ENVIRONMENTAL OFFSHORE SERVICES LIMITED

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Woodside Energy (New Zealand) Limited

Vulcan 3D Marine Seismic Survey

Marine Mammal Impact Assessment

Report 740.10001-R0

17 December 2014

Version: Final

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List of Acronyms

ACE	Annual Catch Entitlement
AEI	Areas of Ecological Importance
ALARP	As Low as Reasonably Practicable
AOI	Area of Interest
BPA	Benthic Protected Area
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
dB	Decibels
DOC	Department of Conservation
ECC	East Cape Currents
EEZ	Exclusive Economic Zone
EEZ Act	Exclusive Economic Zone and Continental Shelf Act 2012
EMP	Environmental Management Plan
EPA	Environmental Protection Authority
FMA	Fisheries Management Area
HSE	Health and Safety in Employment
IAPPC	International Air Pollution Prevention Certificate
IMS	Invasive Marine Species
IOPPC	International Oil Pollution Prevention Certificate
ISPPC	International Sewage Pollution Prevention Certificate
IUCN	International Union of Conservation of Nature
Km	Kilometre
MARPOL	International Convention for the Prevention of Pollution from Ships
MBIE	Ministry of Business, Innovation and Employment
MEC	Marine Environment Classification
MfE	Ministry for the Environment
MMIA	Marine Mammal Impact Assessment
MMMP	Marine Mammal Mitigation Plan
MMO	Marine Mammal Observer
MMS	Marine Mammal Sanctuary
MPI	Ministry for Primary Industry
MSL	MetOcean Solutions Limited
MSS	Marine Seismic Survey
NABIS	National Aquatic Biodiversity Information System

NIWA	National Institute of Water and Atmospheric Research
Nm	Nautical Mile
NZ	New Zealand
NZP&M	New Zealand Petroleum & Minerals
PAM	Passive Acoustic Monitoring
PEP	Petroleum Exploration Permit
PEPANZ	Petroleum Exploration & Production Association New Zealand
PNA	Protected Natural Area
QMS	Quota Management System
RMA	Resource Management Act 1991
SC	Southland Current
SEL	Sound Exposure Level
SOPEP	Shipboard Oil Pollution Emergency Plan
SRD	Self-Recovery Devices
STLM	Sound Transmission Loss Modelling
TACC	Total Allowable Commercial Catch
Vulcan	Vulcan-NOPEC Geophysical Company Pty Ltd
WAUC	West Auckland Current
WC	Westland Current
WEL	Woodside Energy (New Zealand) Limited

1 Introduction

1.1 Background

Woodside Energy (New Zealand) Limited (WEL), are proposing to acquire a 3D Marine Seismic Survey (MSS) of approximately 1,030 km^2 in the Taranaki Basin. The Survey Area will be located over Petroleum Exploration Permit (PEP) 55793 and will be bound by an Operational Area; allowing for operation of line turns, acoustic source testing and soft start initiation (Figure 1). A well tie will take place from the Vulcan Survey Area consisting of one swathe of seismic acquisition to the previously drilled Tane-1 well to tie in the down hole stratigraphy data from the Tane-1 well to the Vulcan 3D MSS. It is anticipated that the Vulcan 3D MSS will take approximately 35 days to acquire, depending on weather constraints and marine mammal encounters. The seismic vessel *Polar Duke* has been contracted to undertake the Vulcan 3D MSS with an anticipated commencement date of January 2015.

Under Section 23 of the Crown Minerals Act 1991, the purpose of a PEP is to identify petroleum deposits and evaluate the feasibility of mining any discoveries that are made, and is exclusive to the permit holder. PEP 55793 allows WEL to undertake geological or geophysical surveying, exploration and appraisal drilling and testing of petroleum discoveries, however this MMIA is only in relation to the acquisition of a 3D MSS. Further details in regards to the Crown Minerals Act is provided in Section 2.1.

The Vulcan 3D MSS will acquire approximately 1,030 km^2 of full-fold seismic data to assess hydrocarbon prospectivity within the area, and if successful, identify possible locations for an exploration well to target any potential reservoirs.

The Exclusive Economic Zone (EEZ) and Continental Shelf (Environmental Effects – Permitted Activities) Act (EEZ Act) was promulgated and came into effect on 28 June 2013. The EEZ Act manages the previously unregulated potential for adverse environmental effects of activities in the EEZ and continental shelf. Under the EEZ Act, a MSS is classified as a permitted activity, providing the operator undertaking the MSS 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 further explained in Section 2.3.

Environmental Offshore Services Ltd (now merged with SLR Consulting NZ Ltd) was contracted to prepare the Vulcan 3D Marine Mammal Impact Assessment (MMIA) in accordance with the Code of Conduct (Appendix 1: Marine Mammal Impact Assessment) to assess the potential environmental effects from the Vulcan 3D MSS, the sensitive environments and marine species in the surrounding areas and mitigation measures to avoid or minimise any potential effects.

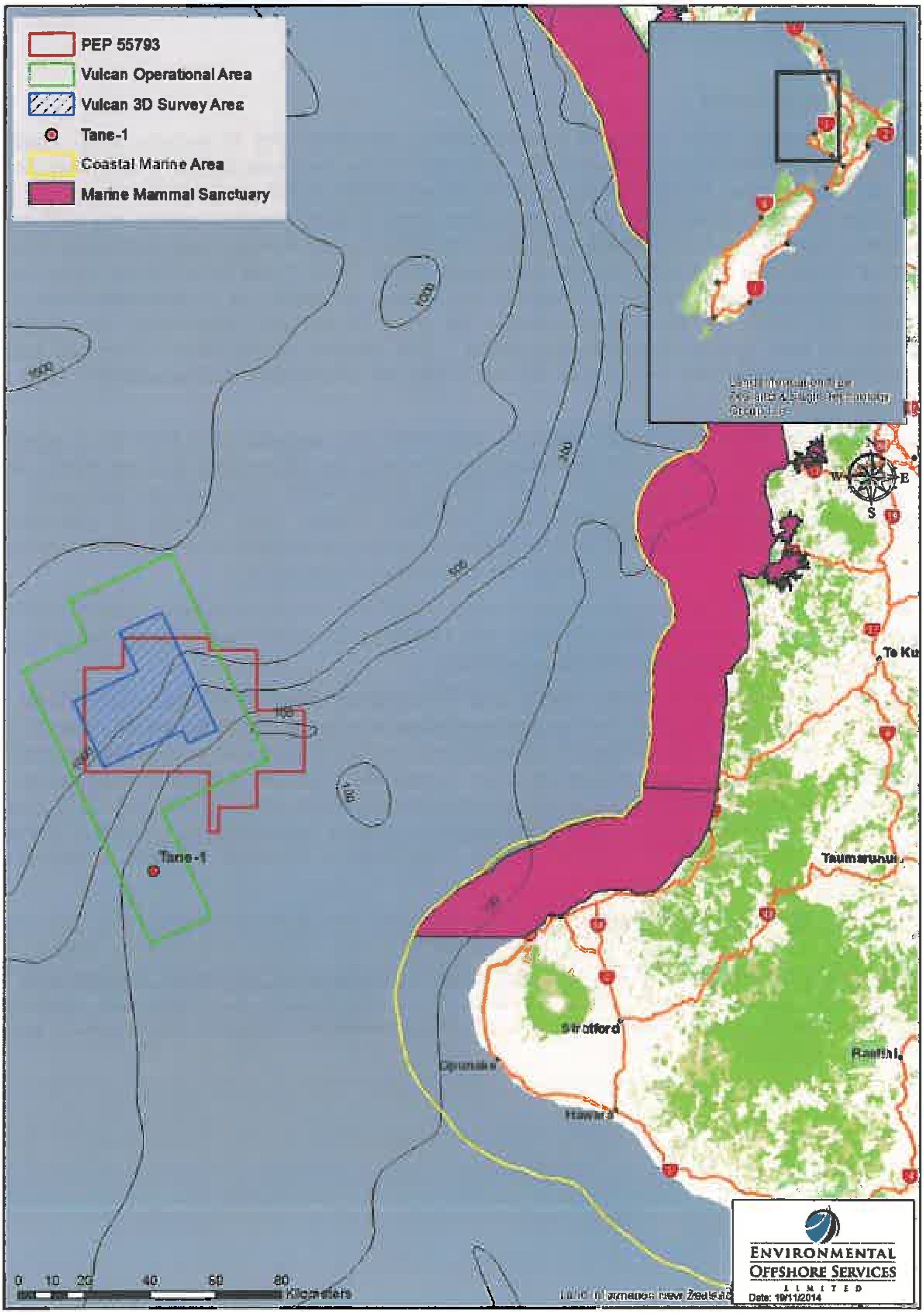

Figure 1: Location Map of Vulcan Survey Area, Operational Area, Marine Mammal Sanctuary and Tane-1 well tie

1.2 General Approach

The MMIA is an integral component to ensure WEL undertake the Vulcan 3D MSS in adherence to the EEZ permitted activities regulations and the DOC Code of Conduct. As well as the Code of Conduct, WEL will operate in accordance to relevant NZ laws and regulations, international guidelines and procedures and their own internal environmental standards.

The Vulcan 3D MSS is classified as a 'Level 1 Survey' within the Code of Conduct and WEL will comply with these requirements while carrying out the Vulcan 3D MSS. The requirements of a Level 1 MSS within the Code of Conduct and associated mitigation measures that WEL will implement is outlined in Section 2.3.1 and Section 5.3.1.

During the preparation of the Vulcan 3D MMIA, an extensive review of literature and existing data has been undertaken from both national and international sources and is summarised within Section 4 of this MMIA for the existing environments surrounding the Vulcan Operational Area. A full list of references can be found in Section 8.

1.3 Consultation

WEL has undertaken consultation with key interested parties, stakeholders, hapū and iwi that were identified in relation to the MSS activities within the Vulcan Operational Area. The groups involved in the engagement process were defined through the geographic extent and location of the Vulcan Operational Area, WEL's internal procedures for community engagement and through discussions with DOC and NZPAM. This consultation process involved groups being consulted either in person, through an information sheet or contacted over the phone or via email to describe the proposed Vulcan 3D MSS operations within the Vulcan Operational Area. A copy of the information sheet sent out for the consultation process is attached in Appendix 1.

The Waikato-Tainui Environmental Management Plan (2013) was considered for engagement with Tainui hapū.

The groups that were consulted with are defined below:

- Department of Conservation – National Office;
- Department of Conservation – New Plymouth Office;
- Department of Conservation – Hamilton Office;
- Environmental Protection Authority;
- New Zealand Petroleum & Minerals;
- Ministry for Primary Industries;
- Petroleum Exploration & Production Associated New Zealand (PEPANZ);
- Te Runanga o Ngati Mutunga;
- Ngati Tama;
- Port Taranaki;
- Venture Taranaki;
- Maniapoto Trust Board;
- Hauauru ki Uta Regional Management Committee;
- Mokau ki Runga Regional Management Committee;
- Taranaki Iwi Trust;
- Te Atiawa Iwi Authority;
- Ngati Maru;

- Waikato Tainui;
- Tainui-o-whiro;
- Tainui Hapu Environmental Management Committee;
- Aotea Harbour (Mahanga-Motakotako);
- Ngati Mahuta – Kawhia Harbour;
- New Plymouth Sportfishing & Underwater Club;
- Deepwater Group;
- Sealord;
- Egmont Seafoods;
- Maruha NZ Ltd;
- Independent Fisheries;
- Talley's Group;
- Sanford Limited;
- Southern Inshore Fisheries Management Company Limited;
- NZ Federation of Commercial Fisherman;
- Fisheries Inshore NZ;
- Anton's Seafoods; and
- Moana Seafoods.

A consultation register of WEL's engagements is included in Appendix 2.

1.4 Research

Throughout the world where MSSs are undertaken, research is being conducted to assess any potential effects from MSS operations on marine species and habitats. The Code of Conduct states that research opportunities relevant to the local species, habitats and conditions should be undertaken, while being aware of not duplicating international efforts (DOC, 2013).

Under the Code of Conduct, within 60 days following the completion of the Vulcan 3D MSS, a Marine Mammal Observer (MMO) report is to be submitted to DOC. This report is to include all the marine mammal observational data, where shut downs occurred due to marine mammals within the mitigation zones and GPS coordinates of each marine mammal sighting. This information will contribute to the DOC marine mammal sighting database and can be used for research purposes by DOC, Universities or other institutions to further understand distribution of marine mammals and their behaviour around a seismic vessel. The two dedicated trained and experienced MMOs on the *Polar Duke* will increase DOC's knowledge of marine mammals in the area as presently there is very little information .

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 will be responsible for all aspects of undertaking a necropsy and coordination with pathologists at Massey University; the performance of a necropsy will assess whether the cause of death was from any auditory pressure related injuries. If a marine mammal is found inshore of the Vulcan 3D MSS operational area and within two weeks of the end of the survey, and cannot be attributed to shark attacks or vessel collision, WEL will consider covering the costs directly associated with Massey University undertaking a necropsy.

2 Legislative Framework

The NZ Government's oil, gas, mineral and coal resources are administered by New Zealand Petroleum & Minerals (NZP&M) and are often regarded as the Crown Mineral Estate. NZP&M has the role of maximising the gains to NZ from the development of mineral resources, in line with the Government's objectives for energy and economic growth. NZP&M is a branch of the Ministry of Business, Innovation and Employment (MBIE) and they report to the Minister of Energy and Resources.

There is a wide range of legislation applicable to the offshore petroleum industry which regulates maritime activities, environmental protection, biosecurity and industrial safety. For the Vulcan 3D MSS, WEL are required to comply with the Crown Minerals Act 1991, EEZ Act – Permitted Activities and the Code of Conduct.

2.1 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, offshore in the EEZ and 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, 2014).

The petroleum minerals programme 2013 took effect on 24 May 2013 and now applies to all applications for permits for petroleum activities. It sets out the policies and procedures to be followed for the allocation of mineral 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.

2.2 Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act

The purpose of the EEZ Act is to promote the sustainable management of natural resources within the EEZ and Continental Shelf. Sustainable management involves managing the use, development and protection of natural resources in a way, and at a rate, that enables people to provide for their economic well-being while:

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

The Minister for the Environment (MfE) can classify activities within the EEZ and Continental Shelf as:

- **Permitted** – the activity can be undertaken provided the operator meets the conditions specified within the regulations. Marine seismic surveys are a permitted activity as long as the operator complies with the DOC Code of Conduct. This Code of Conduct was developed as part of DOC's mandate to administer and manage marine mammals under the Marine Mammal Protection Act (1978). Therefore the Director-General of DOC must assess a MMIA as compliant with the provisions of the Code of Conduct before any MSS can commence. Seismic survey operators do not have to comply with the prior notification requirements in Schedule 1 of the Permitted Activity Regulations, or supply reports of the activity to the EPA. If an operator chooses not to implement the Code of

Conduct during the planning stage of a MSS, then the activity becomes a discretionary activity under the EEZ Act;

- **Non-notified discretionary** – the activity can be undertaken if applicants obtain a marine consent from the Environmental Protection Authority (EPA), who may grant or decline consent and place conditions on the consent. The consent application is not publically notified and has statutory timeframes adding up to 60 working days in which the EPA must assess the marine consent application;
- **Discretionary** – the activity can be undertaken if applicants obtain a marine consent from the EPA. The consent application will be publicly 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 during which the EPA must assess the marine consent application; and
- **Prohibited** – the activity may not be undertaken.

The classification for each activity depends on a number of considerations outlined in Section 33 of the EEZ Act. These considerations include; the environmental effects of the activity, the importance of protecting rare and vulnerable ecosystems, and the economic benefit to NZ of an activity taking place.

The EPA will monitor for compliance with the permitted activity regulations for seismic surveys, which relates to the Code of Conduct, and may conduct audits. The EPA is the enforcement agency for compliance with the EEZ Act and has the authority to take enforcement action if any activities undertaken by an operator are non-compliant within the EEZ.

2.3 2013 Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations

The 2013 Code of Conduct was developed by DOC in consultation with a broad range of stakeholders involved with marine seismic survey operations in NZ. It replaced the 2012 Code of Conduct on 29 November 2013. Schedule 2 of the Code of Conduct classifies all NZ cetacean species except common dolphins, dusky dolphins and NZ fur seals as species of concern (DOC, 2013).

The 2012 Code of Conduct was initially developed as a voluntary regime to be adopted by the petroleum industry while conducting MSS operations in NZ waters. The aim of the code was to manage the potential effects of MSS activities while teething issues around the application of this legislation were ironed out. It was believed the initial 2012 Code of Conduct achieved world-leading environment protection, while providing for the sustainable economic development that is vital to NZ's future prosperity. When the EEZ Act came into effect on 28 June 2013, seismic surveys became classified as "permitted activities" (Section 2.2) and operators undertaking MSSs in the EEZ or Continental Shelf became required to comply with the Code of Conduct. This resulted in a review of the 2012 Code of Conduct to take account of the operational difficulties which had been identified and make the Code of Conduct enforceable from a regulatory perspective.

Amendments included in the 2013 Code of Conduct included a reduced period of time that a NZ fur seal has to be beyond the 200 m mitigation zone before the pre-start observations can commence; operational procedures to implement if the PAM system malfunctions; and a slight change to pre-start observations. The full mitigation requirements within the updated 2013 Code of Conduct are provided in Section 2.3.1.

2.3.1 General requirements

2.3.1.1 Notification

Any operator undertaking a MSS (except those classified as Level 3 (see Section 2.3.2)) has to provide notification to the Director-General of DOC at the earliest opportunity but not less than three months prior to commencement. Notification was provided to the Director-General on 9 September 2014 in regards to the Vulcan 3D MSS within PEP 55793.

2.3.1.2 Marine Mammal Impact Assessment

The Code of Conduct requires a MMIA to be developed and submitted to the Director-General not less than one month prior to MSS acquisition to ensure that all potential environmental effects and sensitivities have been identified and measures to reduce those potential environmental effects are in place.

2.3.1.3 Areas of Ecological Importance

MSS operations within an Area of Ecological Importance (AEI) require more comprehensive planning and consideration, including additional mitigation measures to be developed and implemented through the MMIA process.

The locations and extent of the AEI in NZ continental waters were determined from DOC's database of marine mammal sightings and strandings, fisheries-related data maintained by Ministry for Primary Industries (MPI), and the National Aquatic Biodiversity Information System (NABIS). Where data was incomplete or absent, technical experts have helped refine the AEI maps.

Within the Code of Conduct it states that, under normal circumstances, a MSS will not be planned in any sensitive ecologically important areas; during key biological periods where Species of Concern are likely to be feeding or migrating, calving, resting, feeding or migrating; or where risks are particularly evident such as in confined waters.

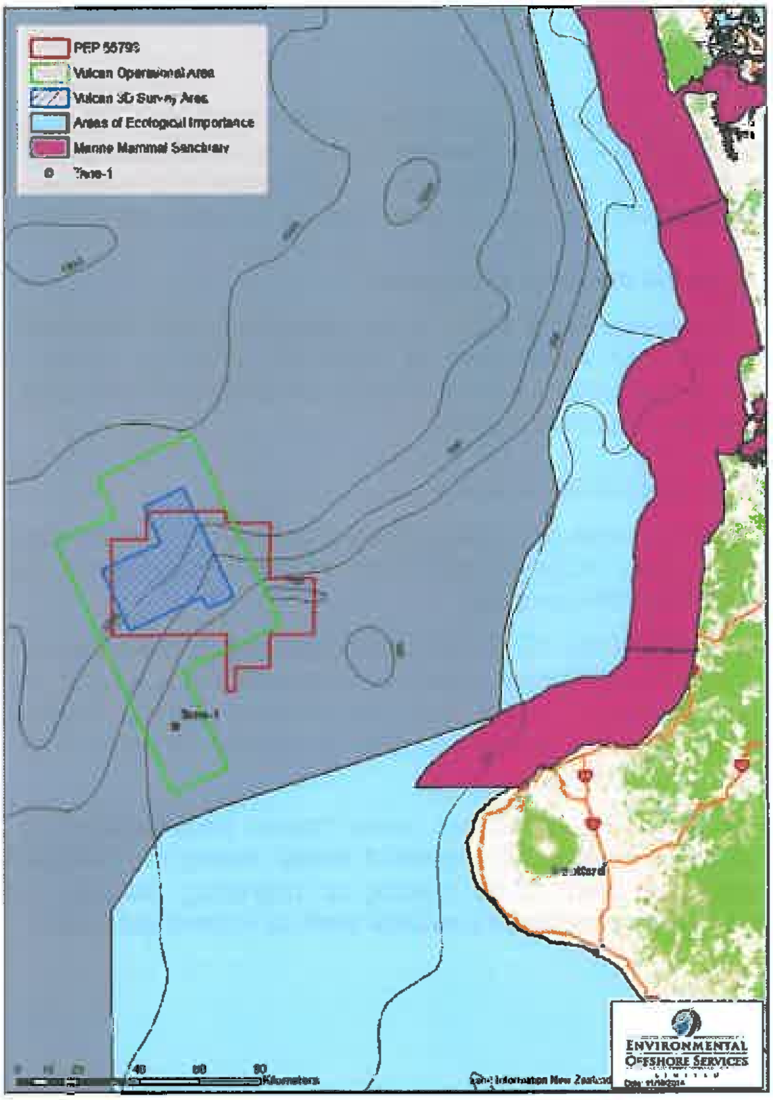

Figure 2: Vulcan Operational Area, Areas of Ecological Importance & West Coast North Island marine mammal sanctuary

As detailed in Schedule 1 of the Code of Conduct, when it is necessary and unavoidable to conduct a MSS in an AEI, additional mitigation measures are to be put in place. The Vulcan 3D Operational Area is located beyond the AEI (Figure 2); however, WEL will still implement additional measures above the Code of Conduct (Section 5.3.2).

When an MSS is being undertaken within an AEI, the Code of Conduct requires Sound Transmission Loss Modelling (STLM) to be undertaken to validate the specified mitigation zones. Even though the Vulcan Operational Area is beyond the AEI and STLM is not required, WEL have included STLM within the scope of the project. The STLM is based on the specific configuration of the acoustic array deployed from the *Polar Duke* and the environmental conditions (i.e. bathymetry, substrate, water temperature and underlying geology) within the Vulcan Operational Area. The Code of Conduct states that if Sound Exposure Levels (SEL's) are predicted to exceed 171 dB re 1μPa^2.s (behaviour criteria) corresponding to the relevant mitigation zones for Species of Concern or 186 dB re 1μPa^2.s (injury criteria) at 200 m, consideration will be given to either extending the radius of the mitigation zones or limiting acoustic source power accordingly.

The STLM is discussed in more detail in Section 5.1.2.1.

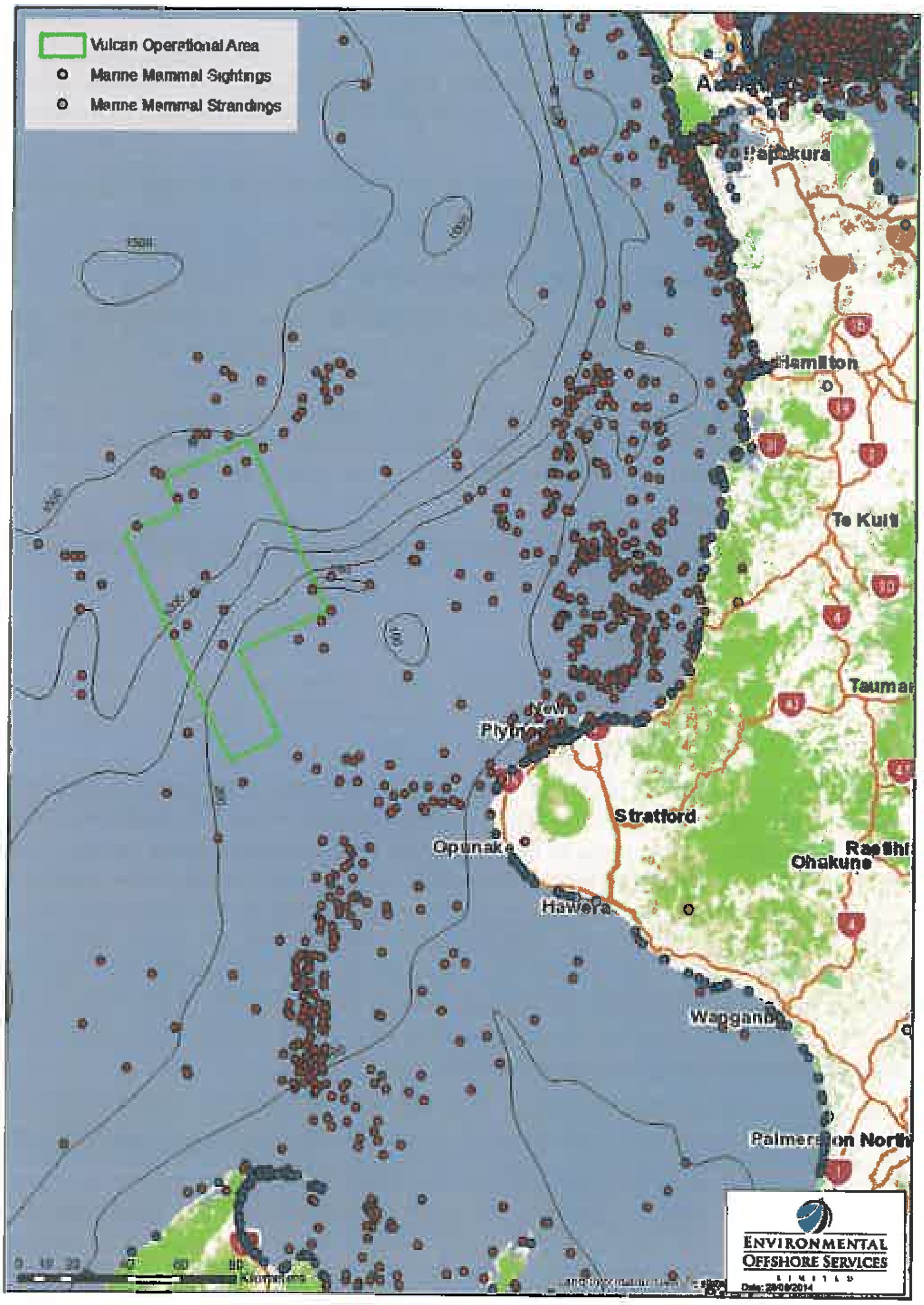

Figure 3: Recorded Cetacean Sightings and Strandings

2.3.1.4 Marine Mammal Sanctuaries

There are six gazetted Marine Mammal Sanctuaries (MMS) around NZ which were implemented to protect marine mammals from harmful human impacts, particularly in vulnerable areas such as breeding grounds, migratory routes or endangered species habitats. All MMS are administered and managed by DOC in accordance with the Marine Mammals Protection Act 1978, Marine Mammals Protection Regulations 1992 and in line with Conservation General Policy 2005.

