1 m receiver grid in both range and depth with a maximum range up to 4 km is applied for the selected water depth. For each 1 m gridded receiver, the received sound exposure level is calculated by following steps 2) – 5).

2) The range from each source in the array to each receiver is calculated, and the transfer function between each source and the receiver is obtained by interpolation of the results produced by modelling algorithm SCOOTER in Step 1). This interpolation involves both amplitude and phase of the transfer function.

3) The complex frequency domain signal of the notional signature waveform for each source is calculated via Fourier Transform, and multiplied by the corresponding transfer function from Step 2) to obtain the frequency domain representation of the received signal from that particular source.

4) The waveform of received signal from each source is reconstructed via Inverse Fourier Transform. The received signal waveforms from all sources in the array are summed to obtain the overall received signal waveform.

5) The overall signal waveform is squared and integrated to obtain the received sound exposure level.

3.2.1.2 Modelling scenarios

A single source location (S1 as shown in **Figure 6**) with the shallowest water depth within the proposed survey area is selected for the short range modelling. Details of the selected source location are listed in **Table 3**.

The chosen source location S1 is close to the edge of the continental slope, and the seabed sediment is predominantly between fine sand and silt/clay in characteristics, and therefore was assumed as very fine sand sediment. The worst case modelling conditions for underwater noise propagation applicable to the proposed survey, i.e., very fine sand seabed sediment and autumn sound speed profiles, have been assumed for the short range modelling.

Table 3 Details of the selected single source location for the short range modelling

Source Location	Water Depth, m	Coordinates [Easting, Northing]	Locality
S1	235	[6.055×10^6, - 3.599×10^6]	East to the centre of the proposed 3D survey area

3.2.2 Long range modelling

3.2.2.1 Modelling methodology and procedure

The long range modelling case requires reasonable accuracy of prediction as it generally involves complex and variable environmental factors such as sound speed profiles and bathymetric variations. Therefore, the modelling prediction for the long range case is carried out using the farfield source levels of octave frequency bands and their corresponding transmission loss calculations.

The fluid parabolic equation (PE) modelling algorithm RAMGeo (Collins, 1993) is used to calculate the transmission loss between the source and the receiver. RAMGeo is an efficient and reliable PE algorithm for solving range-dependent acoustic problems with fluid seabed geo-acoustic properties.

The received sound exposure levels are calculated following the procedure as below:

1) One-third octave source levels for each azimuth to be considered are obtained by integrating the horizontal plane source spectrum over each frequency band, and these levels are then corrected to SEL levels.

2) Transmission loss is calculated using RAMGeo at one-third octave band central frequencies from 8 Hz to 1 kHz, with a maximum range of 200 km and at 5 degree azimuth increments. The bathymetry variation along each modelling track is obtained via interpolation from the CANZ (2008) dataset;

3) The one-third octave source SEL levels and transmission loss are combined to obtain the received SEL levels as a function of range, depth and frequency;

4) The overall received SEL levels are calculated by summing all frequency band SEL levels.

3.2.2.2 Modelling scenarios

Single source location (L1 as shown in **Figure 6**) with the closest proximity to the adjacent marine mammal sanctuaries is selected for the long range modelling. Details of the selected source location are listed in **Table 4**.

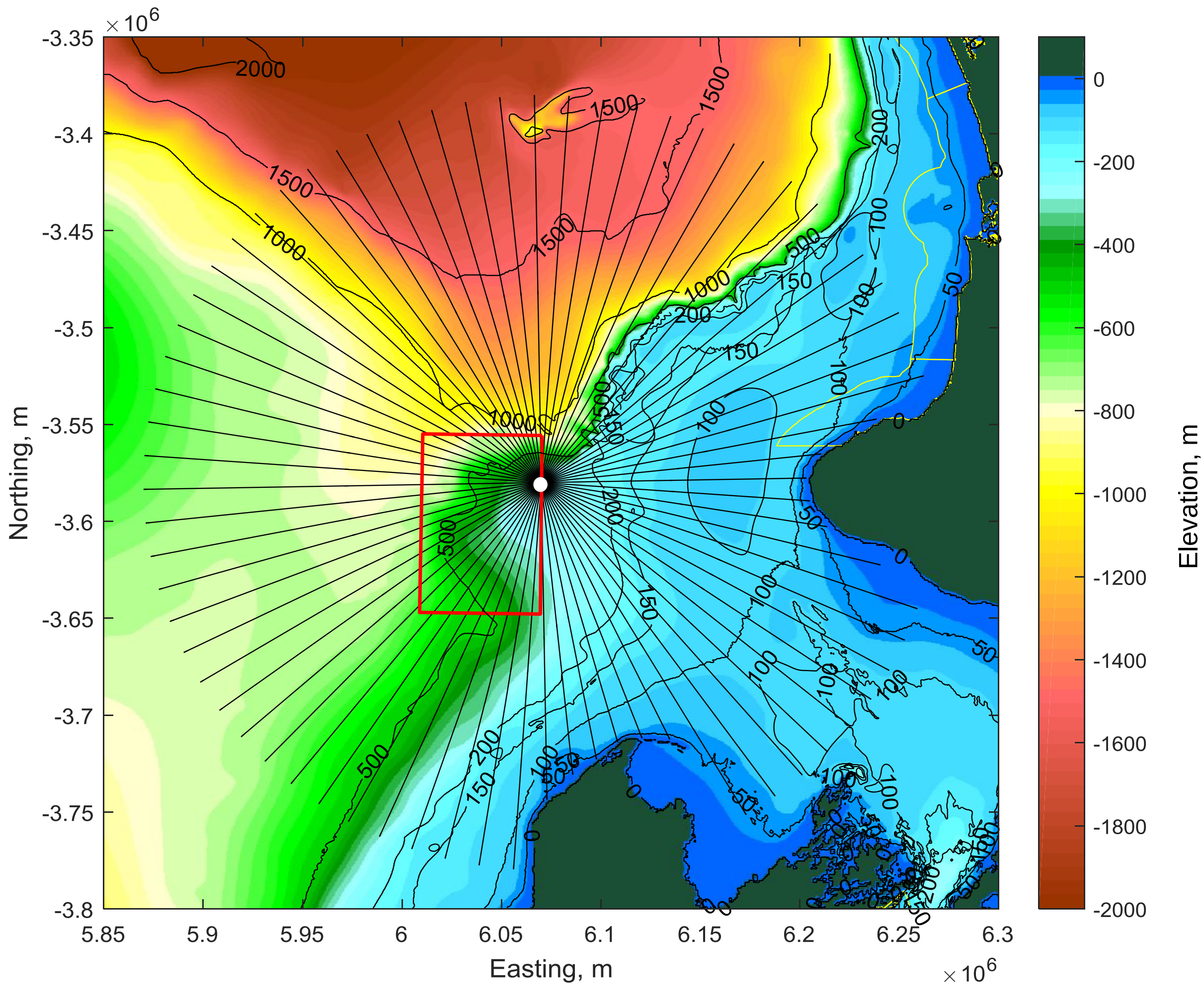
The autumn seasonal sound speed profile, along with the fine sand seafloor geoacoustic model (i.e. the predominant sediment type along the long range propagation path from the source location to the coastal marine mammal sanctuaries) have been used for the long range modelling as a worst case scenario.

PGS have advised that the survey operation is proposed to be carried out with the array in a Northeast-Southwest orientation.

Table 4 Details of the selected single source location for the long range modelling

Source Location	Water Depth, m	Coordinates [Easting, Northing]	Locality
L1	300	[6.070 x 10^6, - 3.580 x 10^6]	Eastern boundary of the proposed 3D survey area

Figure 11 Long range modelling source location (white dot), with modelling sound propagation paths (black lines) overlaying local bathymetry. The coordinate system is based on WGS84 Web Mercator Map Projection.



4 RESULTS

4.1.1 Short range modelling

The received SELs from the PGS 4,130 cubic inch source array for the worst case modelling scenario (i.e. autumn season sound speed profile and fine sand sediment) with the survey operation at the shallowest waters of around 235 m have been calculated. The maximum received SEL levels across the water are presented as a function of azimuth and range from the centre of the array and presented in **Figure 12**. The figure illustrates higher SEL levels in both the in-line and cross-line directions as a result of the directivity of the source array.

The scatter plots of the predicted maximum SELs across the water column from the source array for all azimuths are displayed in **Figure 13**, as a function of range from the centre of the source array, together with the mitigation threshold levels (i.e. 186 dB and 171dB re 1µPa^2·S) and mitigation ranges (i.e. 200 m, 1.0 km and 1.5 km).

As can be seen from the figures below, the maximum received SELs over all azimuths are predicted to be below 186 dB re 1µPa^2·s at 200 m and marginally below 171 dB re 1µPa^2·s at 1.0 km. The predictions of the maximum SEL levels received at three mitigation ranges for the modelling case are listed in **Table 5**. **Table 6** presents the ranges from the centre of the source array to the ranges where the predicted maximum SEL levels equal the threshold levels (186 dB and 171 dB re 1µPa^2·s).

Table 5 Predicted maximum SEL for all azimuths at ranges of 200 m, 1 km and 1.5 km from the centre of the PGS 4,130 cui source array for the source location with water depth of 235 m.

Source location	Water depth, m	SEL at different ranges, dB re 1µPa^2·s		
		200 m	1.0 km	1.5 km
S1	235 (shallowest)	182.7	170.7	166.8

Table 6 Ranges from the centre of the array where the predicted maximum SEL for all azimuths equals the SEL threshold levels for the PGS 4,130 cui array for the source location with water depth of 235 m.

Source location	Water depth, m	Ranges complying with the following SEL thresholds, m	
		SEL < 186 dB re 1µPa^2·s	SEL < 171 dB re 1µPa^2·s
S1	235 (shallowest)	127	960

Figure 12 The predicted maximum received SEL across the water column from the PGS 4,130 cui source array as a function of azimuth and range from the centre of the array. 0 degree azimuth corresponds to the in-line direction. The modelling scenario is for single source location with water depth 235m, autumn sound speed profile and fine sand seafloor. Dark blue circles represent the mitigation zones of 200 m (solid), 1.0 km (dash) and 1.5 km (dash-dot).