A MMS does not exclude all fishing or seabed mining activities; however it can place restrictions on seismic surveys and/or mining to prevent and minimise disturbance of marine mammals the MMS were gazetted to protect. In order to conduct a seismic survey within a MMS, an operator must notify the Director-General of DOC (see Section 2.3.1.1), submit a written Environmental Impact Assessment (see Section 2.3.1.2), and must comply with any additional conditions such as an increase in mitigation zones or number of observers (see Section 5.3.2).

The West Coast North Island MMS is located 75 km inshore of the Vulcan Operational Area. A full description of this MMS can be found in Section 4.3.3.

2.3.2 Level 1 Marine Seismic Survey Requirements

The 2013 Code of Conduct distinguishes three classes of survey according to the size of the acoustic source used for data collection and sets out requirements for each class. The Vulcan 3D MSS is classified as a Level 1 survey under the Code of Conduct (i.e. a survey using an acoustic source which has a total combined operational capacity that exceeds 427 cubic inches (in^3)). Most MSS for oil and gas exploration activities are classified as Level 1, which feature the most stringent requirements for marine mammal protection and is the main focus of the Code of Conduct.

The Level 1 MSS observer and operational requirements which WEL will follow are listed in the following sections.

2.3.2.1 Observer Requirements

In addition to visual MMOs on-board the survey vessel, Passive Acoustic Monitoring (PAM) is also required as a mitigation measure under a Level 1 MSS. A Seiche 250 m Array PAM system will be utilised for the Vulcan 3D MSS.

The ability to acoustically detect animals, including the maximum range at which they can be detected, is critically dependent on the levels of background noise. The Seiche PAM system comprises a 250 m array with integral hydrophones and a depth sensor array. The sensor array comprises of a 20 m detachable array section with four hydrophone elements (two broadband and two wideband). Two are set with a bandwidth of 10 Hz to 200 kHz, where it can be seen in Appendix 3 that the hydrophones start to roll off at 10 Hz, but remains sensitive down to 1 Hz where it will still register 4 dB. Whereas the second set of hydrophones is set to a bandwidth of 2 kHz to 200 kHz sensitivity. This ensures that if the lower frequency pair of hydrophones is saturated by vessel noise, the system will still be capable of detecting vocalising marine mammals (Appendix 3).

The DOC-endorsed senior PAM Operator that will be onboard the *Polar Duke* during the Vulcan 3D MSS also confirmed that the PAM system planned to be used is suitable for detection of NZ endemic and vagrant marine mammal species.

Technical details of the PAM system to be used in the Vulcan 3D MSS are included in Appendix 3. The Code of Conduct states that where additional mitigation measures are required a Marine Mammal Mitigation Plan (MMMP) is to be developed and circulated amongst the observers and crew to guide the offshore operations. Even though WEL are not required under the Code of Conduct to produce a MMMP, WEL have opted to prepare one out of best operator practice and operating above and beyond the Code of Practice. The MMMP has been compiled by the MMO and PAM system provider Blue Planet Marine and is attached in Appendix 4.

To undertake the Vulcan 3D MSS in compliance with the Code of Conduct, the minimum qualified observer requirements are:

- At all times there will be at least two qualified MMOs onboard;
- At all times there will be at least two qualified PAM operators onboard;
- The observers role on the vessel during the Vulcan 3D MSS is strictly for the detection and data collection of marine mammal sightings, and instructing crew on the Code of

Conduct requirements and the crew requirements when a marine mammal is detected within the relevant mitigation zone (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 observer must not exceed 12 hours per day.

DOC also encourage observations at all times where practical and possible to help build on the knowledge and distribution of marine mammals around the NZ coastline.

If during the Vulcan 3D MSS the MMOs onboard the *Polar Duke* consider that there are higher numbers of marine mammals encountered than what is summarised in this MMIA, the Director-General will be notified immediately. A decision on what adaptive management procedures will be implemented if this scenario arises will depend on the marine mammal species observed and the situation which is occurring at that time. This management decision will be made from discussions between DOC and WEL, who shall then advise the MMO/PAM team of the correct approach.

Due to the limited detection range of current PAM technology for ultra-high frequency cetaceans, any such bioacoustics detections will require an immediate shutdown of an active survey 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. 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'.

If the PAM system onboard the *Polar Duke* malfunctions or becomes damaged, MSS 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, MSS 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 MSS operations when PAM is not operational;
- DOC is notified via email as soon as practicable, stating time and location in which MSS operations began without an active PAM system; and
- MSS 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.

2.3.2.2 Operational and Reporting Requirements

Both visual MMOs and PAM operators are required to record and report all marine mammal sightings during MSSs conducted in adherence to the Code of Conduct. All raw datasheets must be submitted by the qualified observers directly to DOC at the earliest opportunity but no longer than 14 days after completion of each deployment. A written final trip report must also be submitted to DOC at the earliest opportunity but no longer than 60 days after completion of the Vulcan 3D MSS.

MMO requirements include:

- Provide effective briefings to crew members, and establish clear lines of communication and procedures for onboard 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;
- Use GPS, sextant, reticle binoculars, compass, measuring sticks, angle boards or any other appropriate tools to accurately determine distances/bearings and plot positions of marine mammals whenever possible during sightings;
- Record and report all marine mammal sightings, including species, group size, behaviour/activity, presence of calves, distance and direction of travel (if discernible);
- Record sighting conditions (Beaufort sea state, swell height, visibility, fog/rain and glare) at the beginning and end of the observation period, and whenever the weather conditions change significantly;
- Record 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; and
- Record and report to DOC any instances of non-compliance with the Code of Conduct.

PAM operator requirements include:

- Provide effective briefings to crew member to establish clear lines of communication and procedures for onboard operations;
- Deploy, retrieve, test and optimise hydrophone arrays;
- 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;
- Use appropriate sample analysis and filtering techniques;
- Record and report all cetacean detections, including, if discernable, identification of species or cetacean group, position, distance and bearing from vessel and acoustic source;
- Record type and nature of sound, time and duration heard;
- Record general environmental conditions;
- Record 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; and
- Record and report to DOC any instances of non-compliance with the Code of Conduct.

2.3.2.3 Pre-start Observations

Normal Requirements

The Vulcan 3D MSS acoustic source can only be activated if it is within the Vulcan Operational Area (Figure 1) and no marine mammals have been observed or detected in the relevant mitigation zones (Section 2.3.2.4) and has followed the procedures listed below in this section.

During daylight hours the Vulcan 3D MSS acoustic source cannot be activated 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.

During night-time hours or poor sighting conditions (daylight visibility of <1.5 km or a sea state greater than or equal to Beaufort 4), the acoustic source cannot be activated 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.

Soft Starts

The Vulcan 3D MSS 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.

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 capacity defined in this MMIA (3460 in^3) is not to be exceeded during the soft start period.

Additional requirements for start-up in a new location in poor sighting conditions

In addition to the normal pre-start observation requirements above, when the *Polar Duke* arrives at the Vulcan Operational Area for the first time, the initial acoustic source activation must not be undertaken at night or during poor sighting conditions unless either:

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

2.3.2.4 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 (which includes soft starts), a qualified observer detects at least one Species of Concern ((DOC, 2013)–Schedule 2) 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 1.0 km

If during pre-start observations or while the acoustic source is activated, a qualified observer detects a Species of Concern within 1.0 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 1.0 km from the source; or
- Despite continuous observation, 30 minutes has elapsed since the last detection of a Species of Concern within 1.0 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 Vulcan 3D MSS 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.

3 Project Description

3.1 Marine Seismic Surveys

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

3.1.1 2D and 3D surveys

MSS fall into two main categories of varying complexity: 2D and 3D. A 2D MSS can be described as a fairly basic survey method which involves a single source and a single streamer towed behind the seismic vessel (Figure 4). In contrast, a 3D MSS is a more complex method which involves a greater investment and much more sophisticated equipment.

Although the 2D MSS is simplistic in its underlying assumptions, it has been and is still used today to great effect in discovering oil and gas reservoirs. The method's underlying assumption is that the reflections from the subsurface lie directly below the seismic vessel's sail line. Sail lines are generally acquired several kilometres apart, on a broad grid over a large area. 2D MSS 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 to be comprehensively examined through a 3D MSS.

Whereas the purpose of a 3D MSS is to focus on a specific area over known geological targets considered likely to contain hydrocarbons, generally discovered from previous 2D MSSs. Extensive planning is undertaken to ensure that the survey area is precisely defined and the direction of the survey lines are calculated to in order to obtain the best results. A sail line separation within the survey area for 3D surveys is normally 200 – 400 m, often with two acoustic sources and up to 10 streamers, typically 100 m apart, producing a three-dimensional image of the subsurface (Figure 4).

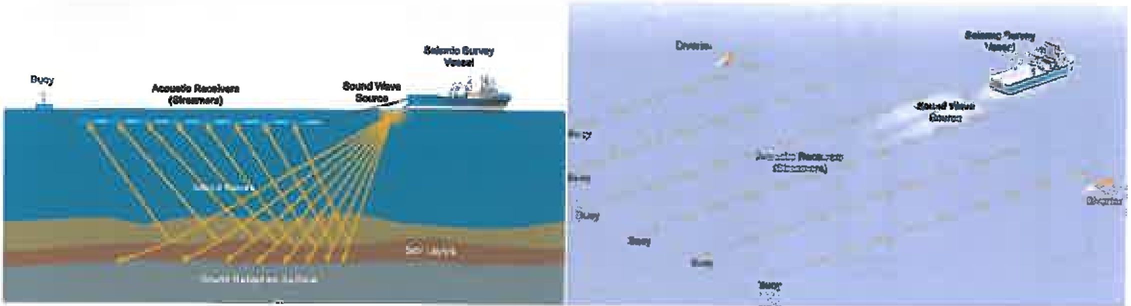

Figure 4: Schematic of a 3D MSS (left) and 3D MSS (right)
Source: www.fishsafe.eu

3.1.2 Equipment

3.1.2.1 The acoustic source

The acoustic source used during a MSS is comprised of two high pressure chambers: an upper control chamber and a discharge chamber (Figure 5). High pressure air (~2,000 psi) from compressors onboard the seismic vessel is continuously fed to the acoustic sources towed behind the vessel via an air hose. This forces the piston downwards, and the chambers fill with high-pressure air while the piston remains in the closed position (Figure 5).

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 through the airports. The air from these ports forms a bubble, which oscillates according to the operating pressure, the depth of operation, the temperature and the volume of air vented into the water. Following this release, the piston is forced back down to its original position by the high-pressure air in the control chamber, so that once the discharge chamber is fully charged with high-pressure air, the acoustic source can be released again. The compressors are capable of recharging the acoustic source rapidly and continuously which enables the acoustic source arrays to be fired every 10 – 11.5 seconds during seismic acquisition.

Acoustic source arrays are designed so that they direct most of the sound energy vertically downwards (Figure 5) although there is some residual energy which will dissipate horizontally into the water. The amplitude of sound waves generally declines with distance from the acoustic source, and the weakening of the signal with distance (attenuation), is frequency dependent, with stronger attenuation at higher frequencies. In practice, 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.

Typical source outputs used in MSS operations 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 alternatively. To place this in perspective, low level background noise in coastal regions with little wind and gentle wave action is ~ 60 dB re 1µPa/m, while in adverse weather conditions, the background noise increases to 90 dB re 1µPa/m (Bendell, 2011).

The sound frequencies emitted from the acoustic source are broad band. Most of the energy is concentrated in the 10 – 250 Hz range with lower levels in the 200 – 1,000 Hz range and the largest amplitudes are usually generated in the 20 – 100 Hz frequency band.

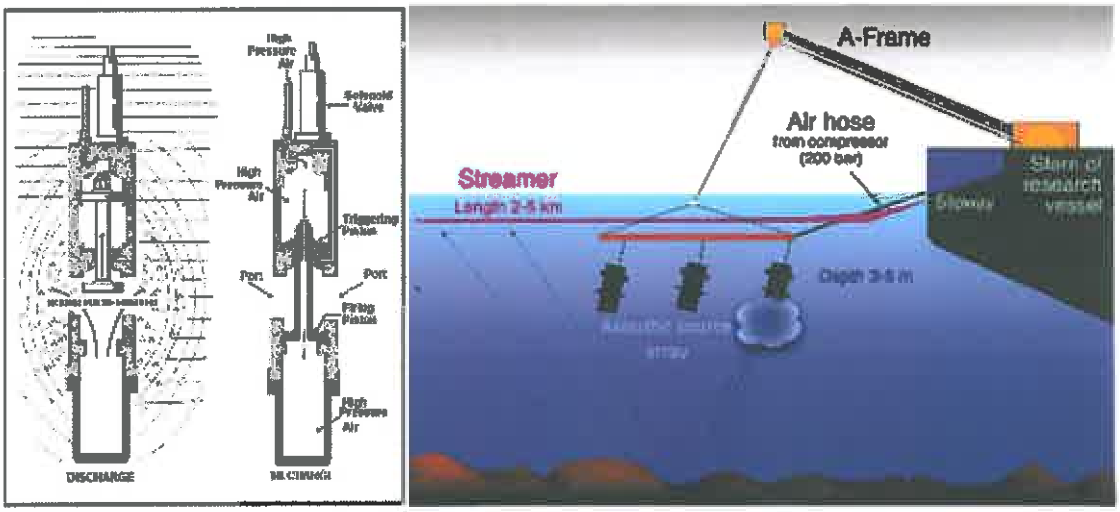

Figure 5: Schematic cross section of a typical acoustic source and a sub-surface multi acoustic source array

3.1.2.2 Sound in Water

The decibel (dB) system is used to express the relative loudness (amplitude) of sound. The decibel system is logarithmic, which results in an exponential scale being represented as a linear scale. Decibel is not a measuring unit, but a ratio that must be expressed using a reference (benchmark) value.

Frequency is another measure of sound. It 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 sound must always be specified. For sounds in water the reference level is expressed as 'dB re 1 µPa' – the amplitude of a sound wave's loudness with a pressure of 1 microPascal (µPa). Whereas the reference level for sound in air is dB re 20 µPa. The amplitude (loudness) of a sound wave depends not only on the pressure of the wave, but also on the density and sound speed of the medium (i.e. air, water) through which the sound is travelling. As a result of such environmental differences, 62 dB must be subtracted from any sound measurement under water to make it equivalent to the same sound level in the air.

Sound travels further in water than it does in air due to water being denser. However, 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, whereas in water it reduces by 6 dB for each doubling of the distance. Underwater sound is also subject to additional attenuation as it interacts with obstacles and barriers, i.e. 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 and the loudness diminishes very quickly close to the source and more slowly away from the source.

The ocean is a noisy environment generated from a variety of natural sources such as wind, waves, marine life, underwater volcanoes and earthquakes. There are also man-made (anthropogenic) sounds in the ocean, i.e. shipping, commercial and recreational fishing vessels, pile-driving for marine construction, dredging and military activities.

The sound produced during seismic surveys is comparable in loudness to many naturally occurring and other man-made sources. Examples of this are provided in Table 1.

Table 1: Sound comparisons in air and water

Type of Sounds	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
Bottlenose dolphin	-	225 dB
Sperm whale click	-	236 dB
Jet engine take-off at 1 metre	180 dB	242 dB
Volcanic eruption	-	255 dB
Colliding iceberg	-	220 dB

Source: www.iagc.org

3.1.2.3 The streamers

The *Polar Duke* will tow 12 streamers for the Vulcan 3D MSS. All streamers can be influenced by wind, tides and currents, which can cause feathering, or the streamers to be towed in an arc offset from the nominal sail line.

When the acoustic source is released the streamers detect the very low level of energy that is reflected back up from the geological structures below the seabed using pressure sensitive devices called hydrophones. Hydrophones convert the reflected pressure signals into electrical energy that is digitised and transmitted along the streamer to the recording system onboard the seismic vessel.

Each streamer is divided into sections (50-100 m in length) to allow for modular replacement of damaged components. Solid streamers will be used for the Vulcan 3D MSS which are constructed from neutrally buoyant extruded foam. This type of streamer has a number of advantages over fluid filled streamers: it is more robust and resistant to damage (i.e. shark bites); it is less sensitive to weather and wave noise (provides higher quality seismic images); it requires less frequent repairs; and it is steerable allowing greater control, resulting in less infill lines, reducing the cumulative sound energy introduced into the marine environment.

Towing a streamer underwater removes it from the 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 regards to weather and surface noise, but this also results in a narrower bandwidth of the data. Typically the range of operating depths varies 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.

At the end of the streamers tail buoys are connected to provide both a hazard warning (lights and radar reflector) of each submerged towed streamer between the tail buoy and vessel, and to act as a platform for positional systems of the streamer (Figure 6). During the Vulcan 3D MSS, the *Polar Duke* will be travelling at 4.5 kts so the streamer tail buoys will be travelling approximately 60 minutes behind the vessel.

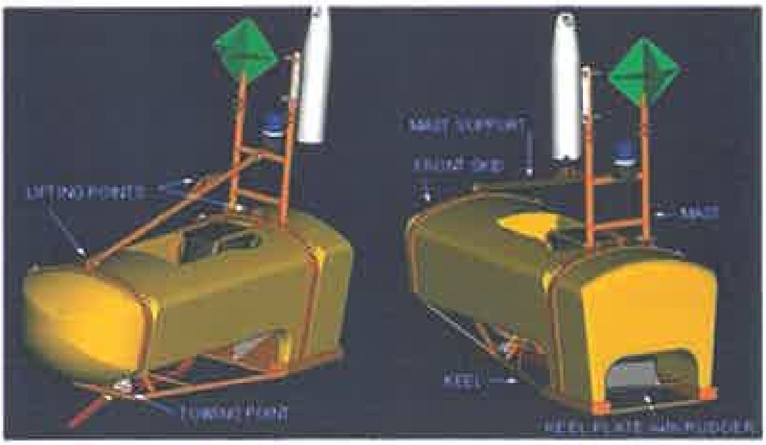

Figure 6: Example of a tail buoy with light and radar reflector

3.2 Vulcan 3D Marine Seismic Survey

The Vulcan Survey Area is located to the northeast of New Plymouth, over 110 km offshore, at the edge of the continental shelf. As a result of this, depths within the survey area range from 150 m (on the shelf) to 1,500 m (on the continental slope).

WEL will use the seismic vessel *Polar Duke* and will tow 12 solid streamers, 7 km in length and 100 m apart. The acoustic source will have an effective volume of 3,460 in^3 and will be comprised of three sub-arrays with seven acoustic sources on all but one of the sub-arrays, which has nine. The acoustic array will be located at a depth of 7 m below the sea surface and approximately 450 m behind the survey vessel. The depth of the sub-arrays will ensure that the volume used enables the survey to be run effectively in regards to data acquisition, but also to minimise the potential environmental disturbance. In the case of dropouts during acquisition, the gun array may operate at a slightly lower capacity for a short period of time. STLM was conducted by Curtin University and was based on the specific acoustic source volume and operating pressure of the Vulcan 3D MSS outlined within this MMIA. The STLM is further discussed in Section 5.1.2.1 and is attached in Appendix 5.

The acoustic source will have an operating pressure of 2,000 psi and will be fired at a sourcepoint interval of 18.75 m apart. For a typical boat speed of 4.5 knots (kts), this equates to a sourcepoint activation every 8 seconds.

The Vulcan 3D Survey Area is located within PEP 55793, although the Vulcan Operational Area does extend beyond this permit area (Figure 1). WEL are planning to acquire the Vulcan 3D MSS in January 2015 and is scheduled to take approximately 35 days. MSS operations will be conducted 24 hours per day, 7 days per week, subject to suitable weather conditions and marine mammal encounters within the mitigation zones.

The technical specifications of the *Polar Duke* are provided in Table 2. One support vessel (*Sanco Sky*, Figure 8) will be contracted for the duration of the Vulcan 3D MSS and will be in close proximity to the *Polar Duke* at all times except if the support vessel has to go into port for supplies. A chase vessel will also be utilised for the duration of the Vulcan 3D MSS.

There are four main components involved with the acquisition of the Vulcan 3D MSS:

- **Mobilisation of *Polar Duke* to Vulcan Operational Area:** In preparation for the start of the Vulcan 3D MSS, the *Polar Duke* will mobilise to the Vulcan Operational Area. The *Sanco Sky* will accompany the *Polar Duke* at all times during the passage to the Vulcan Operational Area. During transit to the Vulcan Operational Area, a MMO will be on the bridge to observe for any marine mammals that would add to the knowledge and distribution of marine mammals around NZ (Section 5.3.2.2);
- **Deployment of Streamer:** The *Polar Duke* will utilise the wind and currents present at the time for the successful deployment of the streamer and acoustic source and will take approximately 72 hours to deploy. Once all the seismic gear is deployed the MMOs will begin pre-start observations as required under the Code of Conduct when arriving at a new location (Section 2.3.2.2). Once these procedures have been followed, a soft start can begin for commencement of the Vulcan 3D MSS;
- **Data Acquisition:** The *Polar Duke* will follow predetermined survey lines which have been calculated to get the best images from the data and provide greater interpretation of the underlying geology. The two MMOs and two PAM operators on board the *Polar Duke* will monitor for marine mammals 24 hours a day for the duration of the Vulcan 3D MSS to ensure compliance with a Level 1 survey under the Code of Conduct; and
- **Demobilisation:** Once the *Polar Duke* has completed the Vulcan 3D MSS the seismic array will be retrieved and the vessel will likely make a port call as part of mobilisation to the next destination.

If the vessel has to go on standby during the MSS due to certain adverse weather conditions, it is likely that the acoustic source array would be retrieved to reduce any potential damage, while the streamers may be left deployed.

Figure 7: Seismic Survey Vessel – *Polar Duke*

Figure 8: Seismic Support Vessel – *Sanco Sky*

Table 2: *Polar Duke* Technical Specifications

Seismic Survey Vessel – General Specifications	
Vessel Name	Polar Duke
Vessel Owner	GCRiber Shipping AS
Engine Details	2 x MAK 9L32/40 MAN Diesel plus 2 x MAK 6L32/40 MAN Diesel
Fuel Capacity	1,820m^3
Seismic Survey Vessel – Dimensions and capacities	
Vessel Length	106.8m
Vessel Beam	19.2 m at waterline/22 m max
Max Draft	6.5 m
Gross Tonnage	7,689 t
Cruising Speed	17 knots

Table 3: Vulcan 3D Seismic Specifications

Parameter	**Specifications**
Total array volume	3,460 in^3
Acoustic Source	Bolt Longlife
Number of sub-arrays	3
Number of acoustic sources per sub-array	2 x 7 and 1 x 9
Array length	15 m
Array width	20 m
Nominal operating pressure	2,000 psi
Source Frequency	2 - 250 Hz
Tow depth	7 m (+/- 1m)
Distance from the stern	130 m
Number of streamers	12
Streamer length	7,000 m
Streamer manufacturer/model	Sercel Sentinel
Towing depth	TBC

3.3 Navigational Safety

During the Vulcan 3D MSS, the *Polar Duke* will be towing 12 streamers of 7 km in length and in doing so will be restricted in its ability to manoeuvre. At the operational speed of ~4.5 kts during seismic data acquisition and with the large array of streamers being towed, the vessel cannot turn quickly so avoidance of collision relies on all vessels obeying the rules of the road at sea and the International Regulations for the Prevention of Collisions at Sea (COLREGS) 1972 which is implemented in NZ under the Maritime Transport Act regime. A Notice to Mariners will be issued and a coastal navigation warning will be broadcast daily on maritime radio advising of the Vulcan Operational Area and the presence of the *Polar Duke* and her restriction in ability to manoeuvre while towing the MSS array. The *Polar Duke* has Automatic Identification System (AIS) technology onboard that allows its position to be monitored by other vessels as well as being able to receive the positions of other vessels in surrounding waters to help minimise any risk of collision.

The consultation process has identified all known potential users of that area of ocean, while the presence of the support and chase vessels will be utilised to notify any boats that are unaware of the seismic operations or the vessels that cannot be reached via VHF radio. In accordance with International Maritime Law, the *Polar Duke* will display the appropriate lights and day shapes while undertaking the survey; mainly being restricted in its ability to manoeuvre and towing an array of gear behind the boat. Tail buoys will mark the end of the streamers and these will be equipped with a light and radar reflector for detection both during the day and night.

3.4 Analysis of Alternatives

Most seismic surveys conducted worldwide use acoustic sources, as they generate low frequency signals which can image the underlying geology several kilometres below the seafloor. Each component of the Vulcan 3D MSS is required to not only gather the best information from the underlying geology and hydrocarbon potential within the Vulcan Operational Area but to also reduce any adverse effects on the marine environment to the fullest extent practicable.

WEL will use a 'bolt acoustic source' for the Vulcan 3D MSS, with the acoustic source consisting of three sub-arrays. The energy source and acoustic source array configuration was selected so that it provides sufficient seismic energy to acquire the geological objective of the survey, whilst minimising the environmental disturbance through limiting excess noise to the environment.

As part of the Vulcan 3D MSS design, WEL has identified the source size necessary to adequately record data from a pre-determined depth. A source volume of 3,460 in^3 was identified as an optimum volume given the water depths and geology for the survey to achieve its objectives. Larger source volumes available onboard the *Polar Duke* were not selected in the interest of minimising unnecessary noise being released into the marine environment.

The acquisition period for the Vulcan 3D MSS will utilise the settled summer period to reduce weather-induced down-time to ensure that the survey duration is as short as possible. With the current MSS schedule, the survey will be completed prior to the northwards migrating humpback whales through the Cook Strait and up to the South Pacific.

4 Environmental Description

4.1 Physical Environment

4.1.1 Meteorology

New Zealand's climate is complex and varies 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-NZ 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.

Troughs of low pressure orientated northwest to southeast, and associated cold fronts are found between the anticyclones. As these cold fronts approach from the west, northwesterly winds become stronger and cloud levels increase. A period of rain lasting up to several hours will follow while the front passes over. After the front has gone through, the weather conditions change again, this time to cold showery southwesterly winds.

The stretch of coastline west of New Plymouth is directly exposed to intense weather systems from the Tasman Sea and is subject to high winds and seas. The strongest and most frequent winds and swells are generally from the west to southwest. Weather in the Taranaki Basin has few climatic extremes, but can be extremely changeable. Winters are generally cooler and weather conditions are more unsettled.

Weather conditions from New Plymouth have been used as indicative for the Vulcan Operational Area, where summer daytime temperatures can range from 19°C to 24°C, whereas the relatively mild unsettled winters have temperatures from 10°C to 14°C (NIWA, 2014). The mean monthly weather parameters at New Plymouth are shown in Table 4.