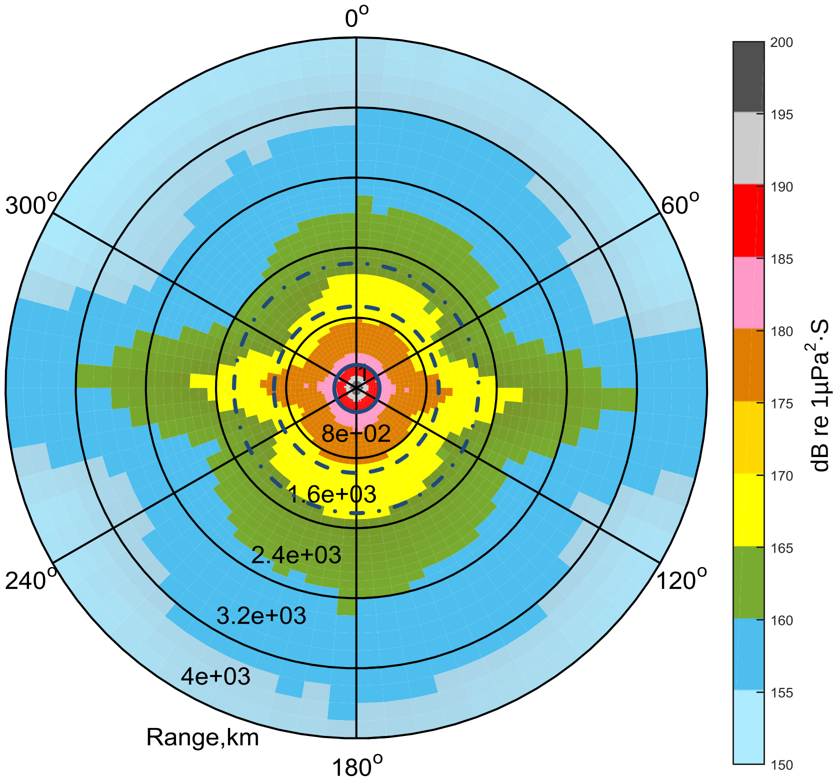
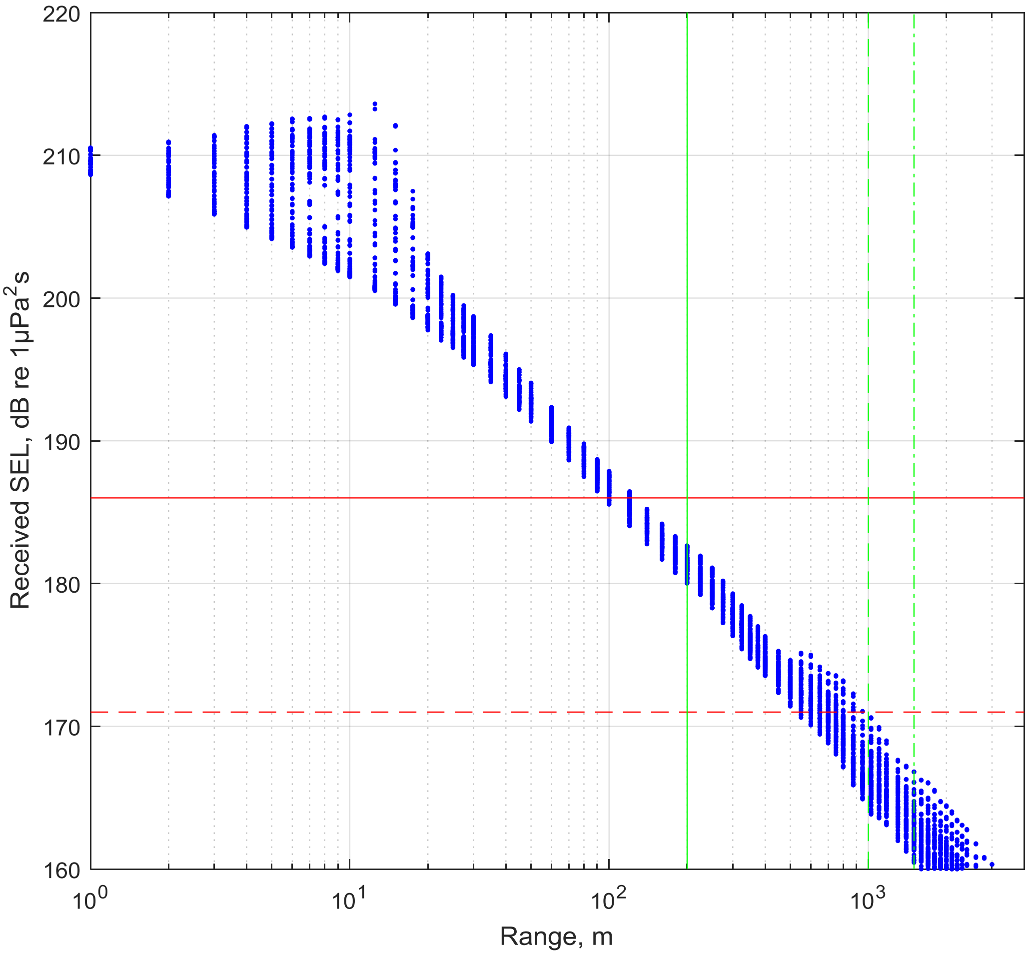


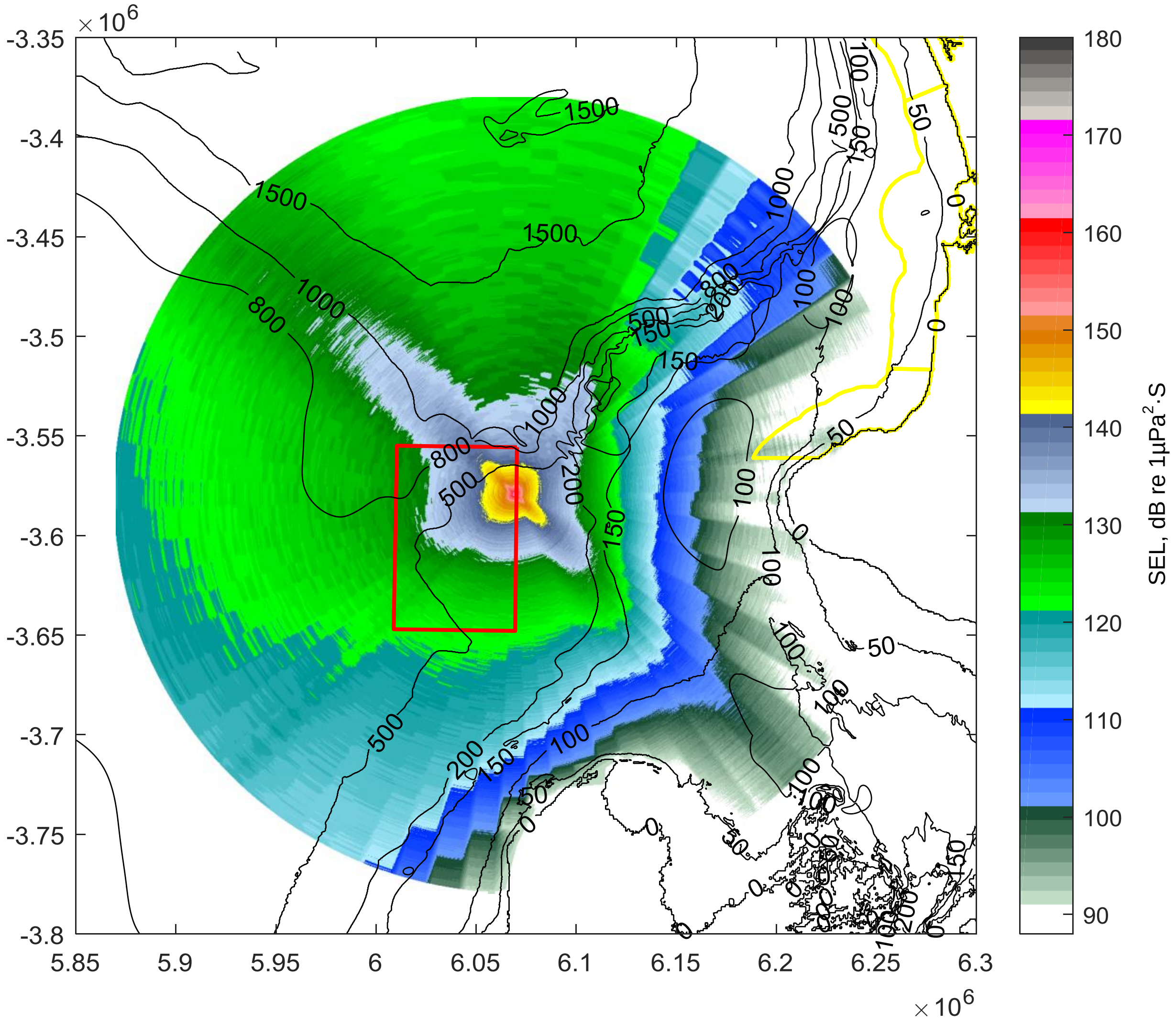
Figure 13 Scatter plot of predicted maximum SEL across the water column from PGS 4,130 cui source array for all azimuths as a function of range from the centre of the source array. The modelling scenario is for a source location with water depth 235 m, autumn sound speed profile and fine sand seafloor. Horizontal red lines show mitigation thresholds of 186 dB re 1µPa²·S (solid) and 171 dB re 1µPa²·S (dash). Vertical green lines show mitigation ranges of 200 m (solid), 1 km (dash) and 1.5 km (dash-dot).



4.1.2 Long range modelling

Figure 14 shows the contour image of the predicted maximum SELs received at locations up to 200 km from the long range source location (L1 in **Table 4**), overlaying the local bathymetry contours.

Figure 14 Modelled maximum SEL (maximum level at any depth) contour (for source location to a maximum range of 200 km), overlaying with bathymetry contour lines.



As can be seen from **Figure 14**, the received noise levels at farfield locations vary significantly at different angles and distances from the source. This directivity of received levels is due to a combination of the directivity of the source array, and propagation effects caused by bathymetry and sound speed profile variations.

Figure 15 shows the modelled SELs vs range and depth along the propagation path in West-East direction from the source location. Significant attenuations are predicted for the shallow water area with up-slope bathymetry profiles in the West-East direction. The up-slope bathymetry profile within the area causes strong interaction between the sound signal and seabed, and consequently causes strong acoustic attenuation.

The West Coast North Island Marine Mammal Sanctuary is over 120 km from the source location. The maximum SELs received from the source location L1 at the sanctuary boundary are predicted to be slightly greater than 90 dB re 1µPa^2·S.

Figure 16 and **Figure 17** present the modelled SELs vs range and depth along the cross-line Northwest-Southeast and Southeast-Northwest direction respectively.

The received maximum SELs at the cross-line Southeast-Northwest direction are the highest among all azimuths from the source location. This is due to the higher array source directivity at the cross-line directions as shown in **Section 2.3.3**, coupled with the downward-refracting sound speed profile and reflective seabed at small grazing angles. At this direction, the received maximum SELs are predicted to be above 125 dB re 1µPa^2·S at a distance of 200 km from the source location.