Table 4: Mean Monthly weather parameters at New Plymouth

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall (mm)	54	83	68	104	112	123	110	101	105	117	102	106
Temp – avg. daytime (°C)	21	22	20	18	16	14	13	13	14	16	17	19
Temp – avg. night time (°C)	14	14	13	11	10	8	7	7	8	10	10	13
Avg. wind speed (kts)	9	9	9	9	10	10	10	10	11	12	11	10
Max. wind speed (kts)	30	38	30	33	35	37	31	31	47	58	31	37

(Weather2, 2014)

4.1.2 Oceanography

4.1.2.1 Current Regime

Around the New Zealand coastline the current regime is dominated by three different components: wind-driven flows, low-frequency flows and tidal currents. The net current flow is a combination of all three of these components and is often further influenced by the local bathymetry.

New Zealand lies in the path of eastward-flowing currents, which are driven by winds that blow across the South Pacific Ocean. This results in New Zealand 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 but is then further modified by the spin of the earth (Coriolis Effect).

The eastward flow out of the Tasman Sea splits into two currents across the top of the North Island of New Zealand: the West Auckland Current (WAUC) which flows from Cape Reinga towards Kaipara; and the East Auckland Current (EAC) which flows from the North Cape towards the Bay of Plenty (Brodie, 1960; Heath, 1985; Stanton, 1973). As the WAUC progresses southward, it is met, in the North Taranaki Bight, by the north-flowing Westland Current (WC) (Figure 9) which courses 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. As a result, the northern limit of the WC (and so the southern limit of the WAUC) is variable, reflecting both local weather conditions and seasonality (Brodie, 1960; Ridgway, 1980; Stanton, 1973).

Further south, the seasonal variation in the WAUC and WC currents results in variation in temperature and salinity off the Taranaki coastline. During the winter months, the WAUC (subtropical origin) extends further south pushing warmer more saline water to 39.3°S. In contrast, the WAUC is weaker in the summer months and the WC (sub-Antarctic origin) extends to 38°S bringing with it colder more saline waters and becoming the predominant current in the area (Ridgway, 1980; Stanton, 1973). Off the Taranaki coastline, additional areas of cold surface water can also be found but these are thought to be caused by land water run-of as no evidence of upwelling has been found (Ridgway, 1980).

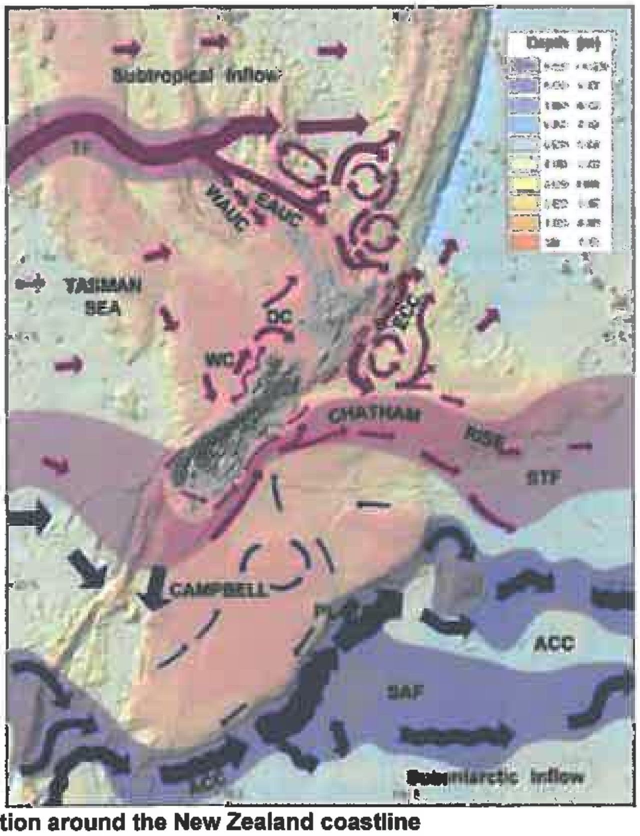

Figure 9: Ocean Circulation around the New Zealand coastline
(Source: http://www.teara.govt.nz/en/map/5912/ocean-currents-around-new-zealand)

4.1.2.2 Thermoclines and Sea Surface Temperature

During spring and summer thermal stratification of the water column becomes evident as a result of solar heating of the upper water column (i.e. 40 – 50 m below the sea surface). The range and form of the stratification varies with weather conditions, with storm conditions causing significant vertical mixing and breakdown of thermal structure. Likewise, the local environmental conditions such as tides and currents can also play a part in the formation of thermoclines. 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 which results from the temperature difference. A change in temperature of 1°C can result in a change of speed by 3 ms^{-1} (Simmonds *et al.*, 2004).

4.1.2.3 Wave Climate

The Vulcan Operational Area is likely to have a high energy wave environment present due to its location in relation to the Tasman Sea in the west and the Greater Cook Strait to the southeast. The Southern Ocean can generate long period swells; often enhanced by the predominant west to southwest winds, resulting in a dominant wave direction off the west coast of NZ from the west or southwest. The wave period is relatively long (6-8 seconds) and the height ranges between 1 m and 3 m (Gorman *et al.*, 2003; Pickrill and Mitchell, 1979). Off the west coast of NZ there are no seasonal variations observed in wave characteristics; however, local weather patterns (see Section 4.1.1) will affect the wave climate (Pickrill and Mitchell, 1979).

4.1.3 Bathymetry and Geology

As is the case of every major land mass, New Zealand is surrounded by a flat, gently sloping zone known as the continental shelf. It extends from the coast out to a water depth of approximately 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 greater than 4,000 m. At the foot of the slope, the seaward gradient flattens out into the ocean basins which are constituted by a wide undulating but relatively flat zone lying at 4,000 to 5,000 m depth and cover most of the central parts of the major oceans (Te Ara, 2014a).

The surface of the continental shelf is predominantly flat although diversified by local banks and reefs, whereas the slope is more irregular and cut in many areas by large marine valleys known as submarine canyons. These tend to occur in slope areas of relatively steep gradient and generally run from the edge of the continental shelf to the foot of the continental slope. The Vulcan Operational Area extends across the continental shelf and is shown in Figure 10.

The width of New Zealand's continental shelf varies from one area to another. The narrowest parts are found off the east coast between Kaikoura and Cape Kidnappers (1-15 Nm in width), and off Fiordland (1-4 Nm in width). Whereas other areas of New Zealand have a more extensive continental shelf, with the western Cook Strait having a continental shelf which exceeds 100 Nm in width (Te Ara, 2014a). The Taranaki Continental Shelf has a 150 km wide opening to the Tasman Sea, occupying 30,000 km^2, and slopes gently towards the west with an overall gradient of <0.1° and locally less than 0.5° (Nodder, 1995).

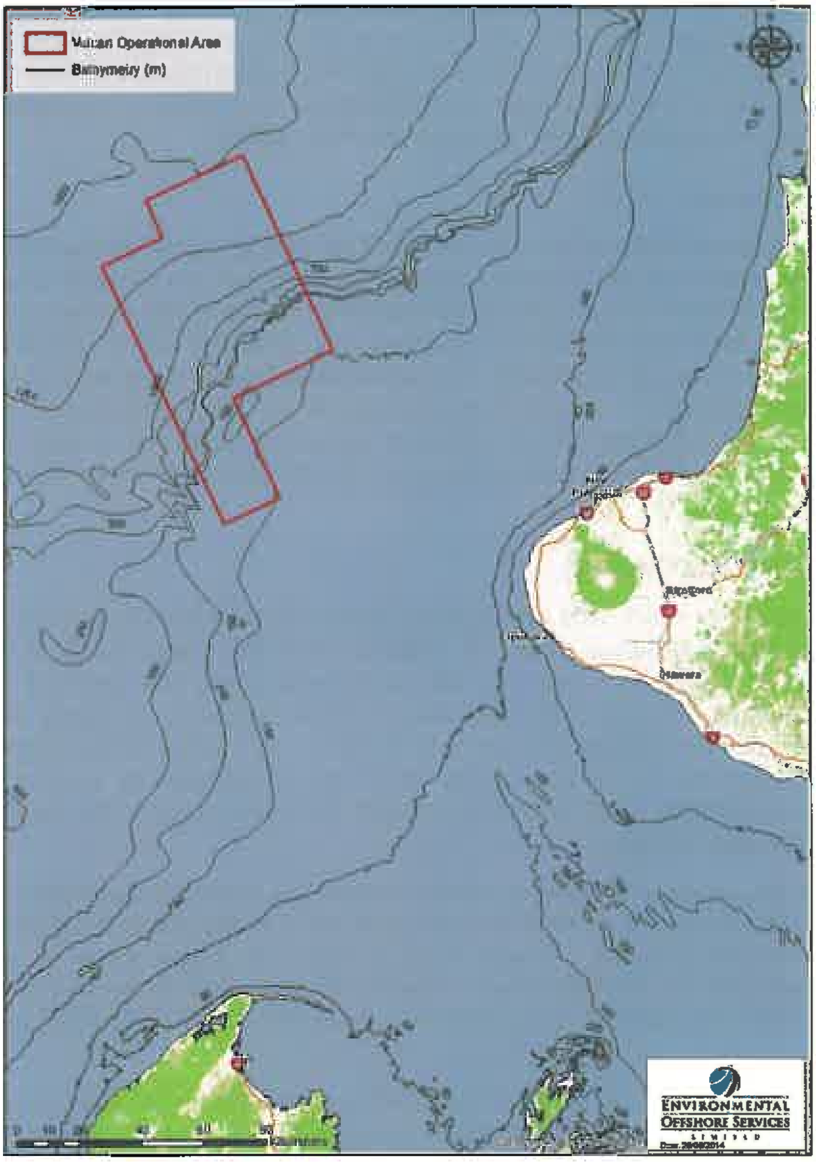

Figure 10: Bathymetry map of the Vulcan Operational Area

This varied underwater topography is the result of Zealandia's breakup from Gondwana (~85 million years ago) 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 resulted in shoreline sands being deposited, followed by marine silts and mud several kilometres thick which were compacted by the weight of the overlying sediment. Due to being both porous and permeable, these materials made ideal reservoir rocks, while the impermeable overlying silts, mud and carbonates formed the seals.

There are eight of these sedimentary basins around New Zealand (Figure 11) both onshore and underlying the continental shelf, with known or potential hydrocarbons present. However, to date, commercial quantities of oil and gas have only been produced from the Taranaki Basin. In addition to these continental sedimentary basins, there are also several deep-water basins offshore (Figure 11).

The New Zealand's sedimentary basins can be subdivided into 'Petroleum Basins' and 'Frontier Basins'. The petroleum basins are based on modern, industry-standard seismic surveys over at least a part of each basin or from well logs. As a result, all or part of each petroleum basin has been licensed for exploration.

Figure 11: NZ Sedimentary Basins.
(Source: GNS)

4.1.3.1 The Vulcan Operational Area

The Vulcan Operational Area is located within the Taranaki Basin which lies at the southern end of a rift that developed sub-parallel to the Tasman Sea rift and now separates Australia and New Zealand. It occupies the site of a late Mesozoic extension on the landward side of the Gondwana margin, covering ~ 330,000 km^2. Within the basin, the structure is controlled by the movement along the Taranaki, Cape Egmont and Turi fault zones (Figure 34). It is a Cretaceous and Tertiary sedimentary basin in which there is a grading from fine to medium sand to silt and muds with an increasing depth range across the Taranaki shelf. Prevailing west-southwest storm generated waves and currents are most likely the predominant sediment transport agents along the Taranaki coastline.

Coastal basement rocks originate from a number of different terrains. These giant crustal slabs can comprise sedimentary, plutonic, and volcanic rocks. Around NZ, the terrains 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. The boundary between these two provinces is a zone of volcanic arc rocks which forms the western section of the Taranaki peninsula. To the north-east, the Waikato coastline is greywacke (hardened sandstone) Eastern Province terrain (Morton and Miller, 1968).

4.2 Biological Environment

4.2.1 Planktonic Communities

Within NZ, the productivity of the ocean is a result of many factors; namely ocean currents, climate and bathymetry which causes upwelling creating nutrient rich waters – ideal conditions for plankton growth and the animals that feed on them (MPI, 2014b).

Plankton are drifting organisms (animals, plants or bacteria) that occupy the pelagic zone of oceans and seas around the world. Plankton are the primary producers of the ocean which places them at the bottom of the food chain. They travel passively with the ocean currents although some plankton species can move vertically within the water column. Nutrient concentrations, seasonality and the physical state of the water column (i.e. settled or well-mixed) influence the abundance of plankton.

There are three broad functional groups for plankton:

- Bacterioplankton – play an important role in nutrient cycles within the water column;
- Phytoplankton – microscopic plants which capture energy from the sun and take in nutrients from the water column via photosynthesis. They create organic compounds from CO_2 dissolved in the ocean and help sustain the life of the ocean; and
- Zooplankton – consisting of small protists, metazoans (i.e. crustaceans), larval stages of fish and crustaceans which feed on the phytoplankton and bacterioplankton. Although zooplankton are primarily transported by ocean currents, many are able to move, generally to either avoid predators or to increase prey encounter rates. Zooplankton primarily live in the surface waters where food resources are abundant.

It is widely accepted that high levels of primary productivity can have a knock-on effect up the food chain, attracting predators to feed in the area. In recent years, satellite imagery has been used to examine primary productivity in the oceans around New Zealand (using Chlorophyll α as a proxy for primary productivity). The images show evidence of great seasonal and regional variation throughout the Taranaki Basin. A consistent annual phytoplankton bloom takes place in the spring months off the west coast of New Zealand. Chlorophyll α levels then proceed to drop to their lowest annual level at the end of the summer and build up again throughout the winter in order to peak once again with the onset of spring.

The Taranaki Bight displays increased primary productivity in comparison with more northerly offshore areas (Murphy *et al.*, 2001). This particular upwelling and associated euphausiid (krill) bloom is of particular relevance as it has been recently discovered to attract feeding blue whales in the South Taranaki Bight.

4.2.2 Invertebrates

NZ has a large diversity of marine invertebrates. This is attributable to the variable seafloor relief and NZ's ancient geological history. From the intertidal to the deep sea trenches, each habitat hosts a unique combination of species which are adapted to the local environmental conditions. The coastal area closest to the Vulcan Operational Area (i.e. northeast Taranaki and south Waikato which lie at a minimum distance of 115 km from the Vulcan Operational Area) presents a range of coastal environments (Hume *et al.*, 1992) which vary in exposure to wave action, substrate (reefs, boulders, sand etc.), coastal morphology (harbours and estuaries) and temperature (see Section 4.1.1). These factors directly impact the occurrence of various species within the intertidal zone. Overall, molluscs tend to dominate rocky shores, while mobile invertebrates are often the most commonly observed in soft shores. On hard shores, sessile invertebrate species (i.e. sponges, ascidians, bryozoans, and hydroids) are conspicuous and form stable communities (Lavery *et al.*, 2007).

Similarly to the intertidal, the deeper subtidal zones within the Vulcan Operational Area present a range of habitats from the relatively flat continental shelf, over the continental slope down into deep water. Water depths from within the Vulcan Operational Area range from approximately 150 m down to approximately 1,500, often resulting in a range of current, and sub-sea temperature conditions. Throughout NZ this range in benthic conditions can contribute to the occurrence of complex and varied assemblages of invertebrate species.

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 can live for hundreds of years and exist either as individuals or as compact colonies of individual polyps. Deep-sea corals are fragile, sessile, slow growing and long-lived. They have limited larval dispersal and are restricted to certain habitats.

The conservation of deepwater corals (also known as cold water corals) is of particular concern as these organisms are at risk from number of anthropogenic activities (fishing, mining etc.). As a result, all deepwater black corals, gorgonians, stony corals, and some hydrocorals have been listed as protected species under the 2010 amendment to Schedule 7A of the Wildlife Act 1953.

In 2013, NIWA used models to predict the occurrence of gorgonians, black corals and red corals in NZ waters (Baird *et al.*, 2013). The results suggest the absence of these types of corals in the Vulcan Operational Area. These results are further confirmed by existing sampling data which do not include any records from Taranaki waters (Figure 12, Figure 13, Figure 14).

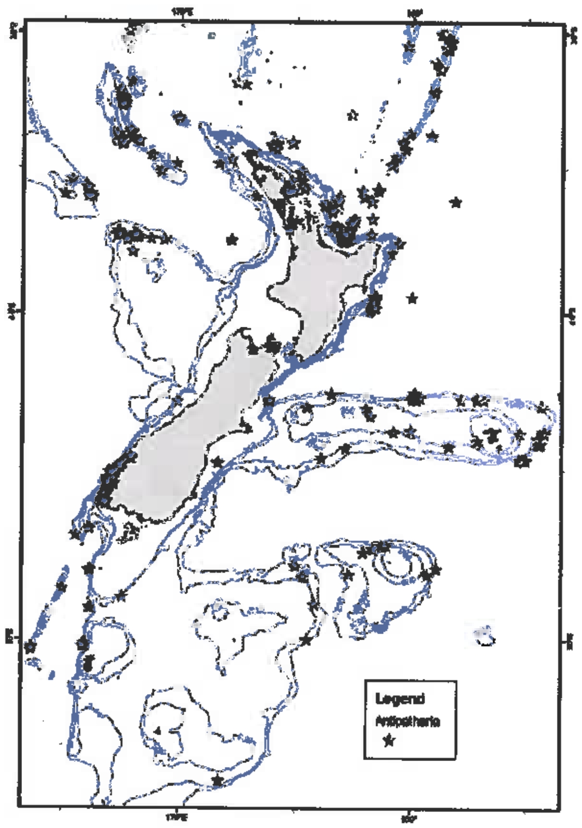

Figure 12: Known localities of black corals within the NZ region
(Consalvey *et al.*, 2006)

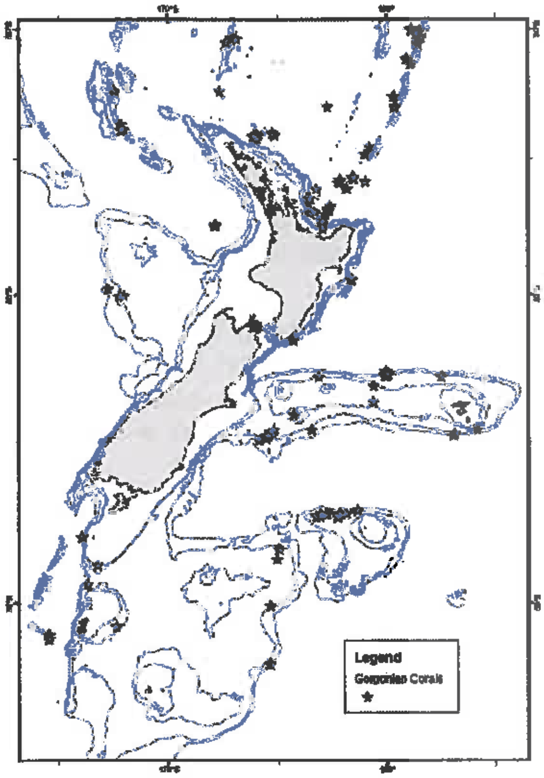

Figure 13: Known localities of gorgonian corals within the New Zealand Region
(Source: Consalvey *et al.*, 2006)

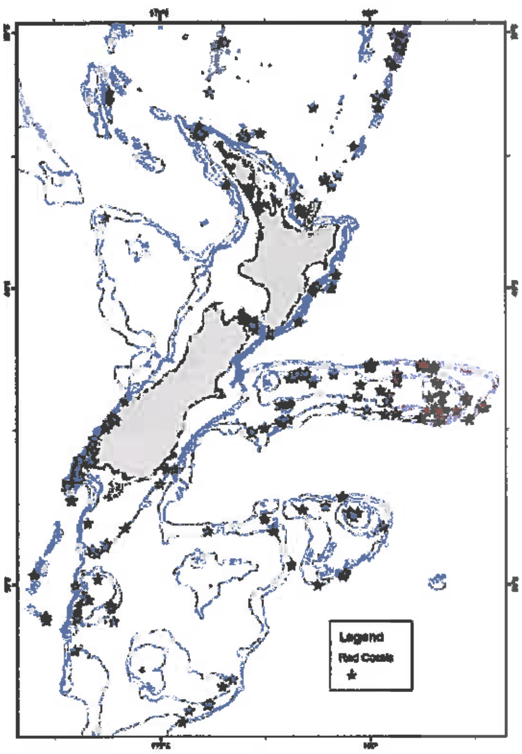

Figure 14: Known localities of red coral within the New Zealand region

4.2.3 Fish Species

The west coast of New Zealand provides habitats for a number of demersal and pelagic species ranging from shallow to deep waters. General distribution for these species are listed in Table 5.

MPI prepared a fisheries assessment for the Vulcan Operational Area for all fishing effort within the period 2008-2013. This assessment identified jack mackerel and school shark as the two most commonly caught commercial fish species within this area. More detail on commercial fishing within the Vulcan Operational Area can be found in Section 4.4.2.

Table 5: Distribution of fish species surrounding the Vulcan Operational Area (MPI, 2013; 2014e)

Water column	Fish species caught between 2008-2013
Demersal	Bass, black flounder, blue cod, blue mackerel, blue moki, blue warehou, bluenose, brill, brown stargazer, butterfish, dark ghost shark, eels, escolar, frostfish, garfish, giant stargazer, golden mackerel, grey mullet, hapūku, horse mackerel, john dory, kingfish, lamprey, leatherjacket, lemon sole, ling, long-finned beryx, murphy's mackerel, northern spiny dogfish, NZ sole, parore, porae, red cod, red gurnard, red moki, red snapper, redbait, rig, rough skate, rubyfish, sand flounder, sea perch, seal shark, silver warehou, smooth skate, snapper, spiny dogfish, spotted black groper, spotted stargazer, squid, tarakihi, trevally, turbot, two saddle rattail, yellow-bellied flounder, yellow-eyed mullet.
Pelagic	Albacore tuna, anchovy, barracouta, basking shark, bigeye tuna, black marlin, blue marlin, blue shark, broadbill swordfish, bronze whaler shark, hammerhead shark, herrings, kahawai, mako shark, moonfish, pilchard, porbeagle shark, ray's bream, school shark, skipjack tuna, striped marlin, thresher shark, white pointer.

4.2.3.1 Protected fish species

Schedule 7A of the Wildlife Act 1953 lists eight species of fish as protected. The list includes basking shark, deepwater nurse shark, great white shark, manta ray, oceanic white-tip shark, spiny-tailed devil ray, spotted black grouper, and whale shark. Two of these species can be found either within or in the vicinity of the Vulcan Operational Area: great white sharks and basking sharks. Additionally, these two species are also protected under the Fisheries Act which prohibits NZ flagged vessels from taking either species, even beyond the NZ EEZ.

Great white sharks occur throughout NZ waters and are at risk of extinction worldwide. They are classified as being in gradual decline under the NZ Threat Classification System and as vulnerable by the IUCN Red List of Threatened Species.

NIWA have played a key role in setting up a shark satellite tagging programme in NZ and 35 great white sharks have been tagged since 2005. The resulting data have demonstrated that NZ great whites migrate seasonally from March to September, between aggregation sites at Stewart Island and the Chatham Islands, to the tropical and subtropical Pacific (i.e. northern New South Wales and Queensland, Norfolk Island, New Caledonia, Vanuatu, Fiji and Tonga); however, they don't appear to cross the equator (DOC, 2014g). Stewart Island great white sharks tend to head northwest of NZ, while the great white sharks tagged at the Chatham Islands head north to warmer waters.

Basking sharks are known to be more common in colder waters south of 39°S, so there is the potential that they could occur off the Taranaki coastline and within the Vulcan Operational Area (DOC, 2014a).

In 2013 the Convention on International Trade in Endangered Species (CITES) made a decision to include three species of hammerhead sharks whereby if they are harvested for either their fins or meat, they have to be traded with CITES permits and evidence that they have been harvested sustainably and legally. DOC have requested that the MMO's make note of any observations of hammerhead sharks in Taranaki waters during the Vulcan MSS or on transit to or from port to further understand the movement and distribution of these sharks within NZ waters.

4.2.4 Cetaceans

Fifty-one species of dolphins and whales can be found in NZ, which is over half of the world's cetacean species (Suisted and Neale, 2004). Taxonomically, cetaceans are split into two suborders: toothed whales (odontocetes) and baleen whales (mysticetes).

Baleen whales are often large; they don't have teeth; and they have a fringe of stiff hair-like material, or baleen, hanging from their upper jaw which they use to filter small animals out of the seawater (DOC, 2007). In contrast, odontocetes have teeth; they are highly social; and they will hunt and navigate in large groups. An additional difference between the mysticete and odontocete suborders is the way in which these animals use sound. While both groups use sound to communicate (at varying frequencies depending on the species), only odontocetes echolocate. Odontocetes direct sound ("clicks") into their environment and use the reflected sound waves to explore their surroundings and identify objects or locate prey. This reliance on sound to communicate and feed makes cetaceans particularly vulnerable to the effects of anthropogenic underwater noise and precautions must be taken during seismic surveys in order to keep impacts to a minimum. Mitigation measures specific to the Vulcan 3D MSS are discussed in Section 5.3.

Cetaceans are elusive creatures which are notoriously difficult to study. Gathering data on deep-diving, offshore and migratory species presents numerous logistical problems and on the whole these are the species that are less well studied. Since distribution data are not necessarily available for all species in all areas, it is important to consider multiple sources of information in order to build an accurate picture of 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 strandings information, knowledge of migration paths and habitat preferences of each species.

In addition, caution should be exercised when interpreting sightings datasets from multiple sources. Importantly, the lack of sightings data in an area does not strictly indicate an absence of cetaceans. A lack of sightings data can, in fact, be an indicator of limited observer effort caused by a low level of boat activity in the area, infrequent dedicated surveys with few or no sightings, or the relative inaccessibility of the area in question. Further, a lack of sightings data could simply be caused by a lack of reporting to the main DOC databases which are referred to in this report.

Similarly, strandings data must also be interpreted with care. Strandings can give a very broad indication of occurrence and information on life history of a species (via stomach contents etc.) but, without the assistance of complex models, will only yield limited indications on species distribution. These data should be considered complementary to detections (acoustic and visual) of live animals.

As mentioned above, where cetacean detections or stranding data are limited or lacking, information on life history, habitat preferences and migratory pathways can be used to infer species occurrence. In particular, seasonality is important in determining which species will be present in an area at a given time of year. Some cetacean species are resident and present year-round whereas others will migrate to an area either to reproduce or forage following migratory paths every year.

This MMIA aims to provide a broad overview of cetaceans which could be present in the Vulcan Operational Area; however, the available data for some species is limited due to logistical limitations mentioned previously. Consequently, the cetacean sightings data collected during the Vulcan 3D MSS will be invaluable towards enhancing available baseline information within the Vulcan Operational Area and in turn will contribute to effective monitoring of vulnerable species.