Figure 15 Modelled SELs vs range and depth along the propagation path in West-East direction from the source location. Black line shows the seabed depth variation.

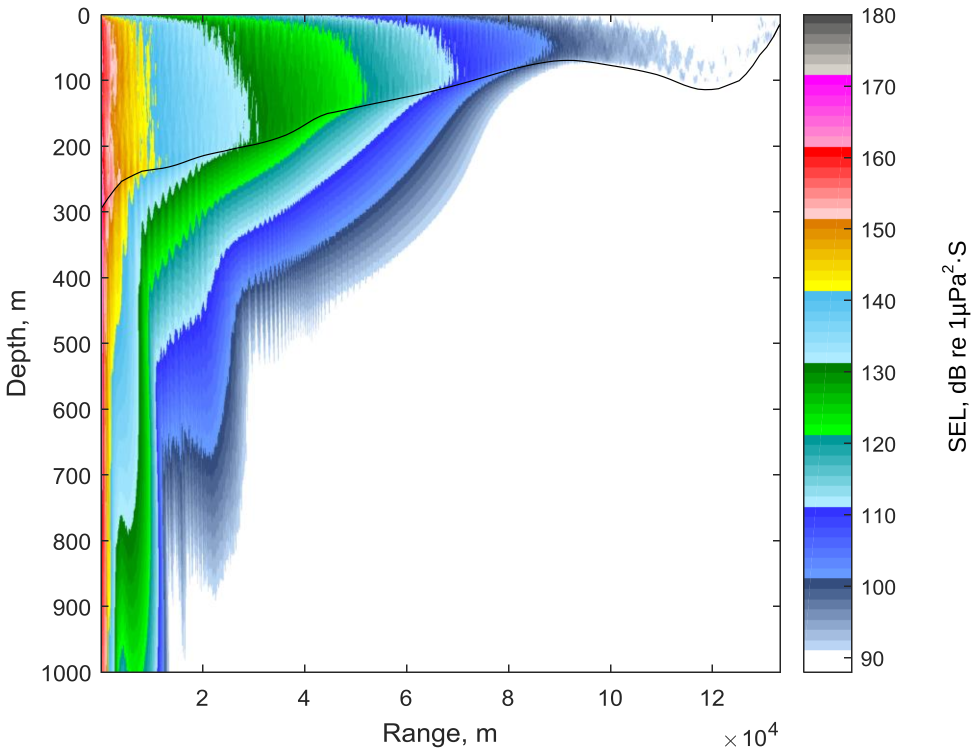


Figure 16 Modelled SELs vs range and depth along the propagation path in Northwest-Southeast cross-line direction from the source location. Black line shows the seabed depth variation.

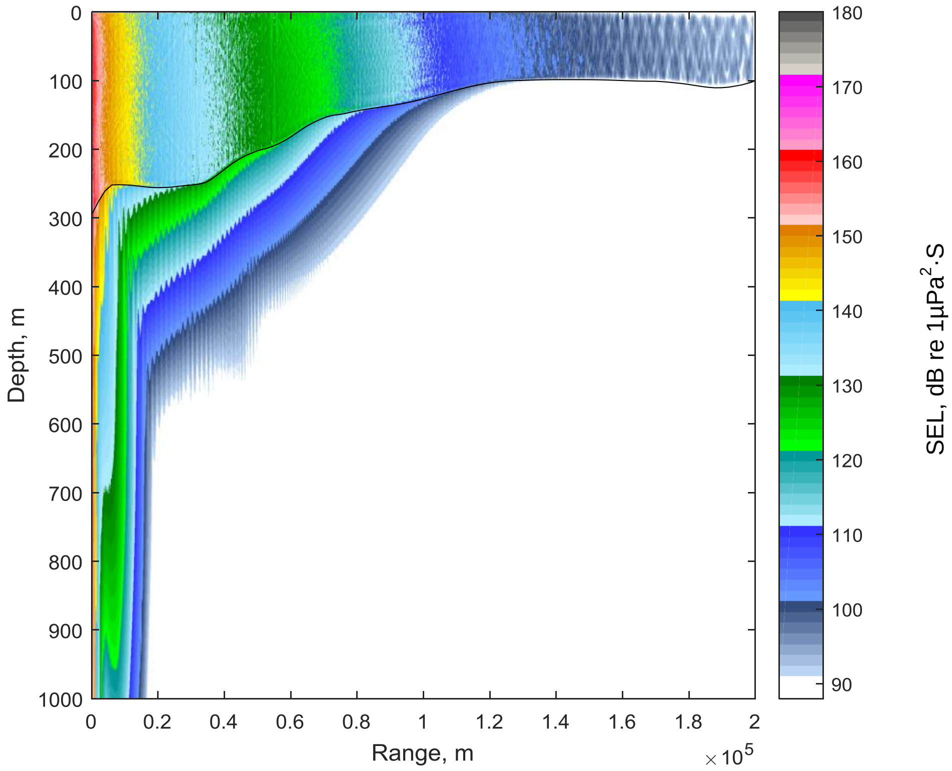
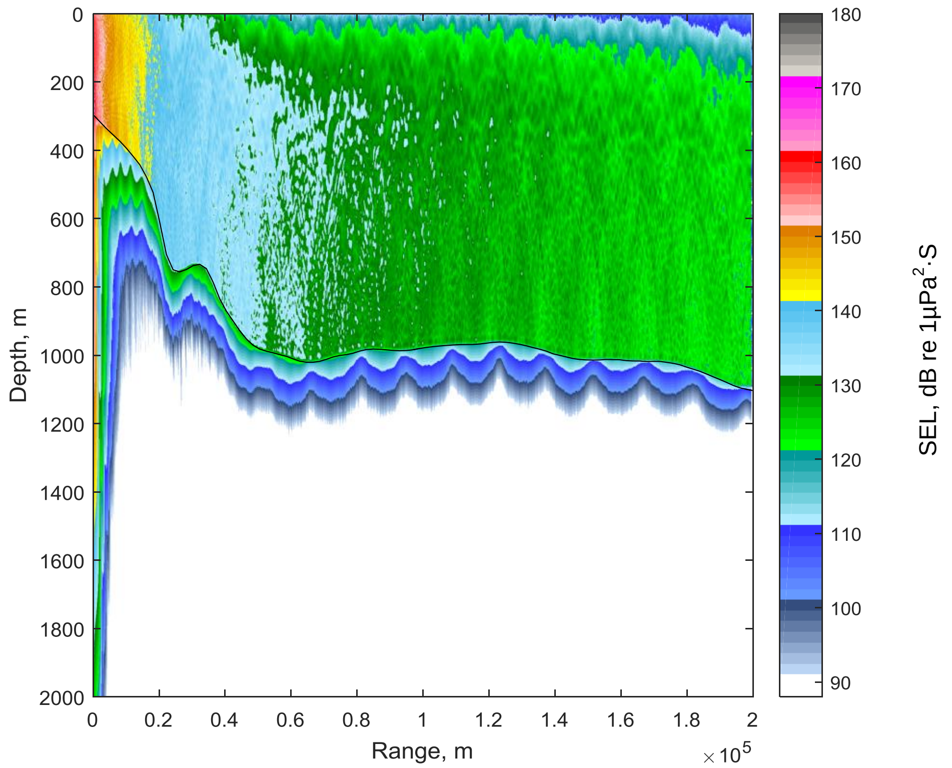


Figure 17 Modelled SELs vs range and depth along the propagation path in Southeast-Northwest cross-line direction from the source location. Black line shows the seabed depth variation.



5 CONCLUSIONS

PGS Australia Pty Ltd (PGS) is proposing to acquire a three dimensional (3D) marine seismic survey in the Taranaki Basin (i.e. the 'Taranaki West 3D Seismic Survey'). This report details the sound transmission loss modelling study that has been carried out for the proposed survey, which includes three modelling components, e.g. array source modelling, short range modelling and long range modelling. The detailed modelling methodologies and procedures for the three components are described in **Section 2** and **Section 3** of the report.

The proposed source array configuration for this survey is the PGS 4,130 cubic inch array. The array source modelling illustrates strong array directivity which has significant angle and frequency dependence for the energy radiation from the array, as a result of interference between signals from different array elements, particularly the three sub-arrays.

The short range modelling prediction demonstrates that the highest SELs occur in the in-line and cross-line directions, as a result of the directivity of the source array. The maximum received SELs over all azimuths are predicted to be below 186 dB re 1µPa^2·s at 200 m and below 171 dB re 1µPa^2·s at 1.0 km.

The long range modelling shows that the received SELs at long range vary significantly at different angles and distances from the source. This directivity of received levels is due to a combination of the directivity of the source array, and propagation effects caused by bathymetry and sound speed profile variations. The West Coast North Island Marine Mammal Sanctuary has a minimum distance of 120 km to the survey area. The maximum SELs received from the nominated source location at the sanctuary boundary are predicted to be slightly greater than 90 dB re 1µPa^2·S.

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ACOUSTIC TERMINOLOGY

Sound Pressure	A deviation from the ambient hydrostatic pressure caused by a sound wave
Sound Pressure Level (SPL)	The logarithmic ratio of sound pressure to reference pressure. The reference pressure underwater is P_{ref} = 1 µPa
Root-Mean-Square Sound Pressure Level (RMS SPL)	The mean-square sound pressure is the average of the squared pressure over some duration. The root-mean-square sound pressure level is the level of the root of the mean-square pressure against the reference pressure
Sound Exposure Level (SEL)	SEL is a measure of energy. Specifically, it is the dB level of the time integral of the squared instantaneous sound pressure normalised to a 1-s period
Power Spectral Density (PSD)	PSD describes how the power of a signal is distributed with frequency
Source Level (SL)	The acoustic source level is the level referenced to a distance of 1m from a point source
1/3 Octave Band Levels	The energy of a sound split into a series of adjacent frequency bands, each being 1/3 of an octave wide
Sound Speed Profile	A graph of the speed of sound in the water column as a function of depth

MARINE MAMMAL MITIGATION PLAN

global environmental solutions

Marine Mammal Mitigation Plan

Taranaki West 3D Seismic Survey

Report Number 740.10034

16 November 2016

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Version: v2.1

Marine Mammal Mitigation Plan

Taranaki West 3D Seismic Survey

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1 INTRODUCTION

1.1 Purpose of the Marine Mammal Mitigation Plan

The purpose of this Marine Mammal Mitigation Plan (MMMP) is to outline the procedures to be implemented for the responsible operation of seismic activities around marine mammals during the 'Taranaki West 3D Seismic Survey'.

The MMMP will be used by observers and crew to guide operations in accordance with the Department of Conservations (DOC) *2013 Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations* ('Code of Conduct').

1.2 Survey Outline

PGS Australia Pty Ltd (PGS) is proposing to acquire a three dimensional (3D) marine seismic survey in the Taranaki Basin. The Operational Area for the Taranaki West 3D Seismic Survey, within which all seismic operations will be restricted, is located directly west of Cape Egmont and north-west of Farewell Spit (**Figure 1**). The coordinates for the corners of the Operational Area are provided in **Table 1**.

Table 1 Operational Area Coordinates

Easting (m)	Northing (m)	Latitude	Longitude	Latitude	Longitude
NZTM-East	**NZTM-North**	**WGS84 Decimal Degrees**		**Degrees/Minutes/Seconds**	
1526498.27	5675287.94	172.15036	-39.06841	172° 9' 1.296" S	39° 4' 6.276" E
1526498.27	5581078.67	172.13996	-39.91720	172° 8' 23.856"	39° 55' 1.92"
1464834.03	5581078.67	171.41863	-39.90961	171° 25' 7.068"	39° 54' 34.596"
1464834.03	5675287.94	171.43774	-39.06104	171° 26'15.864"	39° 3' 39.744"
1526498.27	5675287.94	172.15036	-39.06841	172° 9' 1.296"	39° 4' 6.276"

The Operational Area does not enter the 12 Nm territorial sea, and does not approach or enter the West Coast North Island Marine Mammal Sanctuary. Water depths within the Operational Area range from 220 to 750 m.

This seismic survey is predicted to be a 45 day programme that is scheduled to be acquired during the period approximately December 2016 – January 2017.

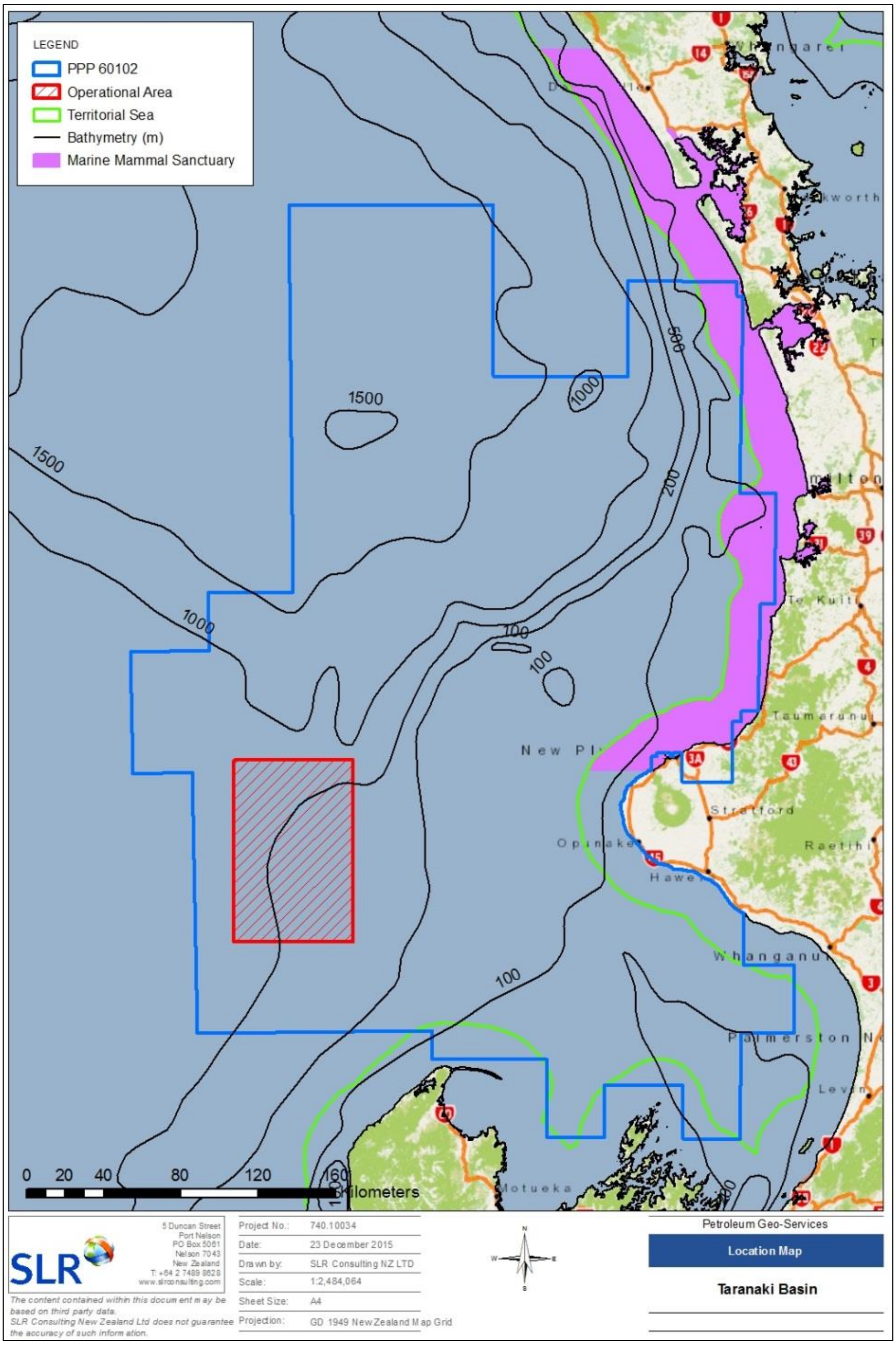
The *PGS Apollo* will undertake the surveys with an acoustic source volume of 3,660 in^3. The acoustic source will be activated at a source-point interval of 16.67 m. For a vessel speed of 4.5 knots, this equates to source activation approximately every 7 seconds. According to the Code of Conduct, the Taranaki West 3D Seismic Survey is classified as a Level 1 survey on account of the acoustic source being greater than 427 in^3.

The seismic vessel will tow 10 streamers that extend for 8.1 km behind the vessel. Each streamer will be separated by 150 m; equating to an overall lateral span of up to 1,350 m. The streamers will remain deployed for the duration of the survey.

The seismic vessel will be accompanied by a support vessel (the *Thor Alpha*) which will serve to ensure a clear path for the seismic vessel, by alerting other marine users to the on-coming seismic vessel and its limited manoeuvrability. An additional chase vessel will also be present.

Seismic data collected during the Taranaki West 3D Seismic Survey will be used to gain a greater understanding of the underlying Taranaki Basin geology in relation to potential hydrocarbon reservoirs. The data collected during this survey will be interpreted in association with re-processed older seismic data (for the broader region) to produce a regional geological perspective.

Figure 1 Location of Operational Area for the Taranaki West 3D Seismic Survey



2 PROCEDURES FOR SEISMIC OPERATIONS

2.1 Standard Procedures

The procedures outlined below are stipulated by the Code of Conduct and represent the standard mitigations that operators implement for compliance with the Code of Conduct. **Section 2.2** describes the procedures that are over and above the standard mitigations and hence represent variations that are specific to the Taranaki West 3D Seismic Survey.

2.1.1 Notification

The notification requirements of the Code of Conduct have been adhered to. A letter was received by the Director-General of Conservation on 7 October 2015 notifying DOC of PGSs intentions to carry out the Taranaki West 3D Seismic Survey.

2.1.2 Marine Mammal Impact Assessment

Under normal circumstances, a Marine Mammal Impact Assessment (MMIA) must be submitted to the Director-General not less than one month prior to the start of a seismic survey. To fulfil this requirement, the MMIA for the Taranaki West 3D Seismic Survey was submitted to DOC in July 2016. This MMMP forms part of the MMIA. Note that the term 'Species of Concern' is used both in the MMIA and the Code of Conduct, **Appendix 1** lists these species.

2.1.3 Observer Requirements

All Level 1 seismic surveys require the use of Marine Mammal Observers (MMOs) in conjunction with Passive Acoustic Monitoring (PAM). MMOs visually detect marine mammals while the PAM system detects marine mammal vocalisations with hydrophones and is overseen by PAM operators. MMOs and PAM operators must be qualified according to the criteria outlined in the Code of Conduct.

The minimum qualified observer requirements for a Level 1 survey are:

- There will be at least two qualified MMOs on-board at all times;
- There will be at least two qualified PAM operators on-board at all times;
- The roles of MMOs and PAM operators are strictly limited to the detection and collection of marine mammal sighting data, and the instruction of crew on the Code of Conduct and the crew's requirements when a marine mammal is detected within mitigation zones (including pre-start, soft start and operating at full acquisition capacity requirements). A summary of MMO and PAM operator duties are presented in **Table 2**;
- At all times when the acoustic source is in the water, at least one qualified MMO (during daylight hours) and at least one qualified PAM operator will maintain 'watch' for marine mammals; and
- The maximum on-duty shift for an MMO or PAM operator must not exceed 12 hours per day.

MMOs and PAM operators must schedule their shifts and breaks in such a way as to manage their fatigue levels appropriately so focus on the required monitoring can be maintained.

Marine mammal observations by crew members are accommodated under the Code of Conduct through the following prescribed process: 1) Crew member to promptly report sighting to MMO; 2) If marine mammal remains visible MMO to identify marine mammal and distance from acoustic source; and 3) If marine mammal is not observed by the MMO, the crew member will be asked to complete a sighting form and the implementation of any resulting mitigation action will be at the discretion of the MMO.

Table 2 Operational duties of qualified observers

MMO duties	PAM operator duties
Provide effective briefings to crew members, and establish clear lines of communication and procedures for on-board operations.	Provide effective briefings to crew members, and establish clear lines of communication and procedures for on-board operations.
Continually scan the water surface in all directions around the acoustic source for presence of marine mammals, using a combination of naked eye and high-quality binoculars from optimum vantage points for unimpaired visual observations.	Deploy, retrieve, test and optimise PAM hydrophone arrays.
Determine distance/bearing and plot positions of marine mammals whenever possible during sightings using GPS, sextant, reticle binoculars, compass, measuring sticks, angle boards or other appropriate tools.	When on duty, concentrate on continually listening to received signals and/or monitor PAM display screens in order to detect vocalising cetaceans, except when required to attend to PAM equipment.
Record/report all marine mammal sightings, including species, group size, behaviour/activity, presence of calves, distance and direction of travel (if discernible).	Use appropriate sample analysis and filtering techniques.
Record sighting conditions (Beaufort sea state, swell height, visibility, fog/rain and glare) at the beginning and end of the observation period, and whenever there is a significant change in weather conditions.	Record and report all cetacean detections, including, if discernible, identification of species or cetacean group, position, distance and bearing from vessel and acoustic source. Record the type and nature of sound, time and duration over which it was heard.
Record acoustic source power output while in operation, and any mitigation measures taken.	Record general environmental conditions, acoustic source power output while in operation, and any mitigation measures taken.
Communicate with DOC to clarify any uncertainty or ambiguity in application of the Code of Conduct.	Communicate with DOC to clarify any uncertainty or ambiguity in application of the Code of Conduct.
Record/report to DOC any instances of non-compliance with the Code of Conduct.	Record/report to DOC any instances of non-compliance with the Code of Conduct.