4.2.4.1 Sightings and strandings within and surrounding the Vulcan Operational Area

The data sources accessed in order to identify cetaceans potentially present within the Vulcan Operational Area include the National Aquatic Biodiversity Information System (NABIS), the DOC sighting database, the DOC stranding database and readily available literature.

The DOC sighting database, current up until February 2014 had the geographical positions of 8,343 sightings of marine mammals, of which numerous records contributed by previous MSSs around the NZ coastline.

The DOC stranding database has also been accessed up until the end of 2013 and plotted on GIS mapping software. A summary of the DOC stranding database was undertaken by Brabyn (1991), and, at that time of writing, 88% of the 1,140 whale strandings in NZ comprised of three species; pilot whales, false killer whales and sperm whales.

The cetacean species identified within these sources are listed in Table 6. A basic ecological summary for each of the more common species likely to be encountered within the Vulcan Operational Area and those which are protected by NZ conservation legislation is included in Section 4.2.4.4.

New Zealand Oil and Gas (NZOG) are a 30% partner in PEP 55793 with WEL. In April 2013, NZOG acquired two MSSs west of Cape Egmont and southeast of the Vulcan Operational Area. The Kokako 3D MSS was acquired 45 km southeast of the Vulcan Operational Area over a 20 day period within PEP 53473 resulting in 23 detections of marine mammal pods, representing a minimum of 262 individual animals. However, these numbers were dominated by a single pod of common dolphins with at least 200 individuals. Of the 23 marine mammal pods detected, eight were classified to the species level and included NZ fur seals, pilot whales, killer whales and blue whales. The blue whale pod was comprised of three individuals, and this observation was made when the seismic vessel was off location, to the west of the Operational Area. During this sighting the blue whales were observed 483 m from the seismic vessel, the acoustic source was not active and there was no apparent reaction to the seismic vessel.

Following the Kokako 3D MSS, NZOG acquired the Karoro 3D MSS at the end of April 2013 over an 11 day period within PEP 52593. The Karoro 3D MSS was acquired 6 km to the southeast of the Vulcan Operational Area. During this survey weather conditions were poor and there were only two acoustic detections of marine mammal pods (one odontocete and one delphinid) representing a minimum of four animals.

Table 6: Cetacean species occurring in and around the Vulcan Operational Area.

Note: Common occurrence in the operational area = located within the core species range; Rare occurrence in the operational area= located in the species full range; vagrancy in the operational area = the operational area is adjacent to the species range but individuals may stray into the operational area; Good data availability= repeated sightings and/or monitoring, strandings data, ecological characteristics are known; Moderate data availability= few sightings, strandings data, ecological characteristics are known; Poor data availability= strandings data, ecological characteristics are known

Species	Distribution	Residency pattern in wider area	Occurrence in the Vulcan Operational Area	Critical life cycle behaviour in Vulcan Operational Area	Protection status	Data availability for the wider area
Blue whale (*Balaenoptera musculus*)	Offshore	Migrant	Common	Migration/Feeding	IUCN endangered	Good
Humpback whale (*Megaptera novaeangliae*)	Offshore	Migrant	Common	Migration	IUCN least concern	Good
Common dolphin (*Delphinus sp.*)	Offshore		Common	Feeding	IUCN least concern	Good
Pilot whale (*Globicephala melas*)	Offshore		Common	Feeding	IUCN data deficient	Good
Killer whale (Orcinus orca)	Coastal/Offshore	Migrant/Resident	Common	Feeding	Nationally Critical; IUCN data deficient	Good
Dusky dolphin (*Lagenorhynchus obscurus*)	Offshore/Coastal		Rare	Feeding	IUCN data deficient	Poor
Minke whale (*Balaenoptera acutorostrata & B. bonaerensis*)	Offshore	Migrant	Rare		IUCN data deficient	Moderate
Sei whale (Balaenoptera borealis)	Offshore	Migrant	Rare		IUCN endangered	Moderate
Fin whale (Balaenoptera physalus)	Offshore	Migrant	Rare		IUCN endangered	Moderate
Risso's dolphin *(Grampus griseus)*	Offshore		Rare	Feeding	IUCN least concern	Poor
False killer whale (*Pseudorca crassidens*)	Offshore		Rare		IUCN data deficient	Poor
Southern right whale (*Lissodelphis peronii*)	Offshore		Rare	Feeding	Not threatened; IUCN data deficient	
Sperm whale (*Physeter macrocephalus)*	Offshore	Migrant	Rare	Feeding	Non-threatened; IUCN vulnerable	Moderate
Pygmy sperm whale(*Kogia breviceps)*	Offshore		Rare	Feeding	IUCN data deficient	Poor
Arnoux's Beaked whale (*Berardius arnuxii*)	Offshore		Rare	Feeding	IUCN data deficient	Poor

Southern Bottlenose whale (*Hyperoodon planifrons)*	Offshore		Rare	Feeding	IUCN least concern	Poor
Andrews Beaked whale (*Mesoplodon bowdoini)*	Offshore		Rare	Feeding	IUCN data deficient	Poor
Blainville's Beaked Whale (*Mesoplodon densirostris)*	Offshore		Rare	Feeding	IUCN data deficient	Poor
Gray's Beaked Whale (*Mesoplodon grayi*)	Offshore		Rare	Feeding	IUCN data deficient	Poor
Strap-toothed Beaked Whale (*Mesoplodon layardii)*	Offshore		Rare	Feeding	Data deficient; IUCN data deficient	Poor
Shepherd's Beaked Whale (*Tasmacetus shepherdi)*	Offshore		Rare	Feeding	IUCN data deficient	Poor
Cuvier's Beaked Whale (*Ziphius cavirostris*)	Offshore		Rare	Feeding	IUCN least concern	Poor
Hector's Beaked Whale (*Mesoplodon hectori*)	Offshore		Rare	Feeding	IUCN data deficient	Poor
Pygmy Beaked Whale (*Mesoplodon peruvianus*)	Offshore		Rare	Feeding	IUCN data deficient	Poor
Southern Right Whale (*Eubalaena australis*)	Coastal/Offshore	Migrant	Rare	Migration	Nationally endangered; IUCN least concern	Moderate
Pygmy right whale (*Caperea marginata*)	Coastal/Offshore		Rare	Feeding	IUCN data deficient	Poor
Bottlenose dolphin (*Tursiops truncates*)	Coastal/Offshore		Rare	Feeding	Nationally endangered/IUCN least concern	Moderate
Dwarf sperm whale (*Kogia sima)*	Coastal/Offshore		Rare	Feeding	IUCN data deficient	Poor
Maui's dolphin (*Cephalorhynchus hectori maui*)	Coastal	Resident	Rare		Nationally critical; IUCN endangered	Good
Striped dolphin (*Stenella coeruleoalba)*	Offshore		Vagrant		IUCN least concern	Poor
Rough-toothed dolphin (*Steno bredanensis*)	Offshore		Vagrant		IUCN least concern	Poor
Beaked whale (*Mesoplodon mirus)*	Offshore		Vagrant	Feeding	IUCN data deficient	Poor
Bryde's whale (Balaenoptera edeni)	Coastal		Vagrant		Nationally critical; IUCN data deficient	Poor
Hector's dolphin (*Cephalorhynchus hectori*)	Coastal		Vagrant		Nationally endangered; IUCN endangered	Poor

4.2.4.2 Migration paths through the Vulcan Operational Area

During spring most of the baleen whales living in the Southern Hemisphere migrate from the Pacific Islands down to the Antarctic Ocean to feed. They return back to the Pacific Islands during Autumn-winter for the breeding season (May-July) (DOC, 2007). The distribution and migration paths around NZ for humpback, sperm, Bryde's and southern right whales are shown in Figure 15 (Section 4.2.4.4). The northern migration routes back up to the Pacific Islands are relatively well known, however the southwards routes are not. The Vulcan 3D MSS is currently expected to start in January 2015 and take approximately 35 days; therefore it is considered that Vulcan 3D MSS will be complete prior to the northward migrations of whales. However, if there are believed to be large numbers of migratory whales within the Vulcan Operational Area, DOC would be notified and any additional mitigation measures would be discussed between DOC and WEL.

Figure 15: Whale distribution and migration pathways in NZ waters
(Te Ara, 2014c)

4.2.4.3 Protected cetacean species in the Vulcan Operational Area

Eight species of marine mammal are included in the NZ threat classification list, either as "nationally critical", "nationally endangered" or "range restricted" (Table 7) (Baker *et al.*, 2010). Four of these species have been identified as potentially being present within the Vulcan Operational Area during the Vulcan 3D MSS (Bryde's whale, killer whale, southern right whale and bottlenose dolphin).

Table 7: Marine mammals on NZ threat classification list (Baker *et al.*, 2010)

Marine Mammal Species	NZ Threat Classification	IUCN Classification	Summary	Distribution	Likely to be in Survey Area
Bryde's whale *(Balaenoptera edeni)*	Nationally critical	Data deficient	Generally a coastal species but does live in the open ocean. Bryde's whales prefer temperate waters and are observed off the NZ coast generally north of the Bay of Plenty. This species of whale is believed to rarely venture beyond 40 degrees south.	Have a preference for warmer waters. However, there is the possibility that this species could occur in the Vulcan Operational Area.	✓
Killer whale *(Orcinus orca)*	Nationally critical	Data deficient	Feeds on a variety of animals which include other marine mammals and fish species. They are believed to breed throughout the year and appear to migrate based on the availability of prey.	Largely unknown but tend to travel according to the availability of food. Killer whales are widely found in all oceans of the world although more dominant in cooler waters. Likely to occur in the Vulcan Operational Area.	✓
Maui's dolphin *(Cephalorhynchus hectori maui)*	Nationally critical	Critically endangered	World's smallest dolphin and found in inshore waters on the west coast of the North Island. Subspecies of Hector's dolphin	Generally live close to shore (within 4 nautical miles) although the 100 m depth contour has been indicated as being their offshore distribution given current scientific understanding. Only found on west coast of the North Island. Unlikely to be observed in the Vulcan Operational Area due to distance offshore.	×
Southern elephant seal *(Mirounga leonina)*	Nationally critical	Least concern	They are the largest species of seal and feed on squid, cuttlefish and large fish. Generally only comes ashore in spring/summer on offshore islands and some mainland areas to breed and moult; otherwise lives mostly at sea. They have an inflatable proboscis (snout) which is most present in adult males which is meant to increase the bull elephant seals roar.	Primary range includes the Antipodes, Campbell, Auckland, Snares Islands and the surrounding Southern Ocean. Occasionally they are found on the mainland from Stewart Island to the Bay of Islands. Unlikely to occur in the Vulcan Operational Area.	×
Southern right whale *(Eubalaena australis)*	Nationally endangered	Least concern	Present both offshore and inshore and their diet consist of krill, particularly copepods. Mate and calve during winter months in sheltered sub Antarctic harbours such as Auckland Islands and Campbell Island. Are baleen feeders and often travel well out to sea during feeding season; but they give birth in coastal areas (American Cetacean Society, 2010).	Likely to occur as a transient species in the Vulcan Operational Area.	✓
Hector's dolphin *(Cephalorhynchus hectori)*	Nationally endangered	Decreasing	One of the smallest dolphin species (less than 1.5m long). Generally live inshore although have been sighted up to 20 Nm from the coast.	Patchily distributed around the South Island coast. On east coast live between Banks Peninsula and Te Waewae Bay and Porpoise Bay in the south. There is also populations around Kaikoura and Cloudy Bay/Marlborough Sounds. There has been sightings of this species in the Southern Taranaki Bight as well as strandings along the Taranaki coastline. Unlikely to be observed in the Vulcan Operational Area although this species will be difficult to distinguish from Maui's dolphin in the field.	×
NZ sea lion *(Phocarctos hookeri)*	Nationally critical	Decreasing	Feeds on fish, invertebrates, and occasionally birds or other seals. Breeding occurs in summer months with pupping occurring in December/January with the pups being weaned in July/August.	Known to forage along continental shelf breaks with primary range including the Auckland, Campbell, and Snares Islands. Unlikely to be encountered in the Vulcan Operational Area.	×
Bottlenose dolphin *(Tursiops truncatus)*	Nationally endangered	Least concern	Are found worldwide in temperate and tropical waters, generally north of 45 degrees south. Population density appears to be higher near shore. Resident bottlenose dolphins are found off the east coast of the North Island, the northern tip of the South Island, and in Doubtful Sound.	Possibly observed in the Vulcan Operational Area.	✓

4.2.4.4 Ecological summary of most commonly occurring or protected cetacean species in the Vulcan Operational Area

4.2.4.4.1 Blue whale

Two subspecies of blue whale occur in the waters of the South Pacific: the Antarctic blue whale (*Balaenoptera musculus intermedia*) and the pygmy blue whale (*Balaenoptera musculus brevicauda*). These two subspecies display differences in the length of their tail stock, length of their baleen and blowhole shape (Todd, 2014; Shirihai & Jarrett, 2006). In the field, they are difficult to distinguish and scientists often rely on acoustics or genetic sampling to confirm identification of animals to sub-species level (Attard *et al.*, 2012; Samaran *et al.*, 2010).

Blue whales hold the impressive title of the largest animals to ever live. Adults of the species can reach up to 33 m long and weigh up to 180 tonnes (Baker, 1999; Todd, 2014). This fact alone can aid identification of the species in the field. Additional distinguishing features include the species' large head, tiny dorsal fin which sits over three-quarters of the way down an elongated body, and columnar blow which is the tallest of the baleen whales, reaching up to 12 m in height (Shirihai and Jarrett, 2006).

Blue whales depend on krill (euphausiids) as their primary food source. They can be seen lunge feeding on krill surface swarms (generally at night) or diving to depths of up to 100 m for 10-20 minutes (although they are capable of diving to 500 m for 50 minutes) (Todd, 2014). Blue whales have the highest prey demands of any predator and can consume up to two tonnes per day (DOC, 2007; Rice, 1978). Large aggregations of food in upwelling areas are therefore of great importance to these whales.

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.*, 2013) resulting in their vocalisations being able to travel hundreds of kilometres through the water. Blue whale calls can reach levels of up to 188 dB re 1ɥPa m^{-1} (Aroyan *et al.*, 2000; Cummings and Thompson, 1971).

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 "migrant" and therefore does not designate a threat status however blue whales are listed as a "Species of Concern" under the Code of Conduct. DOC have stated that the NZ threat classification for blue whales may change if further research demonstrates blue whales are resident or breeding in NZ waters.

Despite blue whales being such large animals, they are fairly elusive and little is known about their distribution or habitat use patterns. Worldwide, aggregations of blue whales are known to occur in areas of upwelling which coincide with lower sea surface temperature relative to surrounding waters and high concentrations of euphausiids (Burtenshaw *et al.*, 2004; Croll *et al.*, 2005; Fiedler *et al.*, 1998; Gill *et al.*, 2011).

Torres (2013) published a paper on a previously unrecognised blue whale foraging ground in the South Taranaki Bight. Despite the difficulties in distinguishing the two blue whale sub-species in the field (as mentioned above), Torres suggested that the animals observed in the South Taranaki Bight are likely to be pygmy blue whales based on the timing of the sightings (summer) and on the widely accepted knowledge that pygmy blue whales will remain at lower latitudes during the austral summer (Torres, 2013). In contrast to sightings in the field, strandings generally enable the identification down to sub-species level. Four pygmy blue whales are recorded on the DOC stranding database from the coasts of Taranaki, Wellington, Tasman Bay and Auckland. The most recent pygmy blue whale stranding was of a 20 m specimen at Himatangi Beach near Wellington in October 2013 and a 19.5 m specimen at Tapuae Beach, Taranaki in July 2014.

In addition to these blue whale feeding grounds off Taranaki Bight, there have also been acoustic detections of blue whales off Three Kings Islands, Great Barrier Island and off the east and west coasts of the South Island (Kibblewhite *et al.*, 1967; McDonald, 2006; Miller *et al.*, 2013; Olson *et al.*, 2013). More recently, feeding blue whales have been observed by MMOs off the Waikato coast within PEP 38451 directly to the north of the Vulcan Operational Area, during the Anadarko 2014 drilling campaign.

4.2.4.4.2 Common Dolphin

The common dolphin has a distinctive colouring of purplish-black to dark grey on top to white and creamy tan on the underside. This species can grow to 1.7 – 2.4 m in length, weigh 70 – 110 kg.

Common dolphins feed on a variety of prey which are generally under 10 cm in length. A recent study determined jack mackerel, anchovy and arrow squid as the predominant prey species for common dolphins in NZ (Meynier *et al.*, 2008). Importantly, all of these species can be found in the Vulcan Operational Area (see Section 4.2.3).

Common dolphins are known to either feed alone or cooperatively and a number of different feeding techniques can be employed. In NZ waters, cooperative techniques such as line abreast (where the dolphins line up and drive the prey in front of them), carouselling (where the prey are trapped against the surface thus creating a 'bait ball'), wall formation (where dolphins will drive the prey towards another group of dolphins) and bubble blowing (where bubbles are produced by the dolphins in order to stun the prey), and individual strategies such as and high speed pursuit, kerplunking (where the dolphin slaps its fluke against the surface of the water to create a noise) and fish-whacking (where the dolphin strikes the prey using its fluke) have been observed (Neumann, 2001).

As in most delphinid species, common dolphin 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 for common dolphins in the Hauraki Gulf. This study indicated that the average frequency and length of whistles are respectively 10-14kHz and 0.27 seconds.

The common dolphin status is listed as "least concern" in the IUCN red list.

Common dolphins are distributed around the entire NZ coastline, generally remaining within a few kilometres of the coast. They are social animals and can often form groups of several thousand individuals. In the Bay of Islands the mean water depth of sightings is 80 m, but ranges from 6 – 141 m (Constantine and Baker, 1997). In addition, results from the study of stomach contents of common dolphins in NZ waters have given indications of an onshore offshore diel migration (Meynier *et al.*, 2008). With a minimum depth of 150 m, the Vulcan Operational Area is located on the deeper side of this species range.

The DOC sighting database has records of common dolphins along the entire west coast of the North Island, including directly inshore of the Vulcan Operational Area. Likewise the DOC stranding database has recorded common dolphins along the stretch of coastline inshore of the Vulcan Operational Area. Therefore it is highly likely that common dolphins will be observed during the Vulcan 3D MSS.

4.2.4.4.3 Pilot Whale

There are two species of pilot whales; long-finned and short-finned, of which the long-finned is more likely to be found in NZ waters.

Long-finned pilot whales are a toothed whale. Males are larger than females and can grow up to 6 m long and weigh 3 tonnes. They are black or greyish-brown in colour, have a low, falcate dorsal fin which is centrally placed along their back, and no distinguishable beak.

Long-finned pilot whale feed on fish and squid in deep water along shelf breaks. A study of stomach contents of stranded pilot whales along the NZ coastline has indicated that this species preys predominantly on cephalopods, mainly arrow squid and common octopus (Beatson *et al.*, 2007). The same study identified a significant proportion of the squid and octopus individuals found in stomach contents as juveniles. Based on this information, a conclusion could be drawn that the majority of feeding events had taken place in waters shallower than 500 m (based on the distribution of juvenile stages of the prey species). However, this should information treated with caution given the small sample size used the study (n=5) and the inherent biases of strandings data. Furthermore, other studies outside of NZ waters have documented this species performing deep foraging dives (Baird *et al.*, 2002; Heide-Jorgensen *et al.*, 2002). Importantly, all of these depth ranges coincide with those found inside the Vulcan Operational Area.

Long-finned pilot whales are listed as data deficient by the IUCN (IUCN red list).

Pilot whales are notorious for stranding along the NZ coastline. Strandings generally peak in spring and summer (O'Callaghan, 2001), with Farewell Spit renowned for the number of whale strandings each year. They are very social animals and often travel in groups of over 100 individuals and it was originally thought that the family relationships among the pilot whales was the cause of strandings. The theory was that if one or more whales stranded due to sickness or disorientation, a chain reaction was triggered which drew the healthy whales into the shallows to support their family members (Oremus *et al.*, 2013). However, from genetic data gathered from stranded whales in NZ and Tasmania, it has been proved that stranded groups are not necessarily members of one extended family and many stranded calves were found with no mother present (Oremus *et al.*, 2013).

Additionally to these stranding records, pilot whales have been observed both within, offshore and inshore of the Vulcan Operational Area from the recorded sightings on the DOC sighting database. The DOC stranding database also shows records along the coastline inshore of the Vulcan Operational Area. Pilot whales are often observed during seismic surveys within the Taranaki Basin and it is highly likely that they will be observed during the Vulcan 3D MSS.

4.2.4.4.4 Killer whales

Killer whales are the largest member of the dolphin family; males can grow to 6 – 8 m and weigh in excess of six tonnes. They have an erect dorsal fin (taller in the male of the species) and the dorsal side of the animals is black with a distinctive oval white patch behind the eye and a grey "saddlepatch" behind the dorsal fin. It is believed that two populations exist within NZ waters; one inshore and one offshore although this is still not verified.

Worldwide, prey species vary from one ecotype to another with some forms of killer whale feeding on mammals and others on fish. As with all predatory species, the distribution of prey affects the distribution of killer whales and in NZ waters, they are more often found inshore during the NZ fur seal breeding season (November to January). This species is also known to feed on elasmobranchs in NZ waters.

Killer whales are known to echolocate and to produce tonal sounds (whistles). The whistles of wild killer whales have been noted to possess an average dominant frequency of 8.3 kHz and to generally last 1.8 s (Thomsen and Franck, 2001). Variations of these whistles (described as dialects) have been documented between pods (Deecke *et al.*, 2000). In addition, the use of echolocation has also been demonstrated to vary between orca groups, depending on the target prey species of a particular group (Barrett-Lennard *et al.*, 1996).

The resident NZ killer whale population is small (mean = 119 ± 24 SE) with broad distribution patterns around both North and South Islands (Visser, 2000). Within the NZ threat classification list killer whales are classified as 'nationally critical' (Suisted and Neale, 2004) whereas worldwide, they are classified as "data deficient" by the IUCN. There are over twenty sightings of killer whales recorded around Taranaki in the DOC website. Most of these are coastal sightings however, given the known range of this species (MPI, 2014e) it is expected that killer whales could occur within the Vulcan Operational Area.

4.2.4.4.5 Dusky dolphin

The dusky dolphin is a compact medium-sized dolphin which can measure up to 2.2 m in length. It has a tall, sickle-shaped fin and distinctive markings on its flank and head. A bluish-black colour covers the dorsal area from its rostrum to its tailstock; while the ventral side of the animal is white and a white blaze extends from its tail stock and branches into grey stripes by its dorsal fin. Another distinctive feature of this animal is sloping forehead and almost indistinctive beak (Shirihai and Jarrett, 2006).

As in other dolphin species, dusky dolphins are known to prey upon a range fish and squid species. Wursig *et al.* (2007) indicated that, overall, target prey species can vary seasonally. However, species that are present year round in the diet of dusky dolphin include lanternfish, hoki and arrow squid (Wursig *et al.*, 2007). Furthermore, an onshore/offshore pattern was detected in the Kaikoura population, with animals ranging further offshore at night to feed in deeper waters on fish, crustaceans and cephalopods (Shirihai and Jarrett, 2006; Wursig *et al.*, 2007). Notably, dusky dolphins are also known to associate with a number of other species and even to feed cooperatively with animals such as fur seals (DOC, 2014b).

The dusky dolphin produces bi-modal echolocation signals, with a low frequency peak at 40-50 kHz and a high frequency peak at 80 to 110 kHz. These frequencies are amongst the highest recorded in the field for dolphins (Au and Wursig, 2004).

The dusky dolphin is listed as "data deficient" in by the IUCN red list.

The dusky dolphin is found exclusively in the southern hemisphere and is known to associate with inshore areas and shallow shelves (Wursig *et al.*, 2007). In NZ, the species can be found in coastal areas of both Islands, with larger populations south of East Cape, in the Marlborough Sounds and off Kaikoura (Hawke, 1989; Wursig *et al.*, 2007). Dusky dolphins also infrequently extend their range as far south as the Banks Peninsula and north coast of Otago (DOC, 2014b; Wursig *et al.*, 2007).

Dusky dolphins can be found in groups of 6-20 animals up to several hundred individuals (Shirihai and Jarrett, 2006; Wursig *et al.*, 2007). It has been proposed that group size will vary depending on the activity (resting in small groups, feeding/travelling in larger groups), location (onshore/offshore), and risk of predation (strength in number for protection against killer whales). Dusky dolphins groups including calves were most frequently recorded in the summer in waters around Kaikoura (Wursig *et al.*, 2007). More widely, calving is known to occur between December and mid-January (DOC, 2014b).

Although there are no reported sightings of dusky dolphins in the DOC database for the area considered in this report, sightings (of individuals presumed to be from the Admiralty Bay population) have been recorded in the Taranaki Bight (Torres, 2012) and historical sightings have been noted in the Taranaki/Wanganui area (Wursig *et al.*, 2007). Furthermore, the Vulcan Operational Area overlaps with the species 'full range' (MPI, 2014e). Based on this information, it is deemed likely that dusky dolphins could be encountered inside the Vulcan Operational Area.

4.2.4.4.6 Minke Whale

Worldwide, there are two species of minke whale and one sub-species: the northern minke (*Balaenoptera acutorostrata*) (confined to northern hemisphere), the Antarctic or southern minke (*Balaenoptera bonaerensis*) (confined to the southern hemisphere including NZ waters) and a sub-species, the dwarf minke (*Balaenoptera acutorostrata*) (present in NZ waters).

The minke whale is a small rorqual measuring up to 10 m in length. It has a sickle-shaped dorsal fin situated two-thirds of the way down its back. The rostrum is triangular and has a single central ridge. Northern and dwarf minkes present pectoral fins which have a marked white band across the upper side. This feature is only clearly seen when the animal breaches or in very clear water (Shirihai and Jarrett, 2006).

Minke whales feed on krill, crustaceans and small fish. They will perform dives which last on average between 3-9 min (maximum 20 min). Antarctic minkes are known to feed in Antarctic feeding grounds during the austral summer and are scarce in NZ and Tasmanian waters. Records of dwarf minkes are limited and suggest a circumpolar distribution in the Antarctic with additional areas of occurrence around 7° S in the Atlantic and 11° S in the Pacific.

The minke whale produces low frequency pulse trains. The overall frequency range of these vocalisations is 100-500 Hz but the main energy is focussed between 80Hz and 140 Hz. These sounds are used for communicating over large distances.

Antarctic minke whale has a "data deficient" population status worldwide according to the IUCN red list. As a result, any sightings of this species at sea collected during the Vulcan 3D MSS will contribute to the knowledge of this species.

There has only been one recorded sighting of a minke whale in Taranaki waters and that was in close to Cape Egmont off Okato. Two strandings have been recorded of the minke whale in surrounding waters although these were both significant distances away. One stranding occurred along the Waikato coastline to the south of Kawhia Harbour while the other was at Waiinu Beach along the South Taranaki coast. Even though the Vulcan 3D MSS is being acquired over summer months when the minke whales are likely to be down in Antarctic waters, there have been observations around NZ during the summer months. As a result, there is the potential that minke whales could be encountered during the Vulcan 3D MSS.

4.2.4.4.7 Sei Whale

On average, sei whales have a body length which ranges between 15 – 18 m and a weight of 20 – 25 tonnes. They have a V-shaped head and an erect dorsal fin situated two-thirds of the way along their back. This rorqual's dive pattern at the surface is distinctive as the dorsal fin is visible almost simultaneously to the blow (Shirihai and Jarrett, 2006).

Sei whales feed mostly on copepod species in Antarctic waters. In the absence of copepods, they may also prey upon euphausiid swarms (Mizroch *et al.*, 1984a). This species of whale is known to feed at dawn and can be seen to turn on its side while feeding (Shirihai and Jarrett, 2006).

The acoustics of sei whales are not well studied and there are indications of geographic variations in frequency and nature of the calls. Vocalisations from this species recorded in Antarctic waters included low frequency tonal calls (0.45 ± 0.3 s long and 0.433 ± 0.192 kHz in frequency), frequency swept call and broadband 'growls' or 'wooshes'.

The IUCN red list classifies the sei whale as "endangered".

Sei whales are among the fastest swimming cetaceans. Swimming speeds of up to 50 km/hour have been recorded enabling animals to travel up to 4,320 km in ten days. During February-March, southern hemisphere sei whales migrate south to subantarctic waters where there is an abundance of food. Unlike other rorquals, their distribution does not extend to the ice edge (Mizroch *et al.*, 1984a). In the winter months, they return to the waters between the South Island of NZ and Chatham Islands to calve. No sei whales have been recorded within the Vulcan Operational Area on the DOC stranding database, however there has been one sighting approximately 10 km to the southeast and other sightings to the northeast and southeast of the Vulcan Operational Area. Therefore, there is the potential that Sei whales could be encountered during the Vulcan 3D MSS.

4.2.4.4.8 Fin whale

The fin whale is the second largest marine mammal, second only to the blue whale, reaching up to 27 m in length (Mizroch *et al.*, 1984b; Shirihai and Jarrett, 2006). This species presents a small backwards swept dorsal fin two-thirds of the way down its back; a "V" shaped head with a longitudinal ridge and asymmetric pale coloration on its right jaw; and variable pale chevrons from flipper to shoulder (Shirihai and Jarrett, 2006).

The fin whale's diet is known to vary locally and seasonally. Target species range from fish and squid to krill and other crustaceans (Mizroch *et al.*, 1984b; Shirihai and Jarrett, 2006). Feeding techniques include lunging and gulping which can sometimes be observed at the surface. This species also has the peculiarity of often feeding on its right side.

The fin whale uses sound to communicate over large distances. These calls are thought to be important for feeding and mating. They have been described as short (<1 second) down-swept tones ranging from 28 to 25 Hz (Širović *et al.*, 2004) at source levels of 189+/- 4dB re 1ųPa m^{-1}.

Fin whales are listed by the IUCN red list as "endangered".

Similarly to other austral balaenoptera species, the fin whale can be found in warmer, lower latitudes in the winter, where the species breeds; and in the cooler waters of the Antarctic during the summer months, where the species feeds on krill and other small crustaceans. Although breeding grounds and migration paths are not well documented for this species, they are generally observed in deep offshore waters and are known to occasionally occur in NZ waters.

The DOC sighting database shows one recorded observation of a fin whale approximately 50 km to the east of the Vulcan Operational Area as well as two further observations in the South Taranaki Bight. All three observations were made during December and January.

4.2.4.4.9 Sperm Whale

Sperm whales are globally distributed and are the largest of the toothed whales. Males can reach 18 m in length and weigh up to 51 tonnes; whereas females are usually half the weight and two-thirds the length.

Squid is their most common food but they are also known to eat demersal fish (Torres, 2012). Sperm whales are odontocetes (toothed whales). Worldwide, squid is known to be a major component of this species' diet and is caught during deep foraging dives which can last over an hour (Evans and Hindell, 2004; Gaskin and Cawthorn, 1967; Gomez-Villota, 2007). During these dives, the sperm whales can reach depths of 3,000 m where no light can penetrate. This is where the whales become entirely reliant on sound to locate their prey and navigate. To do so, these animals produce echolocation clicks which are believed to enable them to determine the size, direction and distance of prey (Ocean Research Group, 2014). In addition, sperm whales also use clicks as a means of communication, to identify members of a group and coordinate foraging activities (Andre and Kamminga, 2000). All of these sounds will allow any sperm whales in the proximity to the *Polar Duke* to be heard on the PAM system onboard.

Under the IUCN classification system, sperm whales are currently listed as "vulnerable" whereas they are classified as "non-threatened" by the NZ classification system.

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 all Māori.

There have been no sightings of sperm whales in the Vulcan Operational Area, although there have been two sightings to the northeast in shallower waters off the Waikato coastline. A sperm whale has been observed dead at sea just to the north of the Vulcan Operational Area, while a number of sperm whales have stranded along the Taranaki and Waikato coastline from the DOC stranding records which date back to the 1960's. Therefore there is the potential that sperm whales could be observed during the Vulcan 3D MSS, even though it is considered that most sperm whales migrate to Antarctic waters during summer months, there have been some observations and stranding events during summer months.

4.2.4.4.10 Pygmy Sperm Whale

Pygmy sperm whales (*Kogia breviceps*) can grow up to 3.5 m in length and weigh 400 kg. They have no teeth in their upper jaw, only sockets, which the 10 – 16 pairs of teeth in the lower jaw fit into. They are very discreet at sea. They lack a visible blow and have a low profile in the water. This makes them difficult to observe at sea unless weather conditions are calm with little or no swell.

Prey species for the pygmy sperm whales include cephalopods, fish and occasionally crustacean species (Shirihai and Jarrett, 2006).

Little is known of the acoustics of this species. However, data collected from live stranded animals has indicated the existence of two types of vocalisations: high frequency clicks which range from 500 Hz to 12 kHz and 'grunts' of approximately 3 kHz.

Given the lack in data available on this species, they are classified as "data deficient" by the IUCN red list.

There have been no recorded sightings of pygmy sperm whales on the west coast of the North Island. However, there have been a number of stranding events along the west coast of the North Island along the north Taranaki and Waikato coastline which were spread throughout all seasons. These stranding events have provided most of the available information for this species in the northwest of New Zealand.

It is assumed that pygmy sperm whales may be present in the Vulcan Operational Area, but could be difficult to observe in most sea conditions.

4.2.4.4.11 Beaked Whale

Due to the limited sightings at sea, very little is known about the distribution of beaked whales around the NZ coastline. 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, and 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 deep ocean waters or continental slope habitats at depths down to 3,000 m.

Offshore areas off the northwest of the North Island (referred to as the "west coast basin") are thought to be important for both Gray's and Shepherd's beaked whales (Arnold, 2013). There have been no sightings of any beaked whales within the Vulcan Operational Area or the west cost of the North Island; however, beaked whales are renowned for being difficult to observe at sea.

Along the coastline inshore of the Vulcan Operational Area seven species of beaked whales have been recorded from the DOC stranding database and include: Andrew's; Blainville's; Gray's; Layard's/strap-toothed; Shepherd's; Cuvier's and pygmy. A lot of the strandings have occurred over the summer months; however, across all of the species the strandings have occurred throughout the year, so it is assumed they are present all year round. Therefore, these beaked whales mentioned here, as determined from DOC's stranding database, could be observed during the Vulcan 3D MSS but they will be difficult to observe at sea.

4.2.4.4.12 Southern Right Whale

Southern right whales can reach between 15 – 18 m in length. Distinguishing features of this species include callosities on the upper jaw and facial area of the animal (often white in colour due to infestations of whale lice, parasitic worms and barnacles) and the absence of dorsal fin. They are a slow moving whale, often swimming at speeds less than 9 km/hr, making them vulnerable to ship-strikes and in the past, whaling.

Right whales feed predominantly on zooplankton and tend to 'skim feed' which involves swimming through swarms of prey with the mouth wide open. This is done either at the surface or at depth (Braham and Rice).

Right 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 and Dawson, 2014). There have been no sightings of southern right whales within the Vulcan Operational Area. A number of sightings have been recorded around New Plymouth; however, most of these have been in the shallow coastal waters and during winter months. With the Vulcan 3D MSS scheduled for the summer period it is unlikely that a southern right whale would be observed as they are likely to be feeding down in Antarctic waters.

Southern right whales are regarded as nationally endangered but recent data indicate that they are making a recovery. The population was heavily reduced by whaling which caused numbers to drop from ~17,000 to ~1,000 (Carroll *et al.*, 2011; Suisted and Neale, 2004). Given this massive decline in southern right whale stocks, DOC prioritised the collection of sighting data and genetic samples for this species. Resulting genetic evidence suggests that southern right whales seen around mainland NZ and the NZ subantarctic are part of a single stock (Carroll *et al.*, 2011) and it is thought that this single NZ population range between two wintering grounds: the primary wintering ground in the NZ subantarctic and secondary wintering ground of mainland NZ (Carroll *et al.*, 2011). Rayment & Childerhouse (2011) estimated the population of southern right whales in the subantarctic using annual photo-ID surveys from 2006-2011. The survey resulted in 511 individuals being identified and subsequent modelling estimated that 1,286 (689-2,402) frequented the survey area.

Worldwide, southern right whales are regarded as of "least concern" (IUCN red list).

Southern right whales are the only baleen whale to breed in NZ waters; during winter months calving occurs in coastal waters whereas in summer they migrate to the Southern Ocean (sub-Antarctic and Campbell Islands) to feed. Their northern migration sees them go through the Cook Strait between May-October, although sightings have been recorded outside of this period (see Section 4.2.4.2). The DOC sightings database contains records of coastal sightings of the species around the Taranaki coastline (New Plymouth, Oakura, Urenui, Opunake). There is also a single more offshore sighting from the Maui A platform which could indicate that this species could be observed inside the Vulcan Operational Area despite its general coastal distribution in NZ waters.

4.2.4.4.13 Bottlenose Dolphin

Bottlenose dolphins range from 2.4 – 4 m in length and 250 - 650 kg in weight. Throughout the world, bottlenose dolphins are widely distributed in cold temperate and tropical seas, with NZ being the southernmost point of their range.

Bottlenose dolphins will feed on fish, krill and crustaceans and are known to feed cooperatively (Shirihai and Jarrett, 2006).

As members of the odontocete family, bottlenose dolphins produce two varieties of sound: 'clicks' which are used for echolocation purposes (0.8-24 kHz) and 'whistles' which are used as a form of communication (40-130 kHz).

This species is now listed as "Nationally Endangered" on the NZ threat classification list, largely due to their low abundance and concerns over potential decline in populations. Internationally, the species is classified as "least concern" by the IUCN red list.

Within NZ there are three main coastal populations of bottlenose dolphins; approximately 450 live along the northeast coast of Northland, 60 live in Fiordland and there is a population living in the area between the Marlborough Sounds and Westport. The three populations each have differences within their DNA indicating little or no gene flow between the populations (Baker *et al.*, 2010). A sub-population of offshore bottlenose dolphins also exists that travels more widely and often in larger groups.

There are two sightings in offshore waters surrounding the Vulcan Operational Area, one to the west and one to the northeast. While at Cape Egmont there has been a recorded stranding of a bottlenose dolphin. As a result, there is the potential for bottlenose dolphins to be observed during the Vulcan 3D MSS; however, given the distance offshore, if sighted it is most likely that they would be the offshore sub-species of bottlenose dolphins.

4.2.4.4.14 Dwarf Sperm Whale

They can grow up to 2.7 m in length and weigh up to 250 kg, which is smaller than some of the larger dolphins. These whales make slow, deliberate movements with little splash or blow and usually lie motionless when they are at the sea surface, making them hard to be observed in anything but very calm seas.

The dwarf sperm whale is very similar in appearance to the pygmy sperm whale, making differentiation difficult at sea; however, the dwarf sperm whale is slightly smaller and has a larger dorsal fin.

Feeding behaviour and target prey species are similar to that of the pygmy sperm whale but in shallower waters (Shirihai and Jarrett, 2006).

Given the lack in data available on this species, they are classified as "data deficient" by the IUCN red list.

Dwarf sperm whales are known to occur in temperate and tropical seas mainly along the shelf edges (Shirihai and Jarrett, 2006). They are rare in NZ waters (Te Ara, 2014b) and are not often sighted at sea, so most of the information on this species comes from stranded whales.

4.2.4.4.15 Maui's dolphin

The Maui's dolphin is a subspecies of the Hector's dolphin and is found off the west coast of the North Island (Maunganui Bluff in Northland to at least Oakura Beach, Taranaki) (see Section 4.2.4.4.17 for physical description, feeding, and acoustics of this species)

Under the Marine Mammals Protection Act 1978, Maui's dolphins are a protected species. They are classified as 'nationally critical' in the NZ threat classification and 'nationally endangered' by the IUCN. The most recent population estimate for the species is 55 individuals (95% confidence intervals of 48 – 69), which is significantly lower than the 2005 estimate of 111 individuals (95% confidence intervals of 48– 252) (Hamner *et al.*, 2012).

Maui's dolphins have a coastal distribution and are generally found in water depths of less than 20 m. Most sightings occur within 4 Nm of the coastline, although they have been sighted up to 7 Nm from the shore (Du Fresne, 2010) and from the Māui A platform located 19 nm from shore (Figure 16). The latter of the two sightings should be treated with caution as it was a public sighting without photo/video evidence.

Over the last ten years, marine mammal surveys have extended south of Raglan and Kawhia but no Maui's dolphins have been observed (Ferreira and Roberts, 2003; Slooten *et al.*, 2005; Webster and Edwards, 2008). This lack of sightings could be explained by the fact that these areas lie outside of the core range of the species or that dolphins are resident in the area but numbers are so low that they were simply missed during the surveys conducted in the region (Du Fresne, 2010). There is evidence that Maui's/Hector's dolphins visit the stretch of Taranaki coastline from reports of this species in Port Taranaki in 2007, video footage of a Maui's/Hector's dolphin off the Waiongana Stream in December 2009 and a Maui's/Hector's dolphin caught in a set net near Cape Egmont.

The Vulcan 3D MSS is being acquired in deep waters over 115 km offshore and beyond the AEI and west coast North Island MMS. However, even though the Vulcan Operational Area is located beyond the core range of most Maui's dolphin sightings, there is the potential that one could be observed when the vessel is mobilising to or from Port Taranaki when a MMO will be on the bridge taking any off-survey observations.

All the recorded sightings of Maui's dolphins on the DOC sighting database are all well inshore of the Vulcan Operational Area. The largest distribution of sightings have occurred along the inshore coastal waters centred between Kaipara Harbour to Kawhia Harbour, although they have been observed to the north and south of these harbours.

If a Maui's dolphin is sighted during this survey, DOC would be notified as soon as possible. If the sighting was reliable, DOC staff may mobilise a boat to try and gather a biopsy sample. The biopsy sample would be used to verify sub-species (Hector's or Maui's dolphin) using genetic (DNA) analysis and would add to the knowledge about the Maui's dolphin and their offshore range.

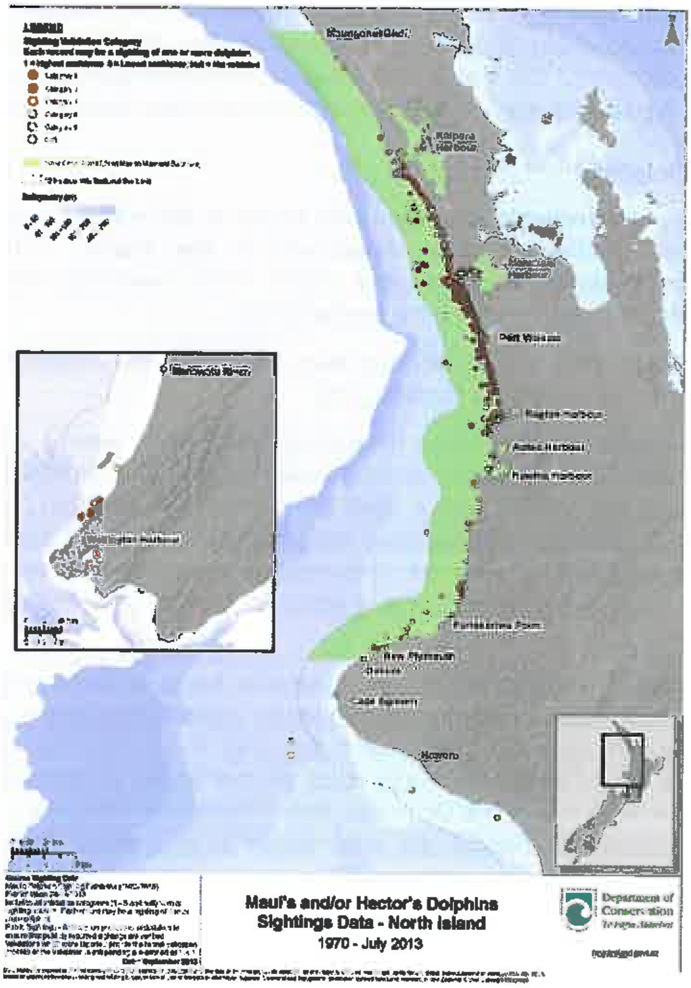

Figure 16: Maui's and/or Hector's dolphin sightings from 1970 – 2013

4.2.4.4.16 Bryde's Whale

This large rorqual can reach 15.6 m in length and weigh between 16-20 tonnes. They have a stream-lined body, an erect dorsal fin and present three rostrum ridges which are diagnostic of this species.

Bryde's whales are described as 'gulp-feeder' which prey upon zooplankton and schools of pelagic fish (Shirihai and Jarrett, 2006). Dives in this species will generally last up to 20 minutes.

Bryde's whales produce a 25-22 Hz downswept call which has been recorded by a number of authors (Kibblewhite *et al.*, 1967; McDonald, 2006). A second 22 Hz tonal call has also been associated to Bryde's whales in NZ waters, suggesting the existence of multiple stocks of this species (McDonald, 2006).

This species is described as data deficient by the IUCN red list and nationally critical under NZ legislation.

These whales are found most frequently in warmer waters and are known to feed on fish (pilchards, mackerel and mullet) but only rarely on zooplankton. In NZ, the Hauraki Gulf is a known year-round feeding ground and although some whales undertake limited seasonal migration, most have a restricted home range (Todd, 2014) (see Section 4.2.4.2).

There are no recorded sightings of Bryde's whales within the Vulcan Operational Area or the general proximity. One stranding event occurred inshore of the Vulcan Operational Area at the Mohakatino River mouth in 2000 so it is apparent they do frequent west coast waters. Therefore, given the timing of the Vulcan 3D MSS is scheduled during summer months there is the potential that Bryde's whales could be encountered when warmer waters are present.

4.2.4.4.17 Hector's Dolphin

Hector's dolphins are an endemic species (only found in NZ waters) and at 1.2 – 1.5 m in length they are one of the smallest cetaceans in the world. They have a highly distinguishable rounded dorsal fin and blunt snout. Their markings include a black mask which extends over the rostrum over to the pectoral fins.

Hector's dolphins forage on a range of small fish and crustacean species. Echolocation is used during foraging dives in order to locate prey.

Hector's dolphin use echolocation clicks (including 'cries' or 'squeals') to locate prey and to communicate. These vocalisations are centred around frequencies of 120-125 kHz (Dawson, 1990). Over the last 40 years, their numbers have declined significantly and as a result, the species is classified as 'nationally endangered' by the NZ threat classification list and as 'endangered' on the IUCN red list. It is believed set nets are responsible for ~75% of the known Hector's dolphin deaths but many more deaths may go unreported (MPI, 2014d; Project Jonah, 2014).

Hector's dolphins have a patchy distribution, generally living in three geographically distinct groups around the South Island. The most frequently sighted Hector's dolphins are found on the west coast between Jackson Bay and Kahurangi Point, on the east coast between Marlborough Sounds and Otago Peninsula, and on the south coast between Toetoes Bay and Porpoise Bay as well as in Te Waewae Bay (Fisheries Management Science Team, 2013). Smaller population densities are also found in Fiordland, Golden Bay and south Otago coast. There is significant genetic differentiation among the west, east and south coast populations, with little or no gene flow connecting them (Hamner *et al.*, 2012).

In recent years, MPI funded survey programmes have been conducted to assess abundance and distribution of the south coast South Island and east coast South Island populations of Hector's dolphin (Clement *et al.*, 2011; MacKenzie and Clement, 2013). The data collection programme involved summer and winter aerial surveys during which Hector's dolphins observed along transect lines were recorded. The resulting sightings data was analysed using mark-recapture and density surface modelling techniques to yield estimates of density and total abundance. It was estimated that the south coast South Island population includes 628 dolphins (95% CI = 301-1,311).

For the east coast South Island surveys, a total of 354 dolphin groups were sighted in summer and 328 dolphin groups were sighted in winter. After analysis, the data yielded estimates of 9,130 animals (95% CI = 6,342-13,144) for summer and 7,465 animals (95% CI = 5,224-10,641) for winter. Hector's dolphin numbers are believed to have increased within the Banks Peninsula MMS and are now routinely reported around the Marlborough Sounds (Hamner *et al.*, 2012). The South Island west coast population is estimated at about 5,400 (MPI, 2014d).

Hector's dolphins are often observed close to shore in waters of under 100 m depth as they prefer shallow, turbid environment. However, occasional sightings have occurred beyond the 100 m isobaths at distances out to 20 Nm off Banks Peninsula (MacKenzie and Clement, 2013). In addition, a sighting of a Hector's dolphin from the Māui platform in the South Taranaki Bight supports they can be found further offshore. During the Hamner *et al.* (2012) study, two female Hector's dolphins from the west coast South Island were observed in the North Island constituting the first documented contact between these two sub-species and indicating there is the potential for interbreeding to occur.

There have been four recorded sightings of Hector's dolphins inshore of the Vulcan Operational Area, all of which have been in shallow coastal waters, within 1.5 km of the coastline. A number of stranding events have also been recorded around the entire Taranaki coastline indicating that these dolphins do frequent the Taranaki waters.

Therefore it is highly likely that Hector's dolphins will be in the Taranaki waters during the Vulcan 3D MSS; however, they are most likely to be in shallow waters, well inshore of the Vulcan Operational Area.

4.2.5 Pinnipeds

Nine species of pinnipeds (seals and sea lions) have been recorded in NZ waters (Suisted and Neale, 2004). Of these, the NZ fur seal (*Arctocephalus forsteri*) is the most commonly occurring species (50,000-60,000 individuals across both islands) and the only one expected to occur in the Vulcan Operational Area.

NZ fur seals forage for food along continental shelf breaks up to 200 km offshore but are generally distributed inshore, in water depths of less than 100 m. They are known to dive for up to 12 minutes (~ 200 m) to feed on fish (small mid-water fish, conger eels, barracouta, jack mackerel and hoki), squid and octopus.

Breeding season in NZ fur seals extends from mid-November to mid-January and pups are suckled for up to 300 days. During that time, females will alternate between foraging at sea and returning to the rookery to feed their young. The main breeding sites along the Taranaki coastline are the Sugar Loaf Islands Marine Protected Area and Tapuae Marine Reserve (MPI, 2014e).

Sighting information for this species covers the extent the country and it is noted that a large proportion of the sighting observations have arisen from previous MSS around NZ where dedicated MMOs have been onboard. As a result, it is highly likely that NZ fur seals will be observed within the Vulcan Operational Area; however it is unlikely that any other pinniped species would be in this area.

4.2.6 Marine Reptiles

Seven marine reptile species are known to occur in NZ waters: leatherback turtle (*Dermochelys coriacea*) (60 records), green turtle (*Chelonia mydas)* (44 records), yellow-bellied sea snake (*Pelamis platurus)* (21 records), hawksbill turtle (*Eretmochelys imbricate)*

(18 records), the loggerhead turtle (*Caretta caretta)* (18 records), olive Ridley turtle (*Lepidochelys olivacea)* (four records), and the banded sea snake (*Laticauda colubrine)* (two records). These species are most commonly found in warm waters. As a result, most sightings occur around Northland (DOC, 2014e).

Within Taranaki waters, there are records of "live or dead specimen, or shed skin" of the leatherback turtle and the yellow-bellied sea snake (DOC, 2013a). These are rare visitors to Taranaki waters and if any reptiles are recorded during the Vulcan 3D MSS they would be recorded to further increase the knowledge of NZ's marine reptiles. However, it should be noted that Taranaki is outside of the core range of these species and any individuals observed in Taranaki waters would be considered to be vagrant.

4.2.7 Seabirds

There are 86 species of seabirds which breed in NZ waters. These include albatross, cormorants, shags, fulmars, petrels, prions, shearwaters, terns, gulls, penguins and skuas (Farr Biswell, 2007).

Worldwide, seabirds are more threatened than any other comparable bird groups (28% are threatened globally). Furthermore, pelagic seabirds are at higher risk than coastal birds as a result of their comparatively small clutch size (Croxall *et al.*, 2012).

According to a report published by Bird Conservation International, NZ has the highest number of "seabird species of conservation concern (breeding and non-breeding species combined)" (Croxall *et al.*, 2012).