2.1.4 PAM Operations

Due to the limited detection range of current PAM technology, any ultra-high frequency detections will require an immediate shutdown of an active source or will delay the start of operations, regardless of signal strength or whether distance or bearing from the acoustic source has been determined. It is not necessary to determine whether the marine mammal is within a mitigation zone. However, shutdown of an activated source will not be required if visual observations by a MMO confirm the acoustic detection was of a species falling into the category of ‘Other Marine Mammals’ (i.e. not a Species of Concern).

If the PAM system malfunctions[1] or becomes damaged, seismic operations may continue for 20 minutes without PAM while the PAM operator diagnoses the problem. If it is found that the PAM system needs to be repaired, seismic operations may continue for an additional two hours without PAM as long as the following conditions are met:

- It is during daylight hours and the sea state is less than or equal to Beaufort 4;
- No marine mammals were detected solely by PAM in the relevant mitigation zones in the previous two hours;
- Two MMOs maintain watch at all times during seismic operations when PAM is not operational;
- DOC is notified via email as soon as practicable, stating time and location in which seismic operations began without an active PAM system; and

[1] PAM malfunction can relate to the towed PAM equipment, or the software used to receive, process and display acoustic detections.

- Seismic operations with an active source, but without an active PAM system, do not exceed a cumulative total of four hours in any 24 hour period.

2.1.5 Reporting Requirements

Qualified observers are required under the Code of Conduct to record and report all marine mammal sightings during the survey (regardless of where they occur in relation to a mitigation zone). The following standardised excel datasheets must be used:

- On-survey Excel Reporting Form: http://www.doc.govt.nz/Documents/conservation/marine-and-coastal/seismic-surveys-code-of-conduct/on-survey-seismic-mmo-reporting-form.xls
- Off-survey Excel Reporting Form: http://www.doc.govt.nz/Documents/conservation/marine-and-coastal/seismic-surveys-code-of-conduct/off-survey-seismic-mmo-reporting-form.xls

All raw datasheets must be submitted directly to DOC at the earliest opportunity, but no longer than 14 days after the completion of each deployment. A written final trip report must also be provided to DOC at the earliest opportunity, but no later than 60 days after the completion of the project.

If qualified observers consider that there are higher than expected numbers of marine mammals encountered during seismic survey operations, they are required to immediately notify the Director General of Conservation. Adaptive management procedures will be agreed following a discussion between DOC and the Operator. The MMO/PAM team will then implement any required adaptive management actions.

Incidents of non-compliance with the Code of Conduct must be reported immediately to DOC and the EPA. Within 48 hours of the initial notification of non-compliance a short summary of the incident should be sent by email to DOC and the EPA to provide a written record that outlines the nature of the non-compliance, where it occurred, when it occurred, why it occurred, how it occurred and any steps that have been taken to prevent reoccurrence.

2.1.6 Pre-start Observations

A Level 1 acoustic source can only be activated if it is within the specified Operational Area and adheres to the following protocol:

- The acoustic source cannot be activated during daylight hours unless:
  - At least one qualified MMO has made continuous visual observations around the source for the presence of marine mammals, from the bridge (or preferably even higher vantage point) using both binoculars and the naked eye, and no marine mammals have been observed in the respective mitigation zones for at least 30 minutes; and
  - Passive acoustic monitoring for the presence of marine mammals has been carried out by a qualified PAM operator for at least 30 minutes before activation and no vocalising cetaceans have been detected in the respective mitigation zones.
- The acoustic source cannot be activated during night-time hours or poor sighting conditions (visibility of 1.5 km or less or in a sea state greater than or equal to Beaufort 4) unless:
  - Passive acoustic monitoring for the presence of marine mammals has been carried out by a qualified PAM operator for at least 30 minutes before activation; and
  - The qualified observer has not detected any vocalising cetaceans in the relevant mitigation zones.

New Location:

In addition to the above normal pre-start observation requirements, when arriving at a new location in the survey programme for the first time, or when returning to the Operational Area following a port call, the initial acoustic source activation must not be undertaken at night or during poor sighting conditions unless either:

- MMOs have undertaken observations within 20 Nm of the planned start up position for at least the last two hours of good sighting conditions preceding proposed operations, and no marine mammals have been detected; or
- Where there have been less than two hours of good sighting conditions preceding proposed operations (within 20 Nm of the planned start up position), the source may be activated if:
  - PAM monitoring has been conducted for two hours immediately preceding proposed operations;
  - Two MMOs have conducted visual monitoring in the two hours immediately preceding proposed operations;
  - No Species of Concern have been sighted during visual monitoring or detected during acoustic monitoring in the relevant mitigation zones in the two hours immediately preceding proposed operations;
  - No fur seals have been sighted during visual monitoring in the relevant mitigation zone (200 m) in the 10 minutes immediately preceding proposed operations; and
  - No other marine mammals have been sighted during visual monitoring or detected during acoustic monitoring in the relevant mitigation zones (200 m) in the 30 minutes immediately preceding proposed operations.

2.1.7 Soft Starts

A soft start consists of gradually increasing the source's power, starting with the lowest capacity acoustic source, over a period of at least 20 minutes and no more than 40 minutes. With regard to soft starts, the following points are critical:

- **The operational source capacity is not to be exceeded during the soft start period; and**
- **The observer team must draw this to the attention of the seismic staff on-board the vessel.**

The acoustic source will not be activated at any time except by soft start, unless the source is being reactivated after a single break in firing (not in response to a marine mammal observation within a mitigation zone) of less than 10 minutes immediately following normal operations at full power, and the qualified observers have not detected marine mammals in the relevant mitigation zones. No repetition of the less than 10 minute break period in the commencement of a soft start is allowed under the Code of Conduct.

2.1.8 Mitigation Zones for Delayed Starts and Shutdowns

Species of Concern with calves within a mitigation zone of 1.5 km

If, during pre-start observations or while the acoustic source is activated (including during soft starts), a qualified observer detects at least one Species of Concern with a calf within 1.5 km of the source, start-up will be delayed or the source will be shut down and not reactivated until:

- A qualified observer confirms the group has moved to a point that is more than 1.5 km from the source; or
- Despite continuous observation, 30 minutes has elapsed since the last detection of the group within 1.5 km of the source, and the mitigation zone remains clear.

Where marine mammal detection occurs via PAM it shall be recognised that calves and adults cannot be differentiated, therefore calf presence must be assumed and the 1.5 km mitigation zone will apply to all Species of Concern.

Species of Concern within a mitigation zone of 1 km

If during pre-start observations or while the acoustic source is activated (including during soft starts), a qualified observer detects a Species of Concern within 1 km of the source, start-up will be delayed or the source will be shut down and not reactivated until:

- A qualified observer confirms the Species of Concern has moved to a point that is more than 1 km from the source; or
- Despite continuous observation, 30 minutes has elapsed since the last detection of a Species of Concern within 1 km of the source, and the mitigation zone remains clear.

Other Marine Mammals within a mitigation zone of 200 m

If during pre-start observations prior to initiation of the acoustic source soft-start procedures, a qualified observer detects a marine mammal other than a Species of Concern within 200 m of the source, start-up will be delayed until:

- A qualified observer confirms the marine mammal has moved to a point that is more than 200 m from the source; or
- Despite continuous observation, 10 minutes has elapsed since the last detection of a NZ fur seal within 200 m of the source and 30 minutes has elapsed since the last detection of any other marine mammal within 200 m of the source, and the mitigation zone remains clear.

Once all marine mammals that were detected within the relevant mitigation zones have been observed to move beyond the respective mitigation zones, there will be no further delays to the initiation of soft start procedures.

A summary of these mitigation zones are outlined in **Figure 2** and the required mitigation actions are summarised in 'Operational Flowcharts' in **Appendix 2.**

2.1.9 Line turns

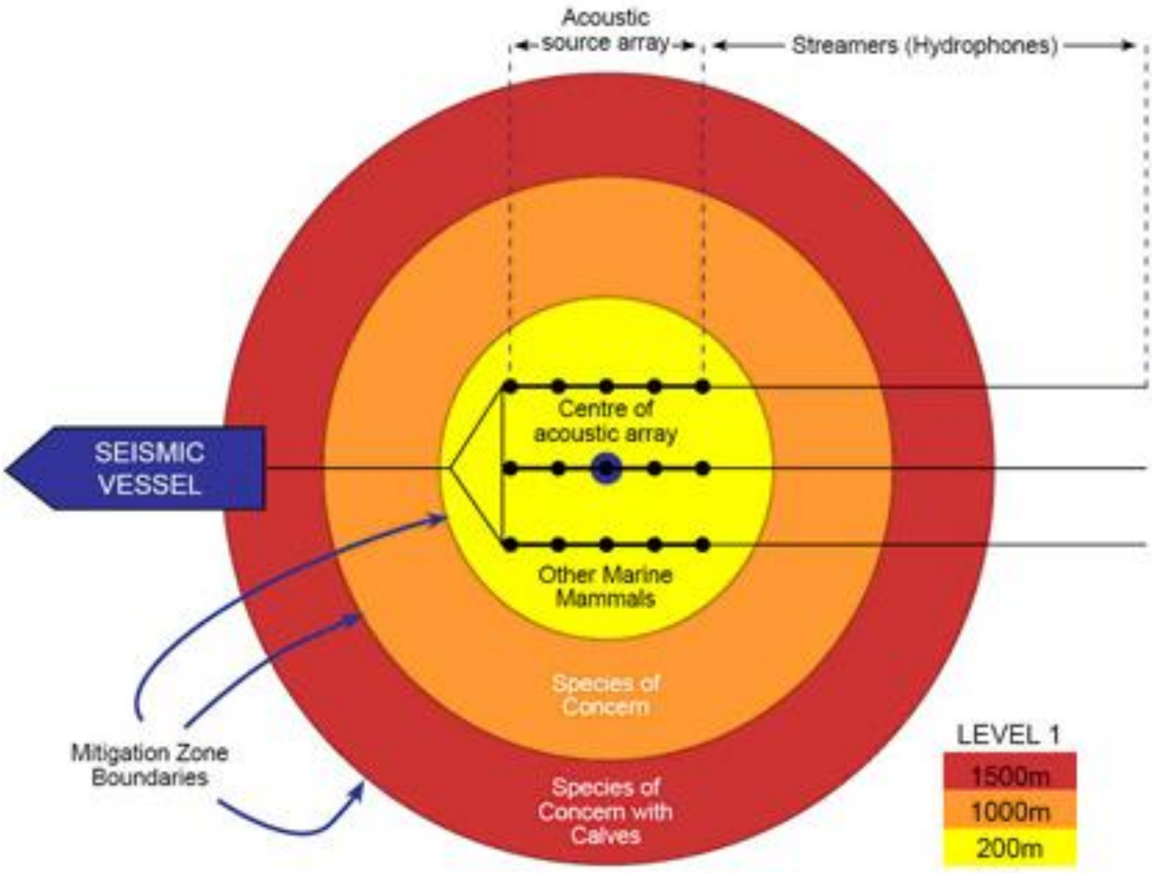
Activation of any seismic source for mitigation purposes during line turns is not supported by the Code of Conduct unless specific approval has been sought through the MMIA. During the Taranaki West 3D Seismic Survey, the seismic source will remain off during line turns and will only be activated for the purpose of source testing during standard maintenance routines, and soft starts on approaching the start of a new line.