A number of sources (IUCN, 2014; NZ Birds online, 2014; Parkinson, 2006; Robertson *et al.*, 2013) have been used to identify the seabirds most likely to be observed in and around the Vulcan Operational Area and their conservation status. The list is as follows:

- **Snowy wandering albatross** *(Diomedea exulans)* – common visitor to NZ waters; vessel follower; IUCN "vulnerable" status; Vulcan Operational Area within "species normal range"; DOC conservation status "non-resident native, migrant, threatened overseas";
- **Gibson's wandering albatross** *(Diomedea gibsoni)* – uncommon endemic; vessel follower; not yet assessed by IUCN; Vulcan Operational Area within "species normal range"; DOC conservation status "threatened, island endemic, one location";
- **Antipodean wandering albatross** *(Diomedea antipodensis)* – uncommon endemic; vessel follower; IUCN "vulnerable" status; Vulcan Operational Area within "species normal range"; DOC conservation status "threatened, island endemic, recruitment failure, range restricted";
- **Southern royal albatross** *(Diomedea epomophora)* – locally common endemic; IUCN "vulnerable" status; Vulcan Operational Area within "species normal range" and including a hotspot for the species west of Taranaki; DOC conservation status "at risk, naturally uncommon, range restricted";
- **Northern royal albatross** *(Diomedea sanfordi)* – locally common endemic; IUCN "endangered" status; Vulcan Operational Area within "species normal range"; DOC conservation status "at risk, naturally uncommon, range restricted";
- **Light mantled sooty albatross** *(Phoebetria palpebrata)* – uncommon native; vessel follower; appears at the coast in periods of high winds; IUCN "near threatened" status; Vulcan Operational Area within "species normal range"; DOC conservation status "at risk, declining, data poor, range restricted, secure overseas";
- **Black-browed mollymawk** *(Thalassarche melanophris)* – common native; most commonly seen mollymawk; IUCN "near threatened" status; DOC conservation status "non-resident native, coloniser, threatened overseas"

- **Campbell Mollymawk** *(Thalassarche impavida)* – common endemic; vessel follower; IUCN "vulnerable" status; Vulcan Operational Area within "species full range"; DOC conservation status "at risk, naturally uncommon, island endemic, one location";
- **Shy mollymawk** *(Thalassarche cauta)* – uncommon visitor; vessel follower; IUCN "near threatened" status; DOC conservation status "non-resident native, vagrant, secure overseas";
- **White-capped mollymawk** *(Thalassarche steadi)* – locally common endemic; keen vessel follower; IUCN "near threatened" status; Vulcan Operational Area within "species normal range"; DOC conservation status "at risk, declining, extreme fluctuations, range restricted";
- **Salvin's mollymawk** *(Thalassarche salvini)* – locally common endemic; keen vessel follower; IUCN "vulnerable" status; Vulcan Operational Area within "species normal range"; DOC conservation status "threatened, nationally critical, range restricted";
- **Grey-headed mollymawk** *(Thalassarche chrysostoma)* – locally common native; gathers around stationary boats; IUCN "endangered" status; Vulcan Operational Area within "species normal range"; DOC conservation status "threatened, nationally vulnerable, one location, threatened overseas";
- **Buller's mollymawk** *(Thalassarche bulleri)* – locally common endemic; vessel follower; IUCN "near threatened" status; DOC conservation status "at risk, naturally uncommon, range restricted";
- **Pacific mollymawk** *(Thalassarche nov spi. / platei)* – locally common endemic; vessel follower; not yet assessed by IUCN; DOC conservation status "at risk, naturally uncommon, range restricted";
- **Flesh-footed shearwater** *(Puffinus carneipes)* – common native; attracted to stationary vessels; migrates to North Pacific in the winter; IUCN "least concern" status; Vulcan Operational Area within "normal species offshore range" and including coastal hotspots; "range restricted"; DOC conservation status "threatened, nationally vulnerable, threatened overseas";
- **Buller's shearwater** *(Puffinus bulleri)* – common endemic; migrates to America during the winter; IUCN "vulnerable" status; Vulcan Operational Area within "species normal range" and including a hotspot on the tip of Northland and off the northwest coast of NZ; DOC conservation status "at risk, naturally uncommon, one location, stable";
- **Sooty shearwater** *(Puffinus griseus)* – abundant native; migrates to northern pacific in the winter; IUCN "near threatened" status; Vulcan Operational Area within the "species normal range" and including a hotspot off Northland; DOC conservation status "at risk, declining, secure overseas";
- **Short-tailed shearwater** *(Puffinus tenuirostris)* - locally common migrant; migrates to the northern pacific in the winter; passes through NZ waters during spring and autumn migrations; not yet assessed by IUCN; DOC conservation status "non-resident native, migrant, secure overseas";
- **Fluttering shearwater** *(Puffinus gavial)* - abundant endemic; ranges offshore in the winter; not yet assessed by IUCN; DOC conservation status "at risk, relict, range restricted";
- **Little shearwater** *(Puffinus assimilis)* - locally common native; IUCN "least concern" status; DOC conservation status "non-resident native, vagrant, secure overseas";
- **Common diving petrel** *(Pelecanoides urinatrix)* - abundant native; IUCN "least concern" status; DOC conservation status "not threatened, designated, range restricted, secure overseas";
- **Black petrel** *(Procellaria parkinsoni)* – rare endemic; IUCN "vulnerable" status; Vulcan Operational Area within species normal range; DOC conservation status "threatened, nationally vulnerable, range restricted";

- **Southern giant petrel** *(Macronectes giganteus)* – common visitor; IUCN "least concern" status; Vulcan Operational Area within the "species full range"; DOC conservation status "non-resident native, migrant, secure overseas";
- **Northern giant petrel** *(Macronectes halli)* – common native; IUCN "least concern" status; Vulcan Operational Area within "species full range"; DOC conservation status "at risk, naturally uncommon, range restricted, secure overseas";
- **Black-winged petrel** *(Pterodroma nigripennis)* – locally common native; IUCN "least concern" status; DOC conservation status "not threatened, designated, increasing, range restricted";
- **Kermadec petrel** *(Pterodroma neglecta)* – locally common native; IUCN "least concern" status; Vulcan Operational Area within the "species full range"; DOC conservation status "at risk, relict, secure overseas";
- **Grey-faced petrel** *(Pterodroma macroptera)* – common native; IUCN "least concern" status; Vulcan Operational Area within "species full range" and including a coastal hotspot; DOC conservation status "not threatened, designated, increasing, range restricted";
- **Wilson's storm petrel** *(Oceanites oceanicus)* – locally common native; IUCN "least concern" status; DOC conservation status "non-resident native, migrant, secure overseas";
- **White-faced storm petrel** *(Pelagodroma marina)* – common native; IUCN "least concern" status; DOC conservation status "non-resident native, vagrant, secure overseas";
- **Snares cape pigeon** *(Daption capense)* - common native; IUCN "least concern" status; DOC conservation status "at risk, naturally uncommon, range restricted"
- **Fairy prion** *(Pachyptila turtur)* – locally abundant native; IUCN "least concern" status; DOC conservation status "at risk, relict, range restricted, secure overseas"
- **Antarctic prion** *(Pachyptila desolata)* – locally common native; IUCN "least concern" status; DOC conservation status "at risk, naturally uncommon, range restricted, secure overseas";
- **Blue penguin** *(Eudyptula minor)* – common native; IUCN "least concern" status; DOC conservation status "at risk, data poor, extreme fluctuations";
- **Australasian gannet** *(Morus serrator)* – common native; common in coastal waters and harbours and estuaries; IUCN "least concern" status; DOC conservation status "not threatened, designated, increasing, secure overseas";
- **Black shag** *(Phalacrocorax carbo)* – common native; seen in sheltered coastal waters, lakes and rivers; IUCN "least concern" status; DOC conservation status "at risk, naturally uncommon, secure overseas, sparse";
- **Little black shag** *(Phalacrocorax sulcirostris)* – locally common native; seen in lakes and sheltered coastal waters in northland; IUCN "least concern" status; DOC conservation status "at risk, naturally uncommon, range restricted";
- **Little shag** *(Phalacrocorax melanoleucos)* - common native; IUCN "least concern" status; DOC conservation status "not threatened, increasing";
- **Arctic skua** *(Stercorarius parasiticus)* - common arctic migrant; occurs in coastal waters of NZ in summer; IUCN "least concern" status; DOC conservation status "non-resident native, migrant, secure overseas";
- **Pomarine skua** *(Stercorarius pomarinus)* - uncommon arctic migrant; occurs in coastal and oceanic waters of NZ in summer; IUCN "least concern" status; DOC conservation status "non-resident native, migrant, secure overseas";
- **Black-backed gull** *(Larus dominicanus)* – abundant native; occurs in most coastal areas; IUCN "least concern" status; DOC conservation status "not threatened, secure overseas";

- **Red-billed gull** *(Larus novaehollandiae)* – abundant native; occurs in most coastal areas; IUCN "least concern" status; DOC conservation status "threatened, nationally vulnerable";
- **Black-billed gull** *(Larus bulleri)* – endangered endemic; IUCN "endangered" status; Vulcan Operational Area within "normal coastal species range" from mid-Taranaki to north of Kaipara and full range north of that; "recruitment failure"; DOC conservation status "threatened, nationally critical";
- **Caspian tern** *(Hydroprogne caspia)* – reasonably common native; occurs in sheltered coastal waters, harbours and estuaries; species not yet assessed by IUCN; Vulcan Operational Area is within the "normal coastal species range" and includes hotspots located around the harbours of the west coast and the tip of northland; DOC conservation status "threatened, nationally vulnerable, secure overseas, sparse";
- **White-fronted tern** *(Sterna striata)* – abundant endemic; occurs in inshore NZ waters; IUCN "least concern" status; DOC conservation status "threatened, nationally vulnerable, data poor, range restricted";
- **Little tern** *(Sterna albifrons)* – uncommon Asian migrant; occurs in Kaipara and Manukau harbours to the northeast of the Vulcan Operational Area; IUCN "least concern" status; DOC conservation status "non-resident native, migrant, secure overseas";
- **White tern** *(Anous tenuirostris)* – rare native; IUCN "least concern" status; Vulcan Operational Area within "species normal range"; DOC conservation status "threatened, conservation dependant, one location, secure overseas".

4.2.7.1 Seabird Breeding Areas

New Zealand has been recognised to have the "highest number of endemic breeding seabird species worldwide" (Croxall *et al.*, 2012). Numerous seabird colonies are known to breed along the Taranaki and Waikato coastlines which are located at least 115 km away from the Vulcan Operational Area (ARC, 2013; Brooks *et al.*, 2011; DOC, 1999; Gill *et al.*, 2010; MPI, 2014e; NZ Birds online, 2014; Parkinson, 2006; Pierce and Parrish, 1993; Powlesland, 1990). These species are listed below and the locations of the main breeding areas for all species are displayed on the map in Figure 17.

- Australasian gannet *(Morus serrator)* – breeding season: August to March;
- Black-backed gull *(Larus dominicanus)* – breeding season: September to March;
- Black shag *(Phalacrocorax carbo)* – breeding season: year round;
- Blue penguin *(Eudyptula minor)* – breeding season: July to February;
- Flesh-footed shearwater *(Puffinus carneipes)* – breeding season: September to May;
- Grey-faced petrel *(Pterodroma macroptera)* – breeding season: March to January;
- Little black shag *(Phalacrocorax sulcirostris)* – breeding season: October to December;
- Little shag *(Phalacrocorax melanoleucos)* – breeding season: August to March;
- Little shearwater *(Puffinus assimilis)* – breeding season: April to November;
- Red-billed gull *(Larus novaehollandiae)* – breeding season: September to January;
- Sooty shearwater *(Puffinus griseus)* – breeding season: November to May;
- White-fronted tern *(Sterna striata)* – breeding season: October to January; and

It should be noted that a number of coastal and estuarine bird species also breed along the Taranaki and Waikato coastlines ((ARC, 2013; DOC, 1999; NZ Birds online, 2014); however these breeding areas are located 115 km inshore of the Vulcan Operational Area. These include the "nationally critical" grey duck *(Anas superciliosa)*; "nationally endangered" Australasian bittern *(Botaurus poiciloptilus)* and reef heron *(Egreta sacra)*; and the "nationally vulnerable" blue duck *(Hymenolaimus malacorynchus)*, NZ dotterel *(Charadrius obscurus)* and banded dotterel *(Charadrius bicinctus)* (Robertson *et al.*, 2013).

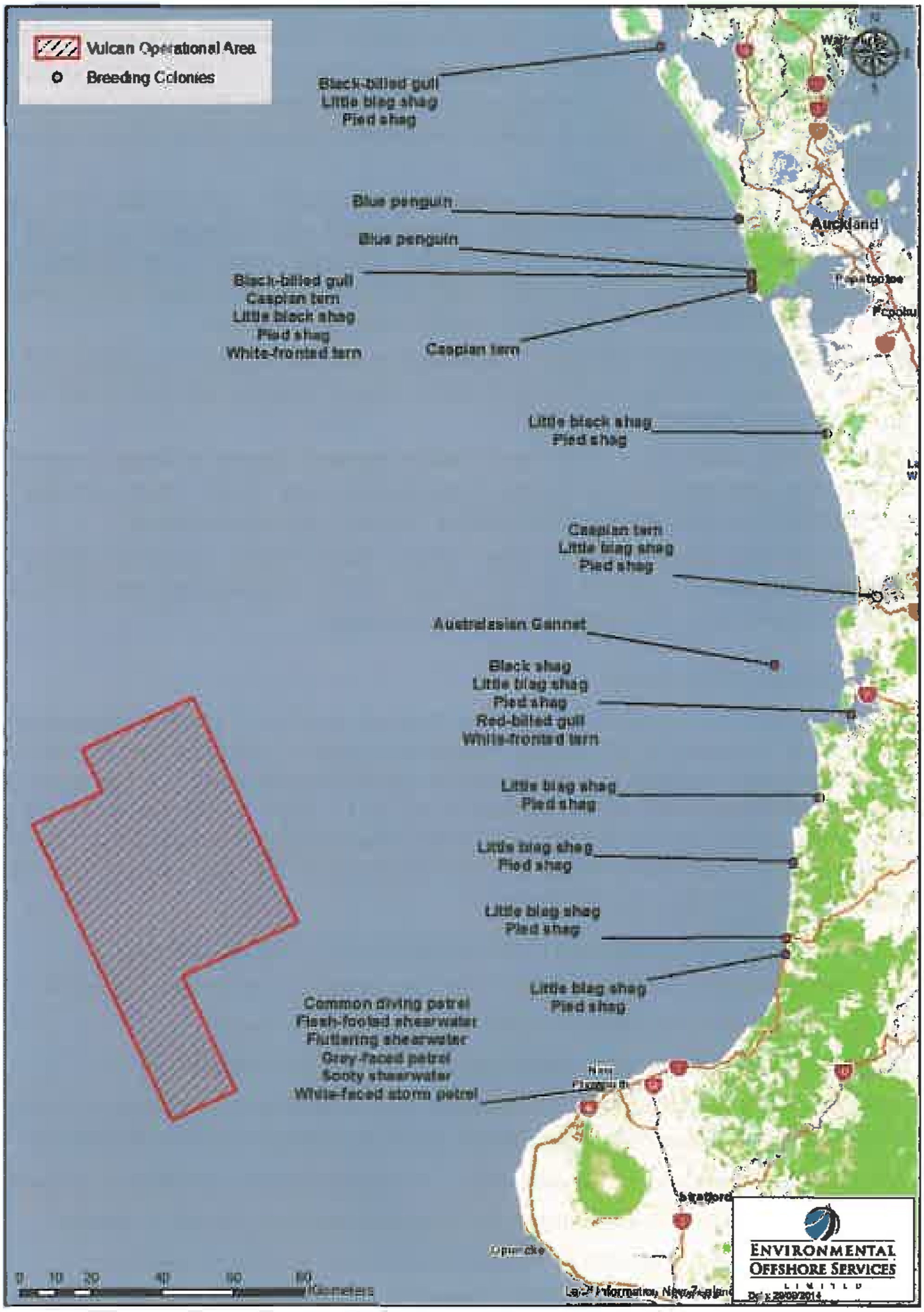

Figure 17: Seabird breeding areas

4.3 Coastal and marine conservation

4.3.1 Regional Coastal Environment

Inshore of the Vulcan Operational Area within the Coastal Marine Area (CMA) is the responsibility of Waikato Regional Council and Taranaki Regional Council (Figure 18). Each Council has within their jurisdiction a range of different habitats and areas of significance that are unique to that region. The following section provides an overview of the regional coastal environments inshore of the Vulcan Operational Area.

Figure 18: Regional Council Boundaries Inshore from the Vulcan Operational Area.

4.3.1.1 Waikato Coastline

Waikato Regional Council has identified the sites listed below as Areas of Significant Conservation Value (ASCV) within the Waikato Regional Coastal Plan (Waikato Regional Council, 2014). The sites are identified based on the presence of Māori cultural values of local, regional or national significance; the presence of protected areas; wetlands estuaries and coastal lagoons or national or international significance; habitats, breeding sites, roost sites or feeding sites of marine mammals and birds; ecosystems, flora and fauna habitats with regionally, nationally or internationally significant or threatened ecosystems or species; scenic sites of regional, national or international importance; historic places of outstanding significance; representative examples of nationally significant or outstanding coastal landforms and associated processes. A summary of the ASCVs along this coastline are shown in Figure 19 and are listed below:

- **Mokau River Estuary** – is a site of cultural importance to Taranaki and Tainui iwi. Furthermore, it is a regionally important site for whitebait (spawning habitat) and native fishery. Rare and threatened wildlife is resident or is known to occur in the estuary's waters (waders and coastal birds, Hector's/Maui's dolphin). The coastal features in this area have also been identified as valuable.
- **Marokopa River Estuary** – is of cultural importance to Tainui iwi for kaimoana gathering. Rare and threatened wildlife is resident or is known to occur in the estuary's waters (waders and coastal birds, Hector's/Maui's dolphin). Important geopreservation sites (Marokopa zeolite facies, Marokopa-Kiritehere coast, Marokopa River mouth Triassic-jurassic contact) have also been identified.
- **Albatross Point and adjoining coastline** – is a site of cultural importance for Tainui iwi for the purpose of kaimoana gathering. NZ fur seals are known to haul out in the area. The site is also significant from a geological perspective (fossils). Arataura Point and Ururoa Point are of particular significance.
- **Kawhia Harbour** – is a valuable site to the Tainui iwi which is referred to as the "Hearth of Tainui". It also encompasses a canoe resting site – Te Ahurei. The harbour is an outstanding habitat for wildlife including endangered rare and threatened wading and coastal bird species. It possesses extensive eel grass communities and Hector's/Maui's dolphin are also know to occur in its waters. Other sites of note include fossil sites (Te Maika Point, Totara Point, Arataura Point, Heteri Point, Ohaua Point, Ururoa Point, Puti Point, and Motutara Peninsula), Waiharakeke Bridge – kinohaku Jurassic sequence, Maire point, the historic pohutukawa tree, and Te Puia Springs.

  Kawhia Harbour has been described as a 'seafood basket' of Tainui, because of the richness of the kaimoana. To help protect the rich kaimoana found at Kawhia, a taiapure was established in 2000 which covers Kawhia Harbour out to 2 Nm (see Section 4.3.5.1).
- **Aotea Harbour** – is a site of cultural importance to Tainui iwi. The harbour adjoins a sandspit and dune system which is classified as Scientific Reserve. The site contains extensive eel grass communities which forms a significant vegetation community in the harbour as well as being the base of the food chain for herbivores. Aotea Harbour is relatively sandy as a result of having the majority of the freshwater wetlands remaining intact. These wetlands provide an important filter between the land and the harbour and provide significant habitat for wetland birds such as the fernbird. Rare and threatened waders and coastal birds are resident or occur in its waters as well as Hector's/Maui's dolphins which can be sighted in the area. From a geological perspective, the site contains a nationally significant dune complex of titanomagnetic iron sand and two geopreservation sites (Aotea dune fields and Taranaki Point).

  The Aotea Harbour is a site of cultural importance as it was the landing place of the Aotea waka, which brought the ancestors of the Ngā Rauru and Ngāti Ruanui tribes to New Zealand. When they discovered the Tainui people in occupation, they travelled south to Taranaki.
- **Gannet Island** – consists of the eroded remnant of a 'tuff ring', and erupted about half a million years ago. It is located on the eastern edge of the North Taranaki graben, rising 15 m above sea level from a base about 65 m deep. Gannet Island is protected as a wildlife sanctuary as it is New Zealand's largest single breeding colony of Australasian Gannets, holding in excess of 20,000 breeding birds through November to February. Gannet Island also provides a haul out area and breeding site for NZ fur seals.
- **Raglan Harbour** – runs 12 km inland from the entrance and is a site of cultural significance to Tainui iwi. Numerous rare and threatened wading and coastal birds reside or frequent the area. The Raglan area has been inhabited for at least 800 years and was originally known by Maori as Whangaroa 'the long pursuit'. To avoid confusion with another place of the same name, Whaingaroa was later adopted. Raglan harbour has resident and frequenting rare and threatened wading and coastal fauna, and is also

known to have sightings of Hector's/Maui's dolphin and is recognised as the southern limit of mangroves.

- **Waikato River mouth and estuary** – is of immense value to Tainui iwi. It is a wildlife habitat of high value and a nationally significant whitebait and native fishery. Rare and threatened waders and coastal birds are known to reside in or frequent the area. In addition, the site is recognised as nationally significant for fossil and exposed land forms and comprises two geopreservation sites (Port Waikato complex landslide, Port Waikato).

4.3.1.2 Taranaki Coastline

The Taranaki Regional Coastal Plan (TRC, 1997) defines a number of areas within the CMA with significant conservation values that have policies in place to protect them from any adverse effects of use or development. The significant areas of relevance to this report within the Taranaki region to the Vulcan Operational Area are shown in Figure 19 and discussed further below.

- **Pariokariwa Point to Waihi Stream** – This section of coastline contains a diverse range of nationally and locally significant features. The area includes fur seal haul-out and seabird roosting areas on Opourapa Island, offshore reefs contain abundant marine life, outstanding natural landscape at White Cliffs and its associated walkway, a shipwreck, important breeding habitat for fluttering shearwaters, the grey faced petrel and little blue penguins. The Mohakatino Estuary to the north is considered nationally significant. The estuary supports whitebait, flounder and shellfish, and the adjacent sand flats and wetland are habitat for threatened species such as Australasian bittern and Caspian tern. The large Tongaporutu Estuary to the south is an important nesting area for little blue penguins and grey-faced petrels. The rare variable oystercatcher has also been recorded there. The estuary includes whitebait spawning habitat and an abundance of shellfish with high species diversity. A large reef, supporting a range of marine life and sponges, extends 8 km offshore. The natural landscape includes offshore stacks, cliffs, and caves.
- **Mimi Estuary** – This area includes tidal mudflats, saltmarsh and sand dune habitat which are uncommon in north Taranaki. It provides habitat for migratory and wading birds, whitebait spawning habitat in upper estuary, feeding grounds for snapper and trevally, nursery area for juvenile marine species including flounder and a periodic breeding site for blue penguins.
- **Sugar Loaf Islands Marine Protected Area (SLIMPA)**- is the remnants of an old volcano formed 1.75 million years ago that has eroded away leaving a group of low sea stacks and seven islands providing a unique semi-sheltered environment with a diverse range of underwater habitats and marine life, along an otherwise exposed coastline (DOC, 2014c). A diverse range of subtidal marine habitats provides shelter for at least 89 species of fish, 33 species of encrusting sponges, 28 species of bryozoans and 9 nudibranchs (DOC, 2014c). SLIMPA is predator free and there are 19 species of seabirds found on and around the island, with ~10,000 seabirds nesting there each year. The NZ fur seal also use SLIMPA as breeding grounds.
- **Tapuae Marine Reserve** - covers 1,404 ha and has a diverse range of habitats including canyons and boulder fields; providing a safe haven and nursery for a wealth of underwater marine life (DOC, 2014e). It adjoins SLIMPA and extends south to Tapuae Stream and has a contrast of marine environments within the reserve. To the northwest of the reserve are islands, remnants of an ancient volcano with caves, canyons, boulder fields, while to the southwest it is less sheltered and is a classic example of the wild Taranaki coastline (DOC, 2014f). A diverse range of fish, invertebrate and algal species live in the reserve and it is an important breeding and haul out area for NZ fur seals.
- **Whenuakura Estuary** - a relatively unmodified estuary providing habitat for the threatened Caspian tern and rare variable oystercatcher. The estuary is a route or migratory birds and is an important whitebait spawning habitat.

- **North and South Traps** - an unusual feature on an otherwise sandy coastline with an extensive *Ecklonia radiata* kelp forest which hosts diverse and abundant in marine life.
- **Waverley Beach** - is regarded as an outstanding natural landscape with eroding stacks, caverns, tunnels and blowholes.
- **Waitotara Estuary** - an unmodified estuary with a number of sub-fossil totara stumps present. It provides habitat to a number of threatened birds (Australian bittern, NZ shoveller and black swan) as well as being a stopover point for migratory wading birds and international migrant birds.
- **Waiinu Reef** - has limestone rock outcrops which extend from shore out to 500 m offshore. Many well-preserved fossils are present in the hard rock platforms and there is an abundance of marine life around these outcrops and platforms.

Figure 19: Waikato and Taranaki Areas of Significant Conservation Value

4.3.2 New Zealand Marine Environmental Classification

MfE, MPI and DOC commissioned NIWA to develop an environmental classification called the NZ Marine Environment Classification (NZMEC). The NZMEC covers NZ's Territorial Sea and EEZ to provide a spatial framework for structured and systematic management, where geographic domains are divided into units that have similar environmental and biological characters (MfE, 2005).

Physical and biological factors (depth, solar radiation, sea surface temperatures (SST), waves, tidal current, sediment type, seabed slope and curvature) were used to classify and map marine environments around NZ.

The Vulcan Operational Area falls within NZMEC groups 22, 60, 63 and 64, representing the moderately shallow waters on the continental shelf out to deep water (Figure 20), and are described below following the categories defined by NIWA (MfE, 2005).

- **Class 22:** is extensive in moderately deep waters (mean = 1,879 m) and is typified by cooler winter SST. Chlorophyll-*α* only reaches low average concentrations, with characteristic fish species being orange roughy, Baxter's lantern dogfish, Johnson's cod and hoki.
- **Class 60**: occupies moderately shallow waters (mean = 112 m) on the continental shelf. It experiences moderate annual solar radiation and wintertime SST and has moderately high average chlorophyll-*α* concentrations. Some of the most commonly occurring fish species are barracouta, red gurnard, John Dory, spiny dogfish, snapper and sea perch, while arrow squid are also frequently caught in trawls. The most commonly represented benthic invertebrate families are Dentaliidae, Cardiidae, Carditidae, Nuculanidae, Amphiuridae, Pectinidae and Veneridae.
- **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-*α* concentrations are also moderate. Characteristic fish species include orange roughy, Johnson's cod, Baxter's lantern dogfish, hoki, smooth oreo and javelin fish. The most commonly represented benthic invertebrate families are Carditidae, Pectinidae, Dentaliidae, Veneridae, Cardiidae, Serpulidae and Limidae.
- **Class 64**: occupies a similar geographic range to the previous class but occurs in shallower waters (mean = 38 m). Seabed slopes are low but orbital velocities are moderately high and the annual amplitude of SST is high. Chlorophyll *a* reaches its highest average concentrations in this class. Some of the most commonly occurring fish species are red gurnard, snapper, John Dory, trevally, leather jacket, barracouta and spiny dogfish. Arrow squid are also frequently caught in trawls. The most commonly represented benthic invertebrate families are Veneridae, Mactridae and Tellinidae.