2.1.10 Acoustic source testing

Acoustic source testing will be subject to the relevant soft start procedure, although for testing, the 20 minute minimum duration does not apply. The power of the acoustic source should be built up gradually to the required test level at a rate not exceeding that of a normal soft start.

Acoustic source tests shall not be used for mitigation purposes, or to avoid implementation of soft start procedures.

Figure 2 Summary of mitigation zones for a level 1 seismic survey.



Source: http://www.doc.govt.nz/our-work/seismic-surveys-code-of-conduct/frequently-asked-questions/

2.1.11 Ground Truthing of Sound Transmission Loss Modelling

As per the Code of Conduct requirements, PGS will conduct ground-truthing during the survey to verify the results of the STLM. In order to do this, representative data recorded on the seismic streamers during the seismic survey will be used to compare actual sound exposure levels with STLM predictions and to measure the SELs at each mitigation zone boundary.

The undertaking of this ground truthing is the responsibility of the on-board PGS seismic data technicians; however, they may seek input from the qualified observers during this process with regards to understanding the mitigation zones and the acoustic thresholds outlined in the MMIA.

2.1.12 Key contacts and communication protocols

The key contact for DOC is Dave Lundquist who can be contacted by phone on +64 27 201 3529or email at dlundquist@doc.govt.nz. Dave is the point of contact for all DOC enquiries or notifications except for those regarding Maui's/Hector's dolphins, humpback whales and southern right whales (see additional contacts provided in **Section 2.2.1**).

Any correspondence with the EPA should be directed to seismic.compliance@epa.govt.nz.

Note that PGS must be kept informed of any correspondence with DOC or the EPA; in this regard please copy all emails to: Terry.Visser@pgs.com. Any phone calls made to DOC should be followed up with an email to confirm the message; please cc these emails to Terry.Visser@pgs.com.

2.2 Additions to the Code of Conduct

The procedures outlined in this section are further to those required by the Code of Conduct. These additional procedures have been adopted by PGS for the purpose of the Taranaki West 3D Seismic Survey and have been agreed with DOC as part of the MMIA process. Based on this it is imperative that these procedures are considered as strict requirements of the survey and therefore constitute additional responsibilities of qualified observers during the Taranaki West 3D Seismic Survey.

2.2.1 Reporting Requirements

In addition to the reporting requirements outlined in **Section 2.1.5**, the following additional reporting components are required:

- Marine mammal sightings will be collected whilst in transit to the Operational Area. These records will be collated onto the DOC standardised 'Off-survey Excel Reporting Forms' (http://www.doc.govt.nz/Documents/conservation/marine-and-coastal/seismic-surveys-code-of-conduct/off-survey-seismic-mmo-reporting-form.xls) and will be provided to DOC no later than 14 days after the completion of each deployment;

- MMOs will be vigilant for marine mammal entanglement incidents with seismic equipment and will report any entanglement incidents immediately to DOC;

- MMOs will be vigilant for dead marine mammals observed at sea and will report details of these incidences to DOC in the final trip report;

- MMOs to notify DOC immediately of any Hector's/Maui's dolphin sightings, and of any humpback or southern right whale sightings in the territorial sea. These sightings will be made via telephone to Callum Lilley on +64 27 206 5842, with a follow up email sent to clilley@doc.govt.nz; and

- Weekly MMO reports will be provided to DOC (Dave Lundquist and Callum Lilley) and EPA. Suggested headings for these reports are as follows:

  - Report Information (date and distribution list);
  - Summary of Operations (seismic operations, weather, observer effort);
  - Marine mammal detections (date, species, number, closest distance, array status);
  - Interruptions to seismic operations (shut downs, delayed starts);
  - Other notable fauna (date, species, number, closest distance, array status etc); and
  - Compliance issues (description of any compliance issues and method of address).

- In the event that seismic operations overlap temporally with field research on blue whales in the South Taranaki Bight, the lead MMO will keep in contact with the research vessel to update them on blue whale detections from the seismic vessel. The position of whales, number of whales and direction of travel should be provided.

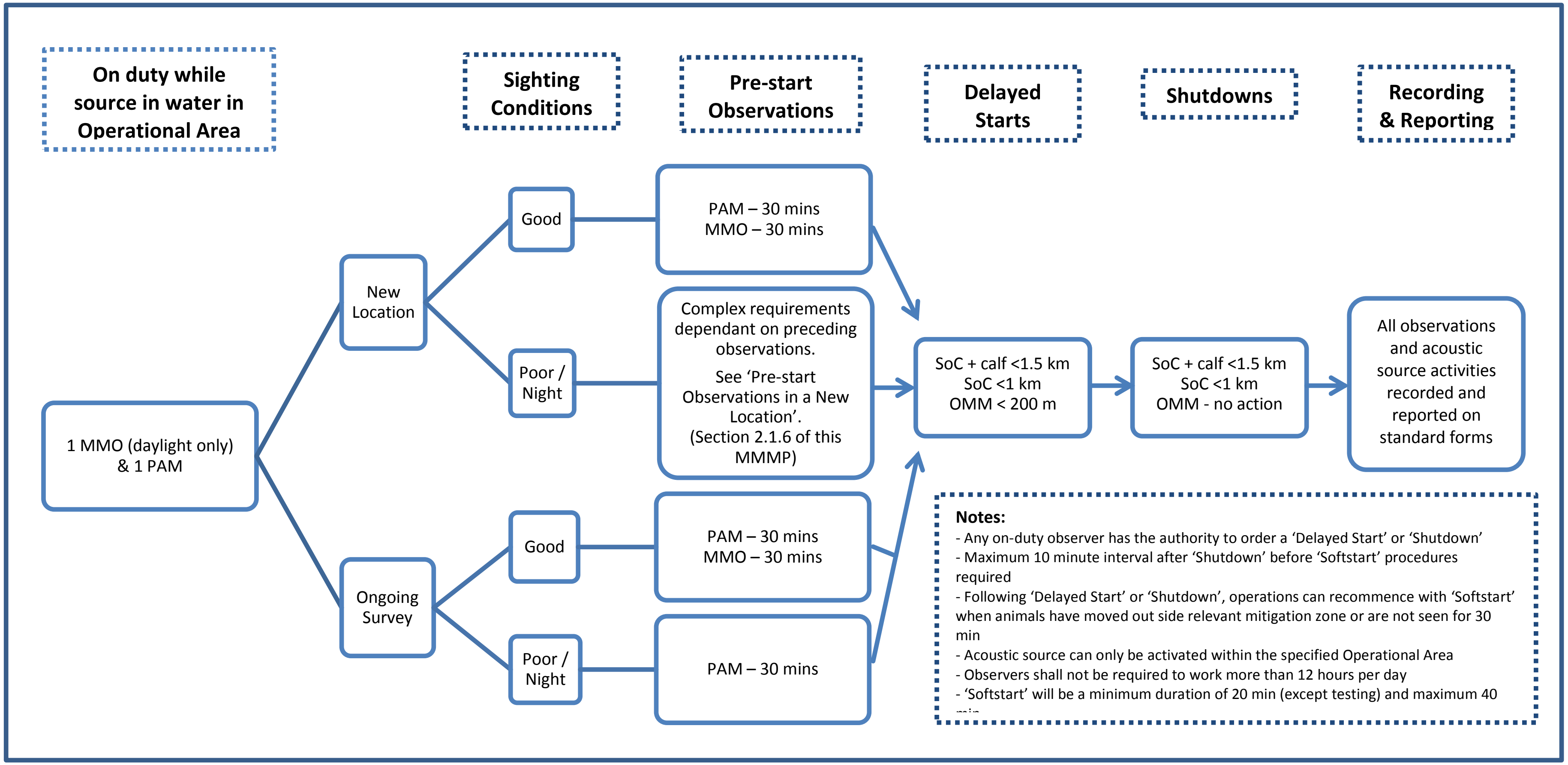
2.2.2 Other

In addition to the four qualified observers, PGS has committed to provide an opportunity for a trained iwi MMO on-board the seismic vessel during the Taranaki West 3D Seismic Survey. A role description for the iwi MMO will be developed by PGS in conjunction with the MMO service provider prior to the survey and the agreed role will be clearly defined and incorporated into an employment contract with the iwi MMO.

APPENDIX 1: SPECIES OF CONCERN

LATIN NAME	COMMON NAME
Megaptera novaengliae	Humpback Whale
Balaenoptera borealis	Sei Whale
Balaenoptera edeni	Bryde's Whale
Balaenoptera bonaerensis	Antarctic Minke Whale
Balaenoptera acutorostrata subsp.	Dwarf Minke Whale
Balaenoptera musculus	Blue Whale
Balaenoptera physalus	Fin Whale
Balaenoptera musculus brevicauda	Pygmy Blue Whale
Eubalaena australis	Southern Right Whale
Caperea marginata	Pygmy Right Whale
Lissodelphis peronii	Southern Right-whale Dolphin
Globicephala melas	Long-finned Pilot Whale
Globicephala macrorhynchus	Short-finned Pilot Whale
Peponcephala electra	Melon-headed Whale
Physeter macrocephalus	Sperm Whale
Kogia sima	Dwarf Sperm Whale
Kogia breviceps	Pygmy Sperm Whale
Mesoplodon grayi	Gray's Beaked Whale
Berardius arnuxii	Arnoux's Beaked Whale
Ziphius cavirostris	Cuvier's Beaked Whale
Mesoplodon layardii	Strap-toothed Whale
Hyperoodon planifrons	Southern Bottlenose Whale
Mesoplodon bowdoini	Andrew's Beaked Whale
Mesoplodon mirus	True's Beaked Whale
Mesoplodon densirostris	Blainville's Beaked Whale
Mesoplodon gingkodens	Ginkgo-toothed Whale
Mesoplodon hectori	Hector's Beaked Whale
Mesoplodon peruvianus	Pygmy/Peruvian Beaked Whale
Tasmacetus shepherdi	Shepherd's Beaked Whale
Orcinus orca	Killer Whale
Pseudorca crassidens	False Killer Whale
Feresa attenuata	Pygmy Killer Whale
Cephalorhynchus hectori	Hector's Dolphin
Cephalorhynchus hectori maui	Maui's Dolphin
Phocarctos hookeri	New Zealand Sea Lion
Tursops truncatus	Bottlenose Dolphin

APPENDIX 2: OPERATIONAL FLOWCHART



Adapted from the Code of Conduct (DOC, 2013); Key: SoC = Species of Concern, OMM = Other Marine Mammal

PASSIVE ACOUSTIC MONITORING SPECIFICATIONS

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11 November 2014

250m Array System and 230m tow with 20m detachable array System Specifications

Commercial in Confidence

Contents

1) Towed PAM

The system is designed to give a flexible approach to the monitoring of marine noise from a towed hydrophone system. The system comprises an array cable, tow cable, deck cable, an electronics processing unit and laptops supporting Pamguard software.

The electronic processing unit contains a buffer processing unit comprising of power supplies, buffer boards, national instrument card for high frequency signal and usb1208 for depth. There is also a radio transmission system that is used to process hydrophone signals for audio output to remote headphones.

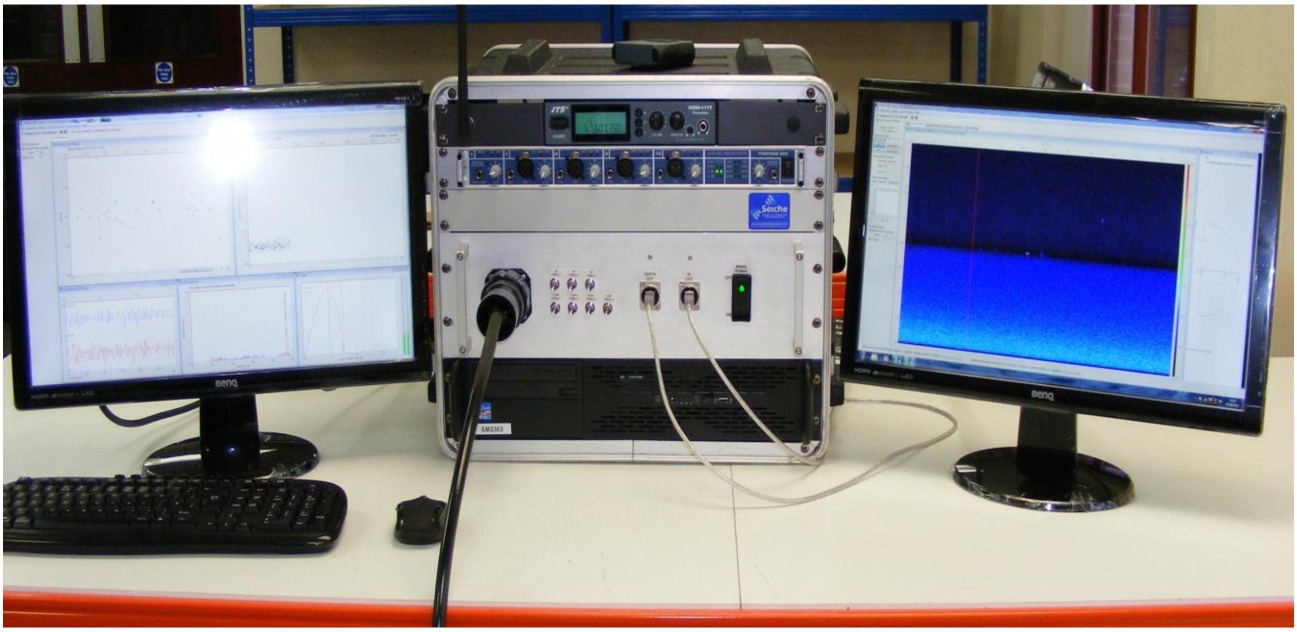


Figure 1: 8U Base unit with Rack-mounted PC and LF and HF monitors

Remote Monitoring Station

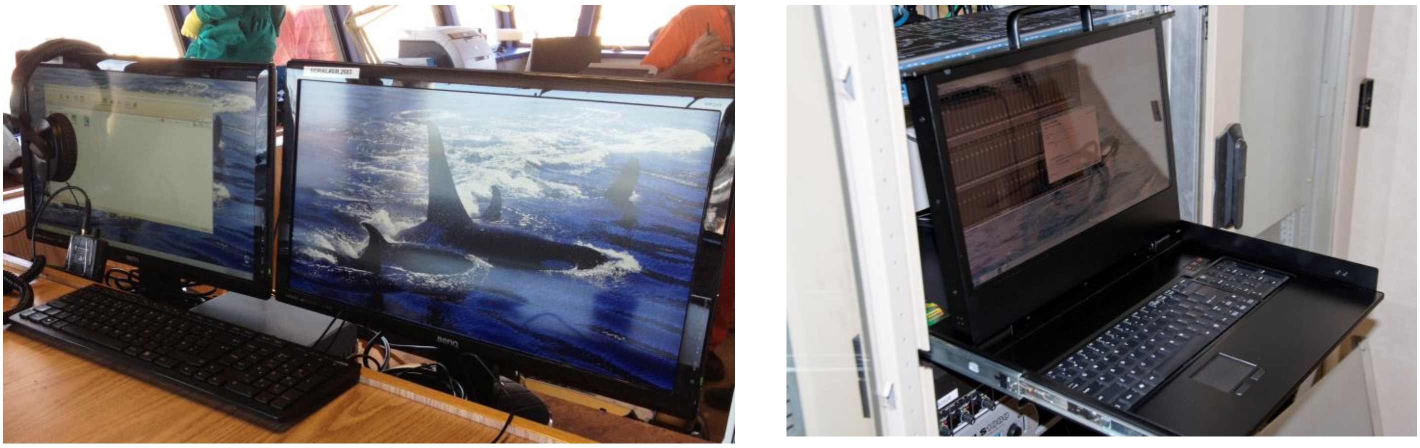


Figure 2: Remote station on bridge and set up screen for Rack mounted base unit

The remote monitoring station enables the base unit to be rack-mounted with other ship based computer equipment and by using the ships internal ethernet system, link to screens in an alternative location on the vessel.

Electronics Monitoring Base Unit

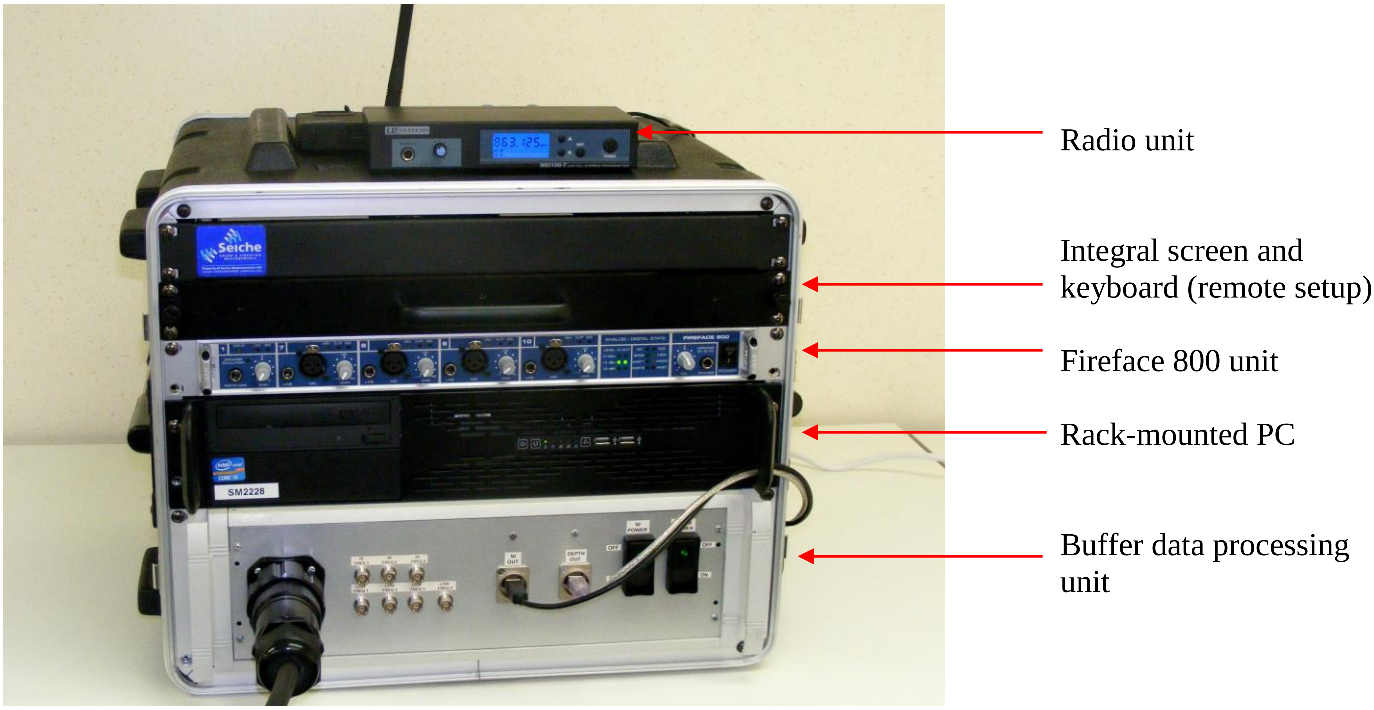


Figure 3: Electronics monitoring base unit

Radio unit
The radio system provides a remote headphone output from the audio output system. (Note: it is limited in frequency to 16 kHz)

Integral screen and keyboard
The rack-mounted integral screen and keyboard can be used to run the rack-mounted PC for monitoring or for troubleshooting. It is contained in a 1U housing which slides out and flips up when in use.