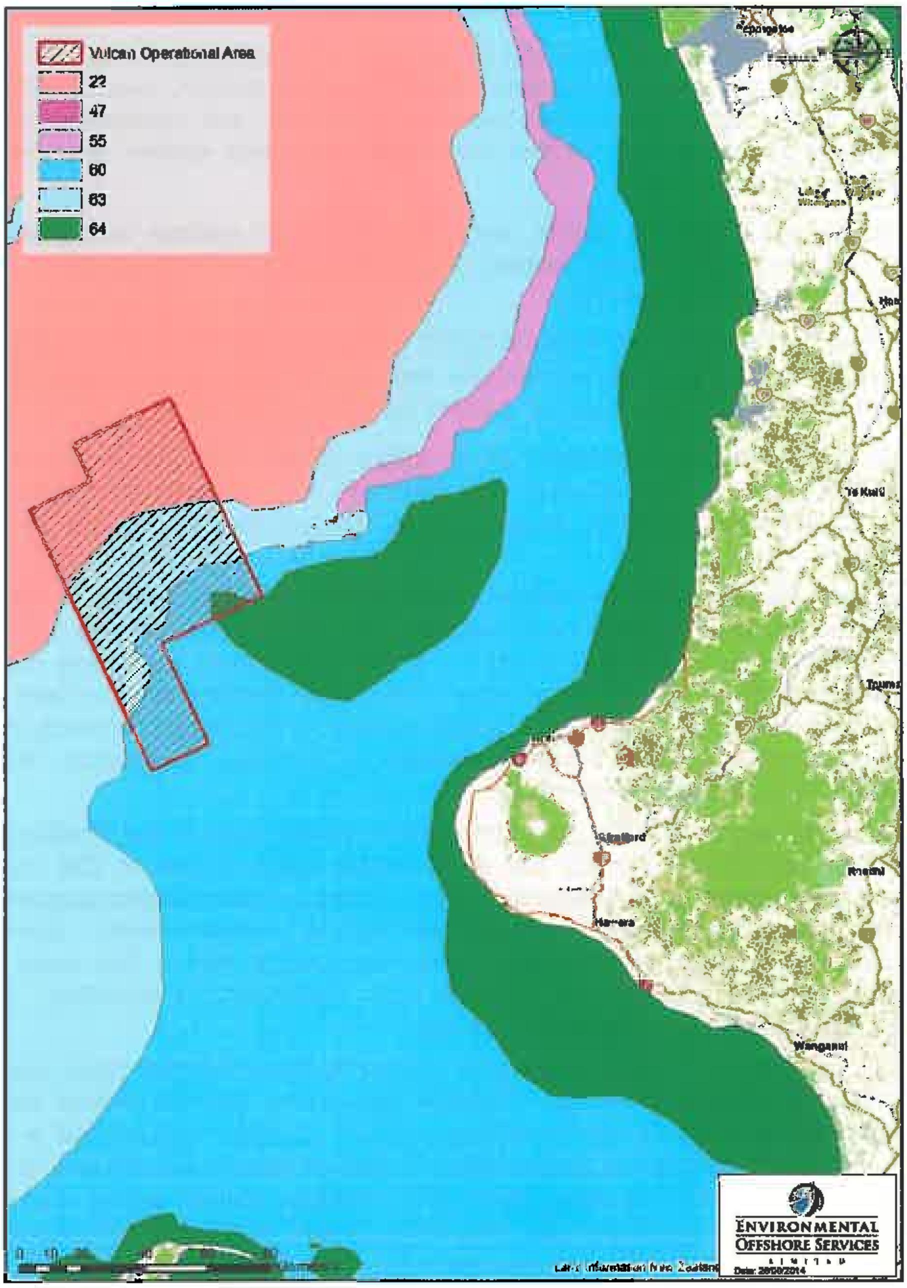

Figure 20: The NZMEC categories for the Taranaki region overlaid with the Vulcan Operational Area.

4.3.3 Protected Natural Areas

Protected Natural Areas (PNA) are put in place for biodiversity conservation and receive varying degrees of protection as a result of their recognised natural ecological values. There are numerous different types of PNAs which include national parks, conservation parks, nature reserves, scientific reserves, and scenic reserves.

They are managed under six main pieces of legislation Conservation Act 1987, National Parks Act 1980, Reserves Act 1977, Wildlife Act 1953, Marine Reserves Act 1971, and the Marine Mammals Protection Act 1979.

The main PNAs in the vicinity of the Vulcan Operational Area are detailed below and displayed in Figure 22.

4.3.3.1 Coastal Protected Natural Areas

There are numerous coastal PNAs around the Taranaki coastline. Along the coastline inshore of the Vulcan Operational Area recreation reserves are the most common type of PNA. These recreational reserves include **Pariokariwa Reef, Bell Block, Pukearuhe, Fitzroy beach, East End Beach, New Plymouth foreshore, Paritutu, Kawaroa Park, Ahu ahu, Weld** and **Timaru Road Beaches, Kina road** and **Oanui Beach**. Historic reserves are also scattered along the shoreline and comprise, amongst others, the **Te Kawau, Pou Tehia**, and **Pukearuhe Historic Reserve.** Other PNAs include scenic reserves such as **Tataraimaka Pā Scenic reserve** and the **Maitahi Scientific Reserve** (TRC, 2004).

Along the Waikato coastline, the main reserves include **Wainui reserve (Ngaranui Beach)**, **Manu Bay**, **Whale Bay**, and **Sunset Beach (Port Waikato)**.

4.3.3.2 Marine Protected Natural Areas

The West Coast North Island MMS is in place for a large part of the west coast of NZ for the protection of Maui's dolphins. The boundary goes from Oakura Beach in the south to Maunganui Bluff in Northland and extends offshore to 12 Nm. The total area of this sanctuary is approximately 1,200,086 ha and covers 2,164 km of coastline. Within certain parts of this sanctuary there are restrictions on acoustic seismic surveys, seabed mining activities, set net and trawl fishing. Seismic surveys are regulated within the entire MMS in accordance with the Marine Mammals Protection (West Coast North Island Sanctuary) Notice 2008. Seabed mining is restricted, while set net and trawl fishing is restricted under the Fisheries Act. The West Coast North Island MMS was gazetted to protect Maui's and Hector's dolphins.

In 2013, the Minister of Conservation varied the West Coast North Island MMS to prohibit commercial and recreational set net fishing between 2 – 7 Nm offshore between Pariokariwa Point and the Waiwhakaiho River, Taranaki under the Marine Mammals Protection Act 1978. This area covers 350 km^2 of the MMS. The purpose of the variation to the MMS was to provide greater protection to Maui's dolphins from the risks resulting from set net fishing (commercial and recreational).

The **Parininihi Marine Reserve** is an offshore reserve located in North Taranaki adjacent to the White Cliffs (Figure 21). The 1,800 hectares of marine environment host numerous fish species and are particularly valued for their sponge gardens (see Section 4.2.2). The reserve is managed using an integrated approach which involves a number of different parties including Ngati Tama, the Conservation Board and DOC (DOC, 2014d).

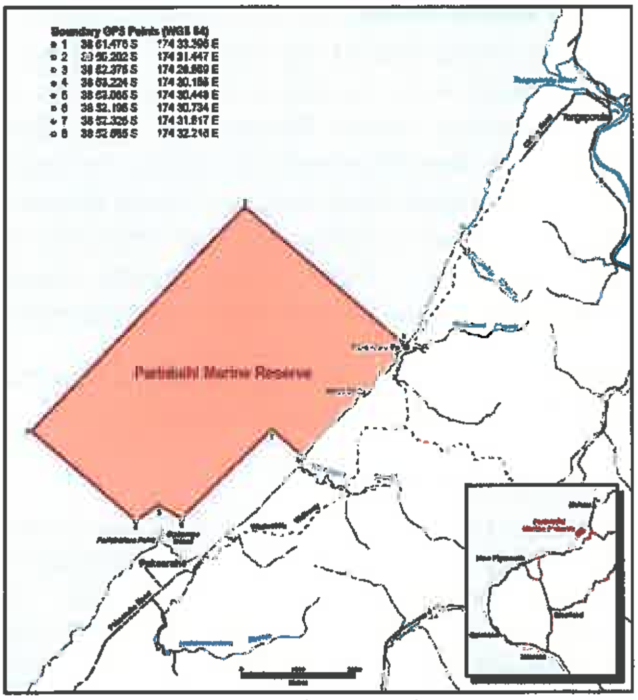

Figure 21: Paraninihi Marine Reserve (source: www.doc.govt.nz)

Other PNAs around the Taranaki coastline include the **Tapuae Marine Reserve** and **Sugar Loaf Marine Protected Area** which are both covered in detail in Section 4.3.1.2.

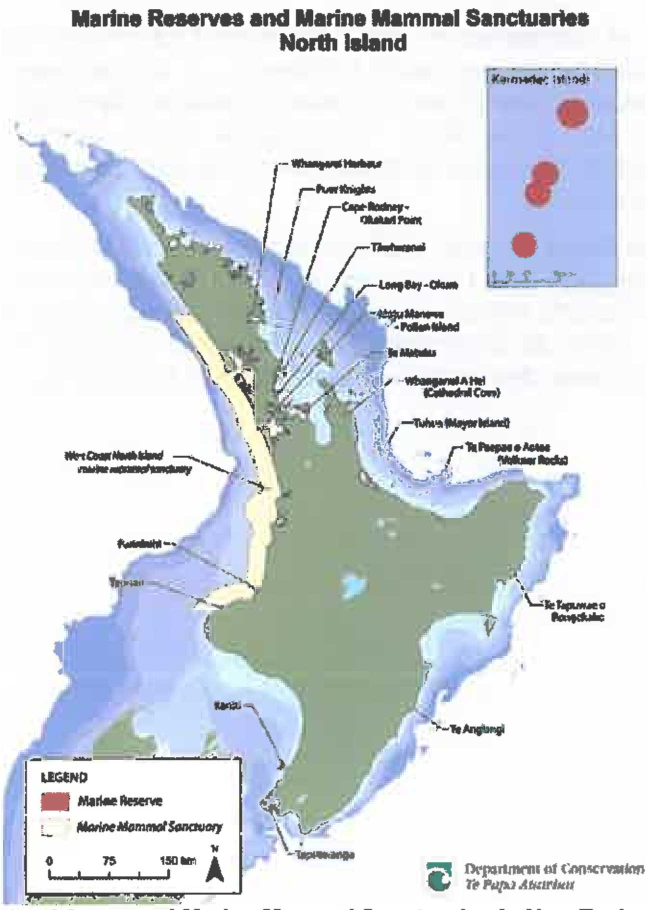

Figure 22: Protected Natural Areas and Marine Mammal Sanctuaries in New Zealand

4.3.4 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" (Barlow, 1994). 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 of the Māori people and the natural environment.

Māori believe in the importance of protecting Papatuanuku (the land) including the "footprints and stories left on the whenua (land) and wai (water) by our ancestors" (Nga Uri O Tahinga Trust, 2012). This is exemplified by the role of kaitiakitanga (guardian) which is passed down from generation to generation within an iwi. The role is central to the preservation of waahi tapu (*"a place sacred to Māori in the tradition, spiritual, religious, ritual, or mythological sense"* (The Historic Places Act, 1993) and taonga (treasures).

In particular, Tangaroa (the seas, oceans and fish) is treasured by all Māori coastal communities. It is valued as a source of kaimoana and commercial fisheries, for its estuaries and coastal waters, for its waahi tapu and spiritual pathways, and its uses for transport and communication (Nga Uri O Tahinga Trust, 2012). The conservation of many of these natural features is discussed in other sections of the report but it is important to stress their equal cultural, spiritual and historical significance to coastal Māori iwi. As custodians of the rohe moana (*A coastal and marine area over which an iwi or a hapū exercises its mana and its kaitiakitanga (MfE, 2014)*), kaitiakitanga call upon ancestral knowledge to manage the natural resources.

The sections below provide a brief overview of sites of waahi tapu and taonga along the stretch of coastline inshore of the Vulcan Operational Area. However, the list of mentioned sites is far from extensive.

4.3.4.1 Waikato

The Waikato region is home to the Tainui confederation of iwi which comprises Ngāti Whātua, Ngāti Mahuta, Ngāti Te Ata, Ngāti Raukawa and Ngāti Maniopoto (which straddles the boundary between Waikato and Taranaki). All of these iwi are kaitiaki for their respective rohe moana (Figure 23) which collectively span a large stretch of the coastline considered in this MMIA and encompass key habitats such as the Kaipara, Manukau, Aotea, Raglan and Kawhia Harbours.

The harbours within the Waikato-Tainui rohe contain many significant historical features. Kawhia harbour in particular is of importance as it is the final resting place for the Tainui waka. After landing on the east coast and being dragged across land to Manukau, the waka explored the coastline, first heading north to Kaipara harbour then south towards Mokau (where its anchor stone was left) and finally Kawhia where it was hauled ashore. The spot is marked by two limestone pillars and is the reason why Kawhia is known as the spiritual and ancestral home of Tainui (kawhia.moari.nz, 2014).

The harbours of Waikato were host to early Māori settlements and provided many traditional food-gathering sites. The natural resources of coastlines provide sustenance and identity to Māori with species such as pingao (plant used for weaving), patiki (flounder), and kuaka (godwits) deemed particularly valuable. Wetlands are equally esteemed for their spawning grounds, and the fish and other taonga species that they harbour. In their Environmental Management Plan (2013) Waikato-Tainui also recognises the ecosystem services rendered by these habitats.

As a result of this cultural and natural heritage, waahi tapu are numerous in the Tainui-Waikato rohe and a proportion of these can be found along the coastline (Tainui Waikato, 2013). In particular, the dunes in the Waikato region contain many sites of significance including middens, remains of general living areas and urupa (burial grounds) (Waikato Region Council, 2014).

The mauri of the coastline within the rohe is critical to Waikato-Tainui. The main issues of concern are fisheries (see Section 4.3.5.1) and any activity which could impact thereupon (Tainui Waikato, 2013).

4.3.4.2 Taranaki

The Taranaki coastline is subdivided among eight iwi: Ngāti Tama, Ngāti Mutunga, Te Ātiawa, Taranaki, Ngā Ruahine, Ngāti Ruānui, Ngā Rauru and Ngati Maru (Figure 23). Māori settlers first arrived in the region between 1250 and 1300 AD but in the early 1800 war parties descended into Taranaki and many people migrated south.

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, 2014b).

The coastal strip extending south from Pukearuhe to Mimi also contains many waahi 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, 2014b). The Parininihi Reserve is located along this coastline and is managed using an "integrated management approach" which involves Ngāti Tama iwi authority in decision making alongside DOC and the Conservation Board(DOC, 2014d).

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 according to the values and tikanga of the iwi (see Section 4.3.5.2). Similarly to Ngāti Tama, Ngā Mutunga used the cliffs to fish mako (shark), tamure (snapper), kahawai, and araara (trevally). These cliffs also hold numerous tauranga waka (canoe berths) (Ngāti Mutunga Iwi, 2014).

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 (Te Ātiawa Taranaki, 2014). 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) (Ministry of Justice, 2014).

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 – a mapping pilot is underway). Moreover, Taranaki iwi places substantial historical and spiritual importance in the Sugar Loaf (Ngā Motu) Islands (Taranaki Iwi Trust, 2013).

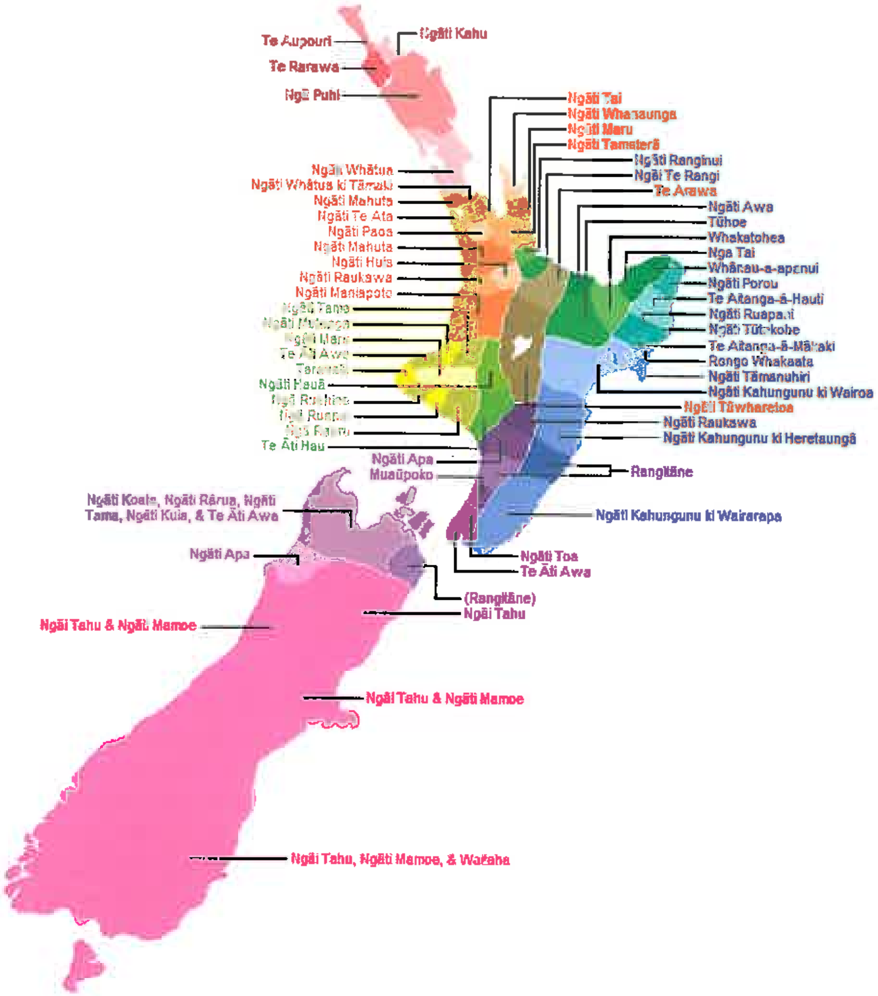

Figure 23: New Zealand Iwi boundaries

4.3.5 Customary Fishing

As stated in previous sections of the report, Māori people maintain a strong relationship with the sea and 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 (people of the land). It allows Māori to provide a food source for whānau (family) and hospitality to manuhiri (guests). Critically, the ability to provide reasonable amounts of these foods to their visitors is a marker of a tribe's mana and status (Tainui Waikato, 2013). 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.

As previously illustrated, the collection of kaimoana is widespread along the entirety of the coastline considered in this report and the list of taonga species is extensive. The following sections aim to highlight the main areas of concern to particular iwi and existing mātaitai, Taiapure and rohe moana.

4.3.5.1 Waikato

Fisheries play a central role in Waikato-Tainui culture. Taonga fish species are recognised as "the most common form of taniwha (spiritual beings)". Taonga species include tuna (short-finned and long-finned eels), whitebait species, smelt, piiharau (lamprey eels), kanae (mullet – yellow-eyed and grey), paatiki (flounder – yellow-bellied), kahawai, trevally, tamure (snapper), wheke (octopus), koura (freshwater crayfish), kaaeo, kaakahi (freshwater mussels), tio (oyster), pipi, kina and kuutai (green-lipped mussel) and marine mammals (Tainui Waikato, 2013).

4.3.5.2 Taranaki

Taranaki iwi regard pāua (abalone) as taonga and are highly valued as kaimoana. Pāua along the Taranaki region only seem to attain a maximum size of about 90-100 mm shell length, and do not appear to reach the national minimum legal size, and are commonly referred to as 'stunted". It has been shown that about 50% of Taranaki pāua mature at about 60 mm and 95% at about 75 mm. As a result, an amendment was made to the minimum legal size under the Fisheries (Central Area Amateur Fishing) Regulations 1986 to reduce the minimum legal size to 85 mm. This reduction in size was strongly opposed by customary interests as it was believed that recreational fishing pressure would deplete the pāua resource; thereby affecting the ability to harvest pāua for customary needs.

The different life stage cycles of the longfin eel are very important to Māori, in particular the migration of the longfin eel and the return of the glass eel were of particular concern. The longfin eel is an important resource for Māori, both commercially and non-commercially as it provides an important food source and has done so for many years. As result, this species of eel is of significant cultural importance. Longfin eels are only found in NZ and are widely distributed.

NZ longfin eels breed only once at the end of their lifecycle. They migrate to their spawning grounds, which are believed to be near Tonga or east of New Caledonia (exact locations are not known) (Manaaki Tuna, 2014). After the eggs are fertilised, which is thought to occur in deep tropical water, the mature eels subsequently die and the eggs float to the surface and drift with the South Equatorial Current back to NZ which can take up to 18 months (Manaaki Tuna, 2014). Once the eel larvae reach NZ waters, they undergo a transformation into glass eels, which are essentially juvenile transparent adult eels. The glass eels arrive at NZ's coastlines from July to December with numbers peaking in spring (August-October) which coincides with the whitebait migration. When the glass eels enter the estuaries they develop colouration and transform into elvers and migrate upstream to develop into adults.

As longfin eels reach breeding size, they undergo a physical transformation. The eels change from 'yellow-bellies' to 'silver-bellies', they cease to feed and their stomach shrinks as their sexual organs grow large, parts of their body darken, the head changes shape and the pectoral fins and eyes enlarge (Manaaki Tuna, 2014). Longfin male eels start their migration in April with females soon following them. It is believed longfin male eels migrate at an average age of 23 years, while females at 34 years. It is unknown how long the journey takes; however, one female longfin eel tagged from Canterbury's Lake Ellesmere travelled 160 km to northeast of New Caledonia in 161 days (Te Ara, 2014c). The exact migration route of these longfin eels is unknown but research is being undertaken by NIWA to identify migration routes utilising pop off tags.

There are a number of marine species which Taranaki iwi value highly and include snapper, kahawai, blue cod, flat fish, grey mullet, sea urchin (kina), mussels and pāua. Flounder and snapper breeding grounds are particularly significant to Ngati Tama, who also rely on the harvesting of koura, mussels, kina and pāua to supplement their diet (TRC, 2014b). The Taranaki coastline is of great spiritual and historical importance to Ngati Mutunga. Species such as pupu (catseye), papaka (crabs), pipi and tuatua were harvested off the reefs, while hapūku (groper), moki, kanae (mullet), mako shark, flounder and snapper were fished in the waters surrounding (TRC, 2014d). For Ngati Ruanui, koura, pāua, kina, pupu, Papaka, tuatua and other marine species are culturally important (TRC, 2014a).

4.3.5.3 Mātaitai, Taiapure and Rohe Moana

The Fisheries (Kaimoana Customary Fishing) Regulations (1998) allows traditional management to govern the fishing practices within an area that is deemed significant to tangata whenua. Under these regulations, tangata whenua are able to establish management areas (Mātaitai reserves) to oversee fishing and create management plans for their overall area of interest.

Mātaitai are comprised of traditional fishing grounds established for the purpose of recognising and providing kaimoana collection and customary management practices. Commercial fishers cannot fish within a Mātaitai reserve; however, recreational fishers can. Tangata whenua are also able to exercise their customary rights through a customary fishing permit under the Fisheries (Amateur Fishing) Regulations 1986.

A Taiapure can be put in place under the Fisheries Act (1996) and Kaimoana Customary Fishing Regulations (1998) to allow local management of an area. These areas are required to be significant to an iwi or hapū as either a food source or for cultural or spiritual reasons. A Taiapure does not stop all fishing, it simply allows tangata whenua to be involved in the management of both commercial and non-commercial fishing in their area.

A rohe moana is comprised of areas where kaitiaki are appointed for the management of customary kaimoana collection within the rohe under the Kaimoana Customary Fishing Regulations (1998). The Customary Fishing Regulations allow hapū to: appoint tangata kaitiaki; establish management controls; give authorisation (or permits) to exercise customary take; specify responsibility for those acting under the customary fishing regulations; provide penalties to be imposed for breach of the regulations; and to allow for restriction or prohibitions over certain fisheries areas to prevent depletion or overexploitation.

There are three customary fishing reserves in the vicinity of the Vulcan Operational Area: Aotea Harbour Mātaitai, the Marokopa Mātaitai and the Kawhia Aotea Taiapure (Figure 24). Aotea Harbour Mātaitai covers approximately 40 km² including coastal and harbour waters (MPI, 2008). Marokopa Taiapure extends between Harihari Beach and Tirua Point and 3km out to sea. The total area spans 68 km² and includes all estuarine waters (MPI, 2010). The Kawhia Aotea Taiapure includes two areas: Kawhia harbour waters and adjacent coastal waters, and a zone of 1 Nm radius around Gannet Island (Michael Hardie Boys, 2000).

In addition to the Mātaitai and Taiapure, there are a number of rohe moana in the vicinity of the Vulcan Operational Area which extend from the coastline out to the EEZ. There are four rohe moana that bisect the Vulcan Operational Area (Figure 24). 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.

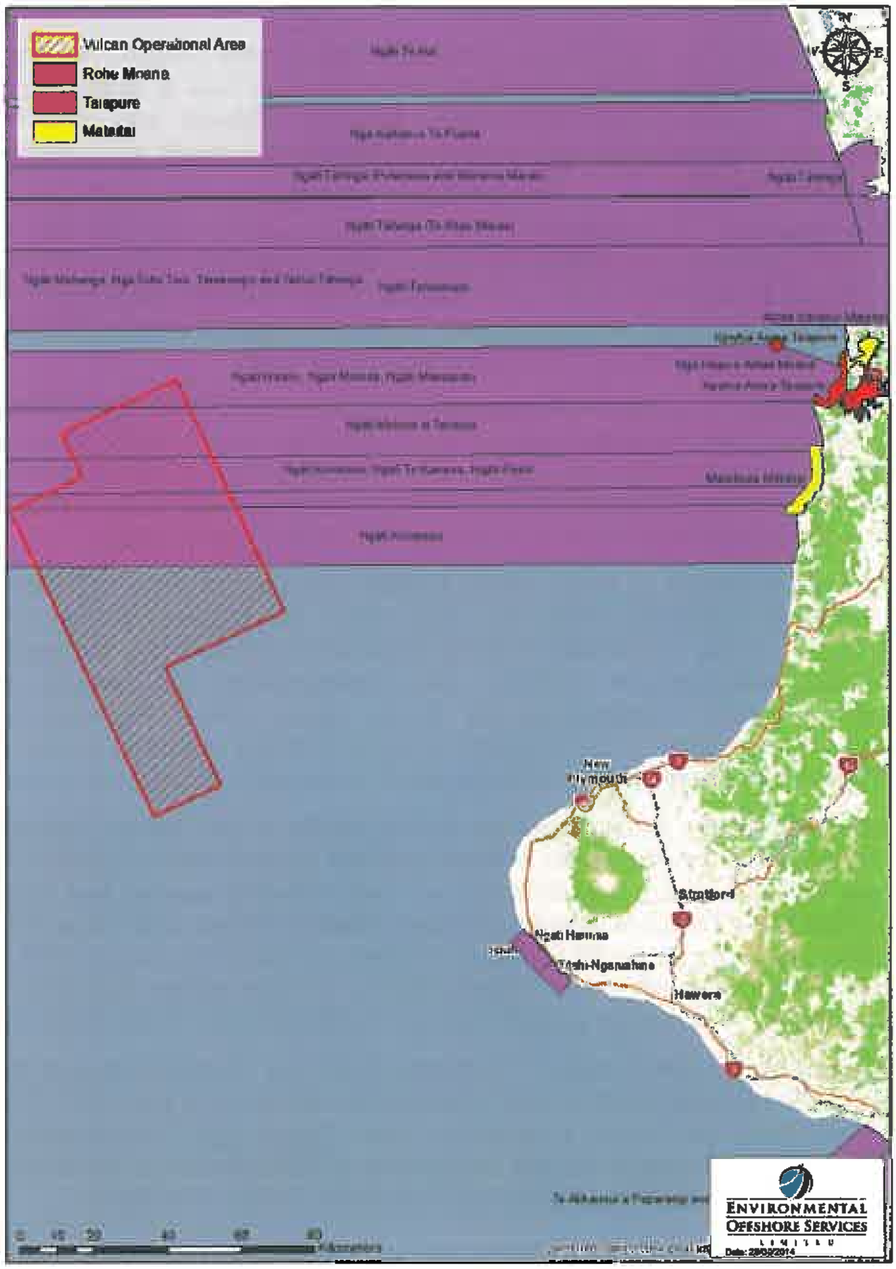

Figure 24: Taiapure, Mātaitai and Rohe Moana in the vicinity of the Vulcan Operational Area

4.4 Anthropogenic Environment

This section focuses on the users of the environments surrounding the Vulcan Operational Area; with particular emphasis on recreational and commercial fishing, shipping, and the petroleum industry.