Fireface 800 unit
This unit is used for the low frequency signal. The analog signal from each hydrophone is sent from the back of the buffer data processing unit to the fireface unit. The detected signals are filtered and amplified then fed to the rack-mounted PC via the firewire cable.

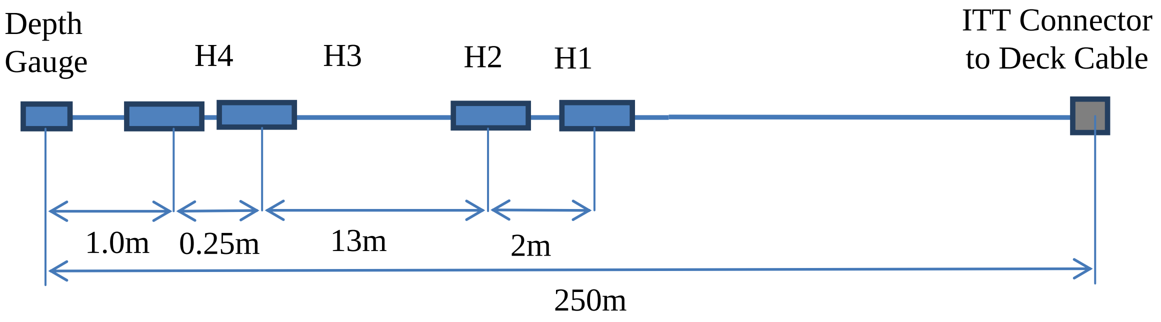
Rack-mounted PC
The rack-mounted PC system has an Intel quad core i5 processor with 8 GB of RAM. This custom built PC system has enough power to run both high and low frequency audio data through Pamguard simultaneously from up to 4 hydrophones.

Buffer data processing unit
This unit connects the deck cable into the system and splits the analog signal from up to 4 hydrophones into high and low frequency acoustic data. The high frequency analog signal is converted into a digital signal and is fed via USB to the rack-mounted PC for real time analysis and display. The low frequency analog signal from 4 hydrophones is fed into the fireface unit which is connected to the PC via firewire. The high and low frequency signal can also be listened to using the BNC connectors for troubleshooting. There is a second USB that enables the depth sensor readings to be input to the PC.

Towed Sensors

Note that frequency bandwidths can be tailored to suit specific applications and country requirements.

250m Towed Array
The sensor array comprises a 250m array with integral hydrophones and a depth sensor array.



Mechanical Information

Length:	250m
Depth Rating:	100m (not connector)
Diameter:	14mm over cable, 32mm over mouldings, 64mm over connectors
Weight:	60kg
Connector:	ITT 19 pin
BS	500 kg

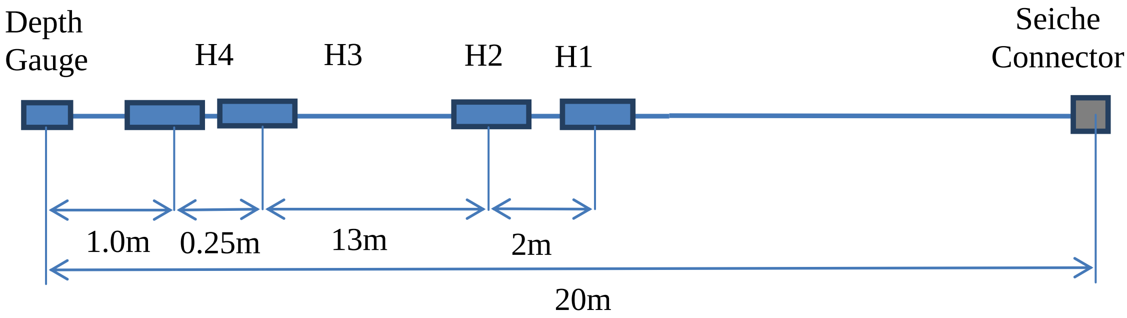
Hydrophone elements

H1	Broadband	10 Hz to 200 kHz (3dB points)
H2	Broadband	10 Hz to 200 kHz (3dB points)
H3	Wideband	2 kHz to 200 kHz (3dB points)
H4	Wideband	2 kHz to 200 kHz (3dB points)

Spacing H1 - H2 (HF detection)	2.00m	1.28mSecs
Spacing H2 - H3 (HF detection)	13.00m	8.32mSecs
Spacing H3 - H4 (LF detection)	0.25m	0.16mSecs

20m Towed array

The sensor array comprises a 20m detachable array section with a 230m heavy tow cable. The connectors are designed in house and are fully waterproof. Longer array sections can be provided to improve detections of low frequency vocalising marine mammals.



Mechanical Information

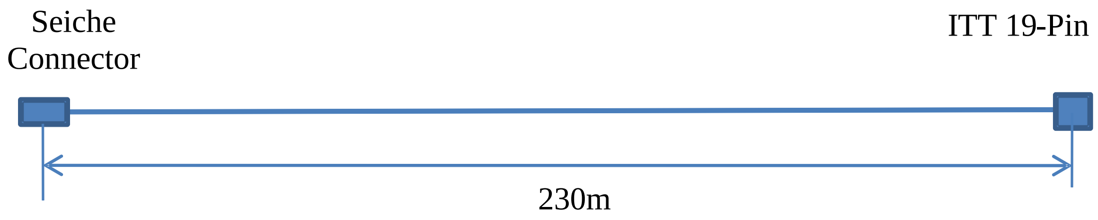
Length:	20m
Depth Rating:	100m (not connector)
Diameter:	14mm over cable, 32mm over mouldings, 45mm over connectors
Weight:	60kg
Connector:	Seiche
BS	500 kg

Hydrophone elements

H1	Broadband	10 Hz to 200 kHz (3dB points)
H2	Broadband	10 Hz to 200 kHz (3dB points)
H3	Wideband	2 kHz to 200 kHz (3dB points)
H4	Wideband	2 kHz to 200 kHz (3dB points)

Spacing H1- H2 (HF detection)	2m	1.28mSecs
Spacing H2 - H3 (HF detection)	13m	8.32mSecs
Spacing H3 - H4 (LF detection)	0.25m	0.16mSecs

230m Tow cable

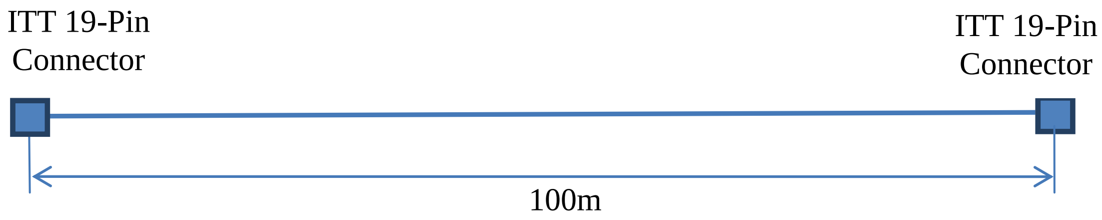


Mechanical Information

Length	230m	
Diameter	17mm over cable	
Connector	Seiche 36-pin	45mm over connectors
	ITT 19-pin	65mm over connectors
Weight	95 kg	
BS	960 kg	

100m Deck Cable

The deck cable is used for all array options



Mechanical Information

Cable Length:	100m
Diameter:	14mm
Connectors:	19 pin ITT (one male, one female)
Connector Diameter:	64mm
Weight:	25 kg
BS	500 kg

2) System Sensitivity

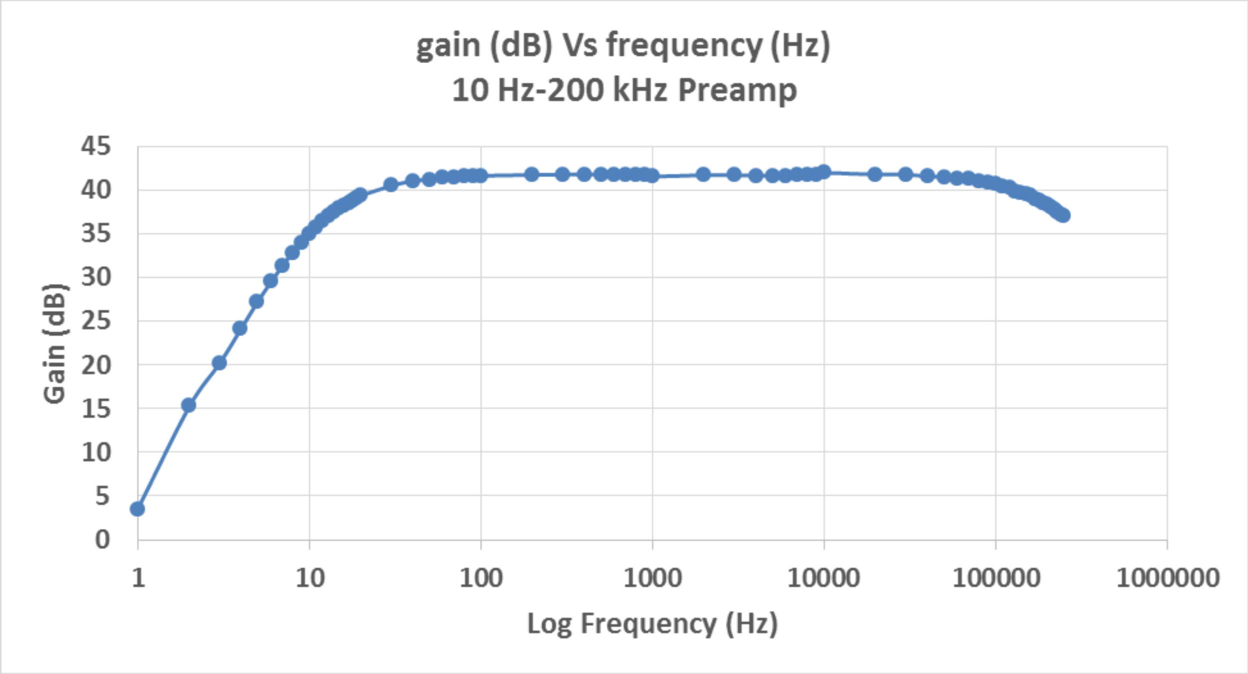


Figure 4: Hydrophone Sensitivity

The array sections consist of four hydrophones.
Two are set with a bandwidth of 10 Hz to 200 kHz, per Figure 4 above, which demonstrates that the sensitivity of the hydrophone starts to roll off at 10 Hz, but remains sensitive down to 1 Hz where it will still register 4 dB

The second pair of hydrophones is set to a bandwidth of 2 kHz to 200 kHz sensitivity. This will ensure that if the lower frequency pair of hydrophones is saturated by vessel noise, the system will still be capable of detecting vocalising marine mammals.