4.4.1 Recreational Fishing

The marine environment is now being accessed for recreational fishing by an increasing number of people with a relative degree of success; mainly due to improving technology and bigger faster boats. Unlike the commercial fishing industry, recreational fishers are not managed under a quota system; but instead are regulated under daily catch limits and minimum legal sizes established by MPI to preserve fish stocks from overexploitation and conserve them for the future generations.

The Vulcan Operational Area is not often fished by recreational fishers due to its distance offshore (approximately 115 km from New Plymouth, 175 km southwest from Kawhia Harbour and 190 km southwest of Raglan Harbour).

However, the main forms of recreational fishing undertaken in the vicinity of the Vulcan Operational Area is game fishing for marlin, as well as targeting hapūku/bass and bluenose. The area is accessed from New Plymouth, as well as from Kawhia and Raglan to the north.

Inshore of the Vulcan Operational Area supports significant recreational fisheries for snapper, kingfish, hapūku/bass, trevally, kahawai, tarakihi, blue cod, gurnard, pāua, mussels, ling, albacore, butterfish, sea perch, kina, blue moki and crayfish.

Notifications will be sent out to the fishing clubs inshore of the Vulcan Operational Area informing fishers of the Vulcan 3D MSS to help alleviate any potential conflict.

4.4.2 Commercial Fishing

Ten Fisheries Management Areas (FMA) have been implemented within NZ waters to manage the Quota Management System (QMS). These areas are regulated by MPI (Figure 25). Over 1,000 fish species occur in NZ waters (Te Ara, 2014d) of which the QMS provides for commercial utilisation of 96 species while ensuring sustainability. These species are divided into separate stocks and each stock is managed independently to ensure the sustainable utilisation of that fishery.

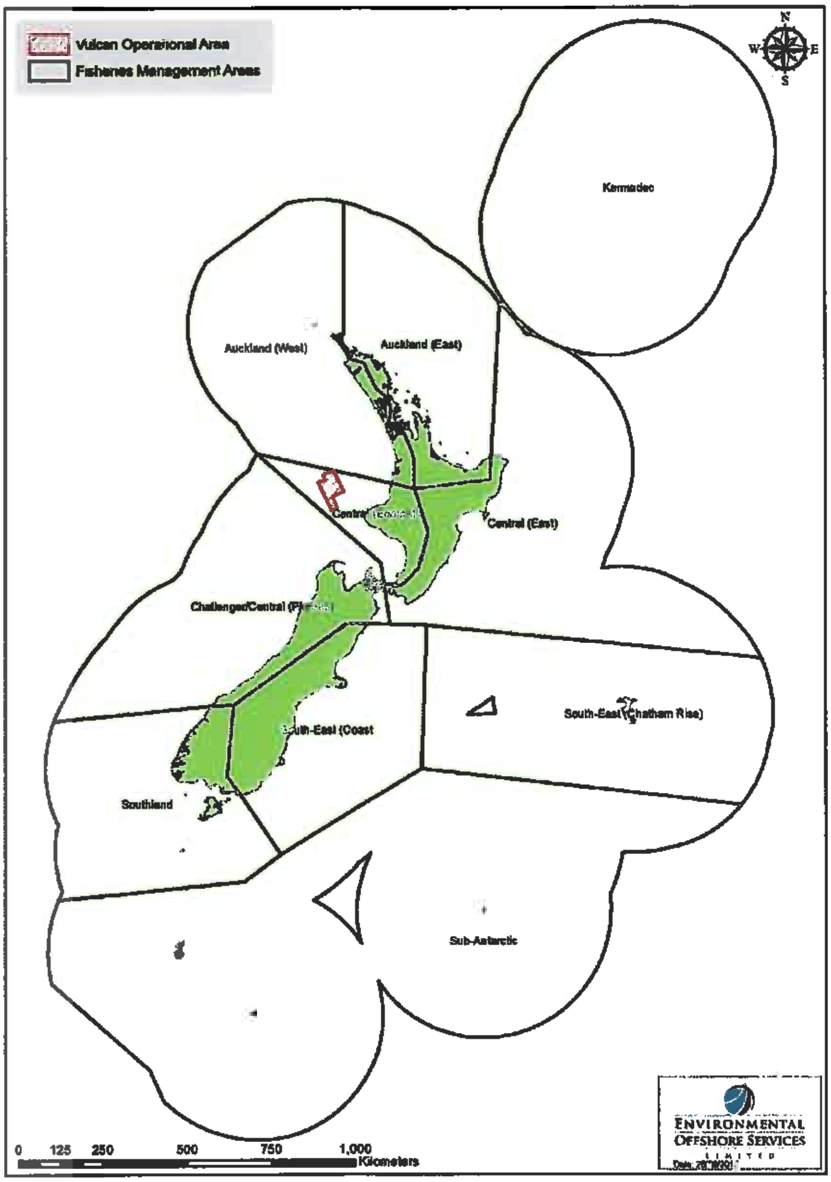

Figure 25: Fisheries management areas within NZ waters

Within NZ, the commercial fishing activities are closely monitored. In 2009, the calculated asset value of NZ's commercial fish resource was $4.017 billion, an increase of 47% from 1996 (Statistics NZ, 2014). The top 20 species of fish contributed 91% of the value of NZ's commercial fish resource; with hoki contributing 20% alone.

MPI undertook an analysis of fishing effort specifically for the Vulcan Operational Area for the 2008/09 – 2012/13 fishing years. These data has been used to provide a summary of commercial fishing activities and which species are targeted.

Data was analysed for all fishing events that started, passed through or ended within the Vulcan Operational Area. The estimated catch of the top five species from fishing events that started, passed through or ended within PEP 55793 is shown in Table 8 with jack mackerel reaching the biggest landings returned. When fishing events were assessed by target species, the most commonly targeted species within the Vulcan Operational Area were tarakihi, hapūka, school shark, jack mackerel, bluenose, and ling.

Table 8: Top five species caught in the Vulcan Operational Area during 2008/09 – 2012/13 fishing year (tonnes)

Species	Total (tonnes)
Jack Mackerel	**4,082**
School shark	**293**
Blue Mackerel	**207**
Tarakihi	**142**
Barracouta	**75**
Others	**392**
Total	**5,192**

The three most common fishing methods used within the Vulcan Operational Area are bottom longlining, trawling, and surface longlining. The number of fishing events by fishing method that started or ended in the Vulcan Operational Area during the 2008/09 – 2012/13 fishing years can be seen in Table 9. Over the five years considered within the fishery assessment, bottom longlining has been the most commonly used fishing method within the Vulcan Operational Area. There is also a considerable amount of trawling events and a small amount of surface longlining.

Table 9: Fishing events by method within PEP 55793 during 2008/09 – 2012/13

Method	2008/09	2009/10	2010/11	2011/12	2012/13	Total
Bottom longline	159	129	190	128	120	**645**
Trawl	118	49	73	118	95	**453**
Surface longline	2	2		3	6	**13**
Other	0	0	1	6	4	**11**
Total	**279**	**180**	**183**	**255**	**225**	**1,122**

Bottom longline fishing events appear to take place year-round with two main peaks in activity. The first and largest peak occurs between November and December, and the second slightly smaller peak occurs between March and April. There is a third peak at the end of the quota year (in August and September), however, this increase is inconsistent between years and is largest in years during which the two other earlier peaks are not so marked, suggesting that it could be explained by attempt to utilise unused quota (Figure 26). Trawling is also a year-round activity within the Vulcan Operational Area. Similarly to bottom lining, there are two main peaks of activity during the year. The earlier peak (December-January) is also the largest and the second is slightly smaller (June) (Figure 27). All fishing methods considered, the bulk of activities takes place between October and May (Figure 28) and overall, fishing (all methods) occurs in the southern half of the Vulcan Operational Area (Figure 29).

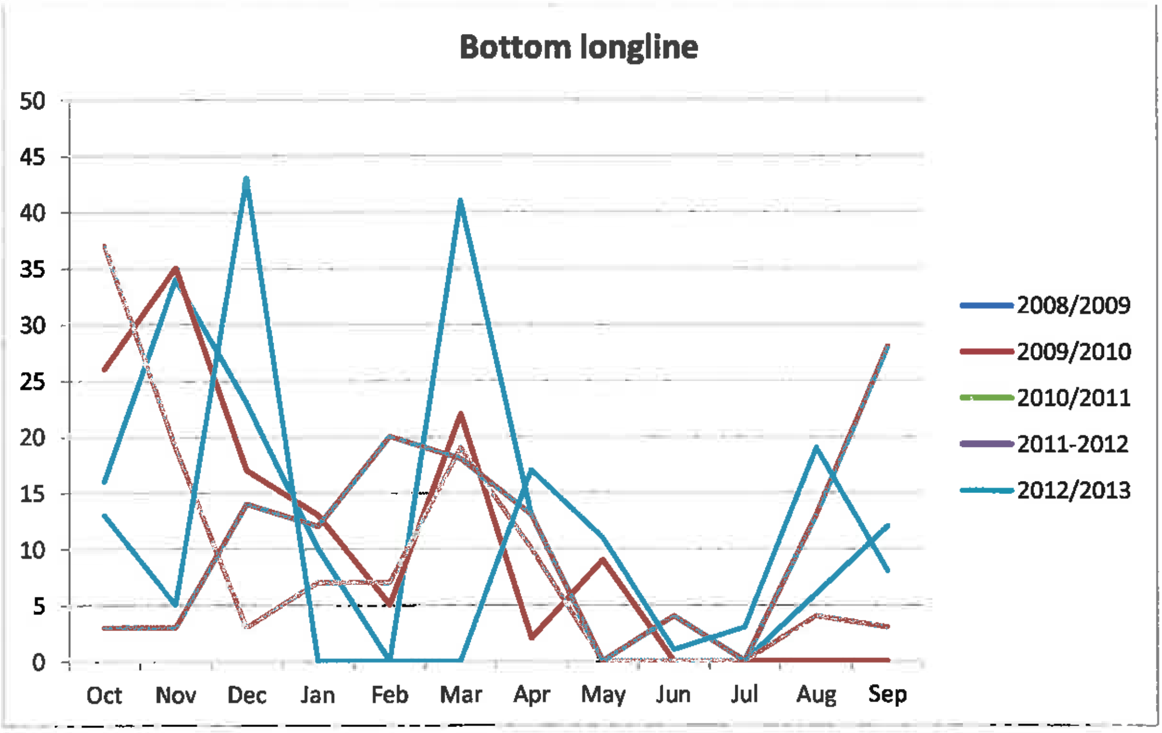

Figure 26: Number of bottom longline fishing events per month that started or ended in the Vulcan Operational Area during the 2008/09-2012/13 fishing years

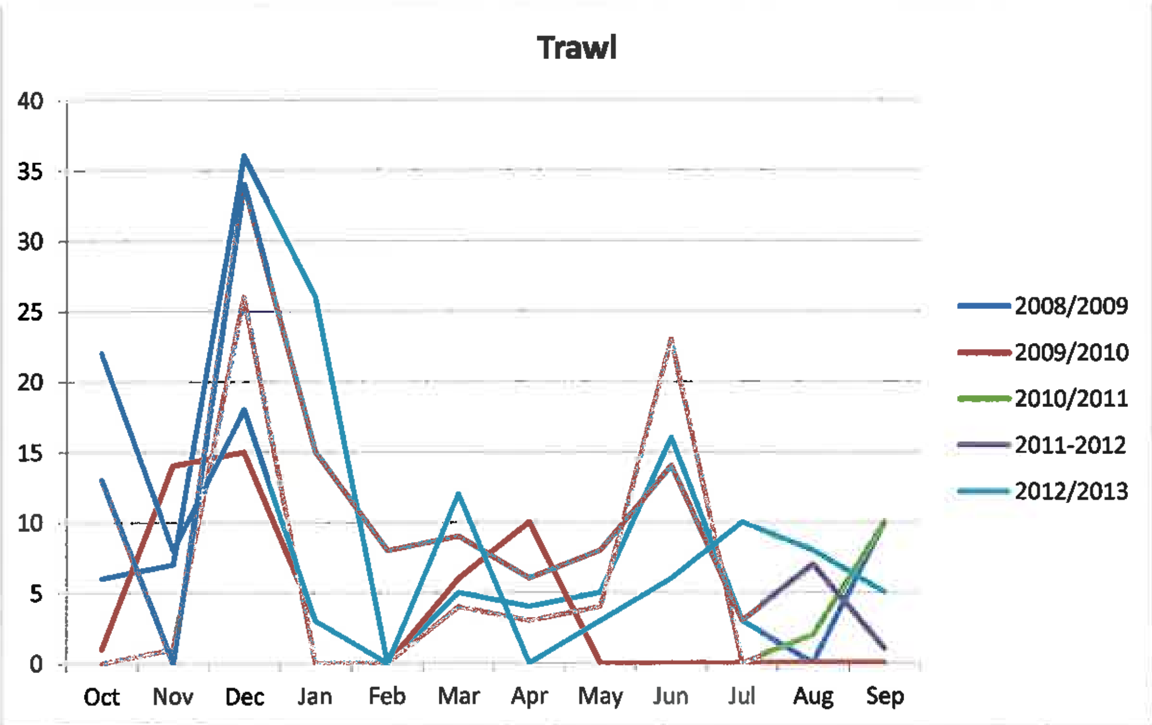

Figure 27: Number of trawl fishing events per month that started or ended in the Vulcan Operational Area during the 2008/09-2012/13 fishing years

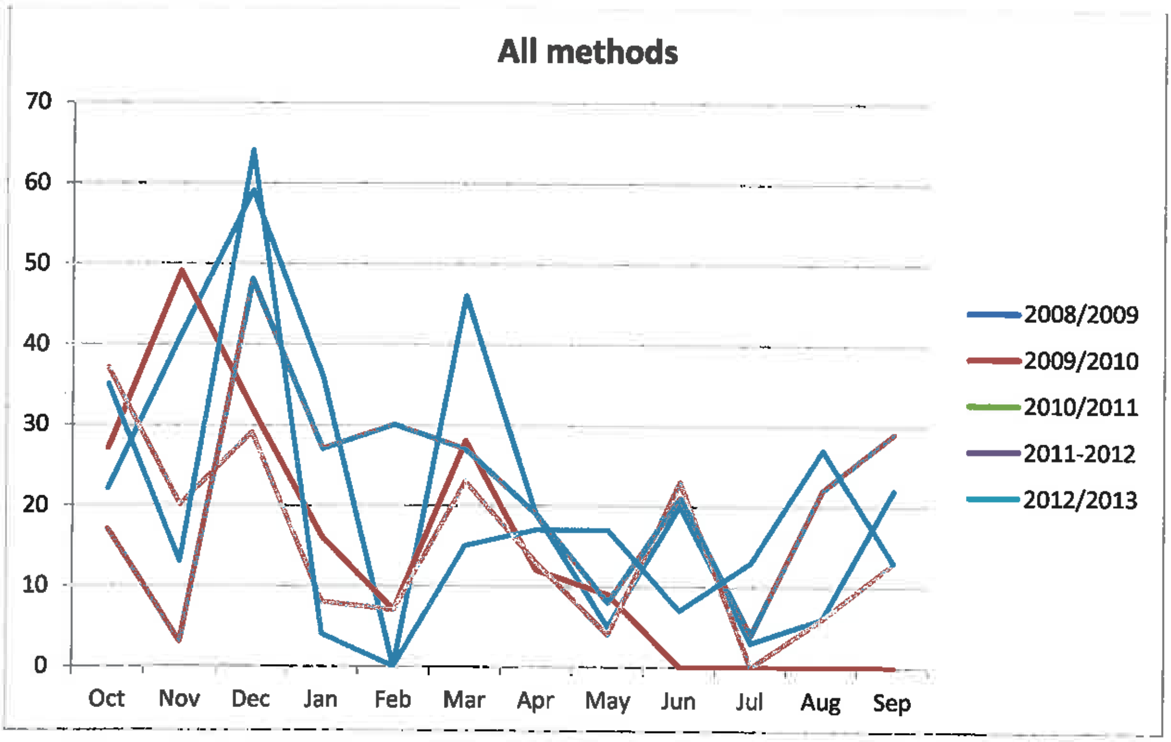

Figure 28: Number of fishing events (all methods) per month that started or ended in the Vulcan Operational Area during the 2008/09-2012/13 fishing years

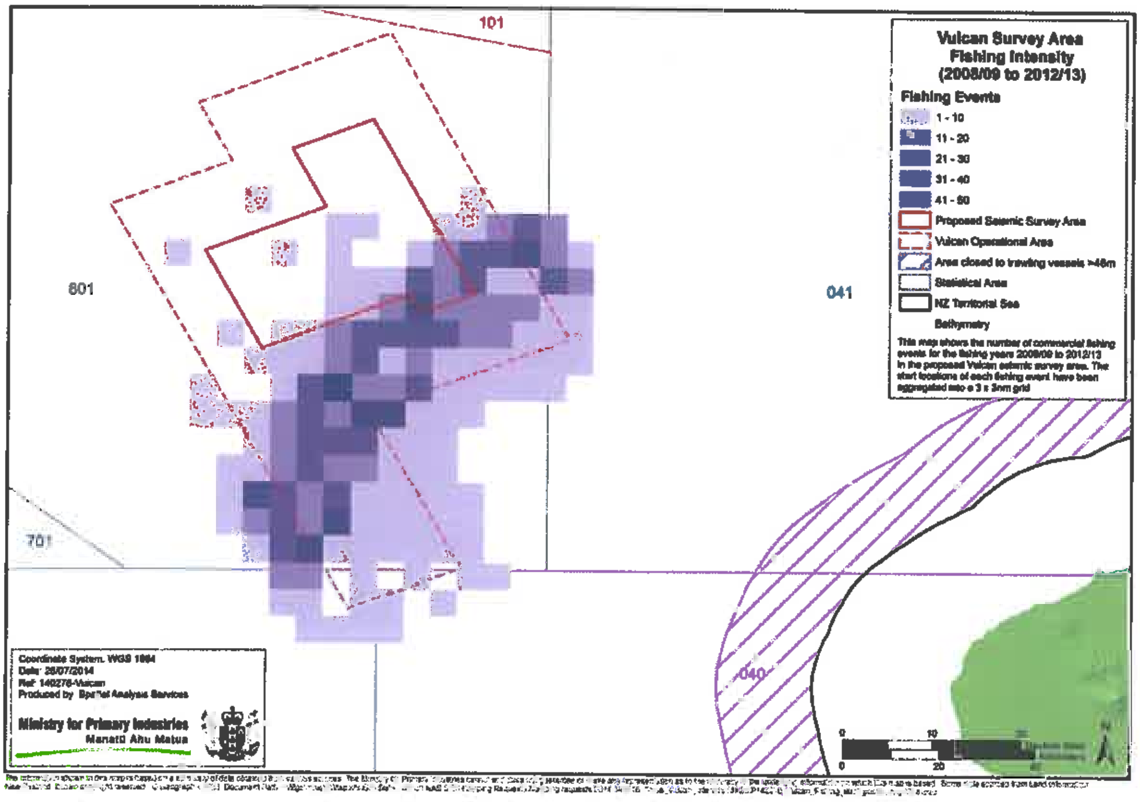

Figure 29: Intensity of fishing activity in and around the Vulcan Operational Area based on aggregated data from the 2008/09 to 2012/13 fishing years

The fishing industry has been notified of the proposed Vulcan 3D MSS (Appendix 2) and approximate commencement date and all groups and fishers that utilise the area have been notified.

Consultation has been undertaken with Deepwater Group, Sanfords, Independent Fisheries, Maruha (NZ) Ltd, Talley's, Sealord, Egmont Seafoods and NZ Federation of Commercial Fisherman to advise them of the proposed Vulcan 3D MSS and the array of gear that will be behind the *Polar Duke*. A summary of the engagement is provided in Appendix 2. These companies will be provided with the contact details of the vessel closer to the commencement date. A Notice to Mariners will be issued for the Vulcan 3D MSS and a coastal navigation warning will be broadcast over maritime radio.

4.4.2.1 Squid fishery

There are two species of squid which make up the NZ squid fishery: *Nototodarus gouldii* and *Nototodarus sloanii*. Squid are widespread across the NZ continental shelf generally in water depths of less than 300 m (MPI, 2014c).

There are no squid fishing grounds in close proximity to the Vulcan Operational Area. The closest areas which have been identified for squid fishing are in the south Taranaki Bight and off the west coast of the South Island (Figure 30). The majority of commercially caught squid within NZ waters is caught off the bottom of the South Island and Auckland Islands between January and May. The squid fishery is seasonal with most of the squid fishing activity taking place in the summer months from January through to May.

In 2010/2011, 37,304 tonnes of squid (from a total allocation of 127,332 tonnes) were harvested from the NZ fisheries. Annual catches of squid vary greatly from one year to the next due to the natural variability of the species' abundance, and since 2004/2005 there has been a general decreasing trend of catch rates. Squid quota value across all fisheries was estimated to be worth $95m in 2008 (MPI, 2014c).

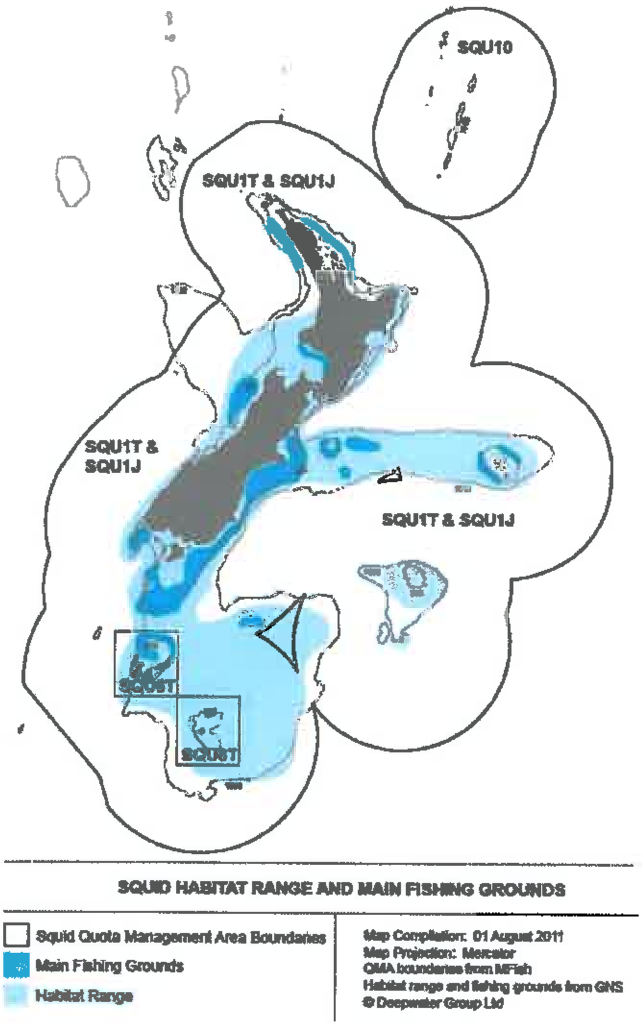

Figure 30: Squid habitat and main fishing grounds

4.4.3 Commercial Shipping

There are thirteen major commercial ports and harbours within NZ, consisting of major ports, river ports and breakwater ports. Ports are important gateways for freight, transport and trading both nationally and internationally. The closest port to the Vulcan Operational Area is Port Taranaki which is the major servicing base to the petroleum industry in the South Taranaki Bight and has been since the beginning of the major Taranaki offshore and onshore petroleum development.

Commercial shipping vessels generally use the most direct path when travelling between ports. Between Port Taranaki and any other NZ port there is no dedicated shipping lane; 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 Vulcan Operational Area are shown in Figure 31 and Figure 32. These figures clearly illustrate that the Vulcan Operational Area is located beyond any coastal shipping route between Port Taranaki and any other NZ ports. During consultation Port Taranaki has been advised of the proposed Vulcan 3D MSS and did not foresee any issues arising.

The routes for foreign destinations from NZ ports are likely to vary and have not been included in Figure 32, although it is likely they will pass through, or in close proximity to, the Vulcan Operational Area. A Notice to Mariners will be issued ahead of the Vulcan 3D MSS commencing and a coastal navigation warning will be issued and broadcast on maritime radio. With adherence of all vessels to the COLREGS there should be no conflict between shipping vessels and the *Polar Duke*.

The International Maritime Organisation (IMO) established a precautionary area for Taranaki waters in 2007 which warns all ships travelling through this area that they must navigate with caution due to the high level of petroleum activity in the area. This precautionary area is a standing notice in the annual Notice to Mariners which are issued each year in the NZ Nautical Almanac. The navigational hazards within this precautionary area listed in the almanac include the Pohokura, Maui, Maari, Tui and Kupe fields. Therefore, all vessels travelling through this area should be aware of the petroleum production and exploration activities and if they are following good practice, safety at sea and adhering to the COLREGS, any risk of collision should be avoided. The Vulcan Operational Area is located beyond the precautionary Area but maritime traffic is aware of the increased presence of installations and vessels within the Taranaki coastal environment due to the activities of the hydrocarbon exploration and production industry (Figure 33).

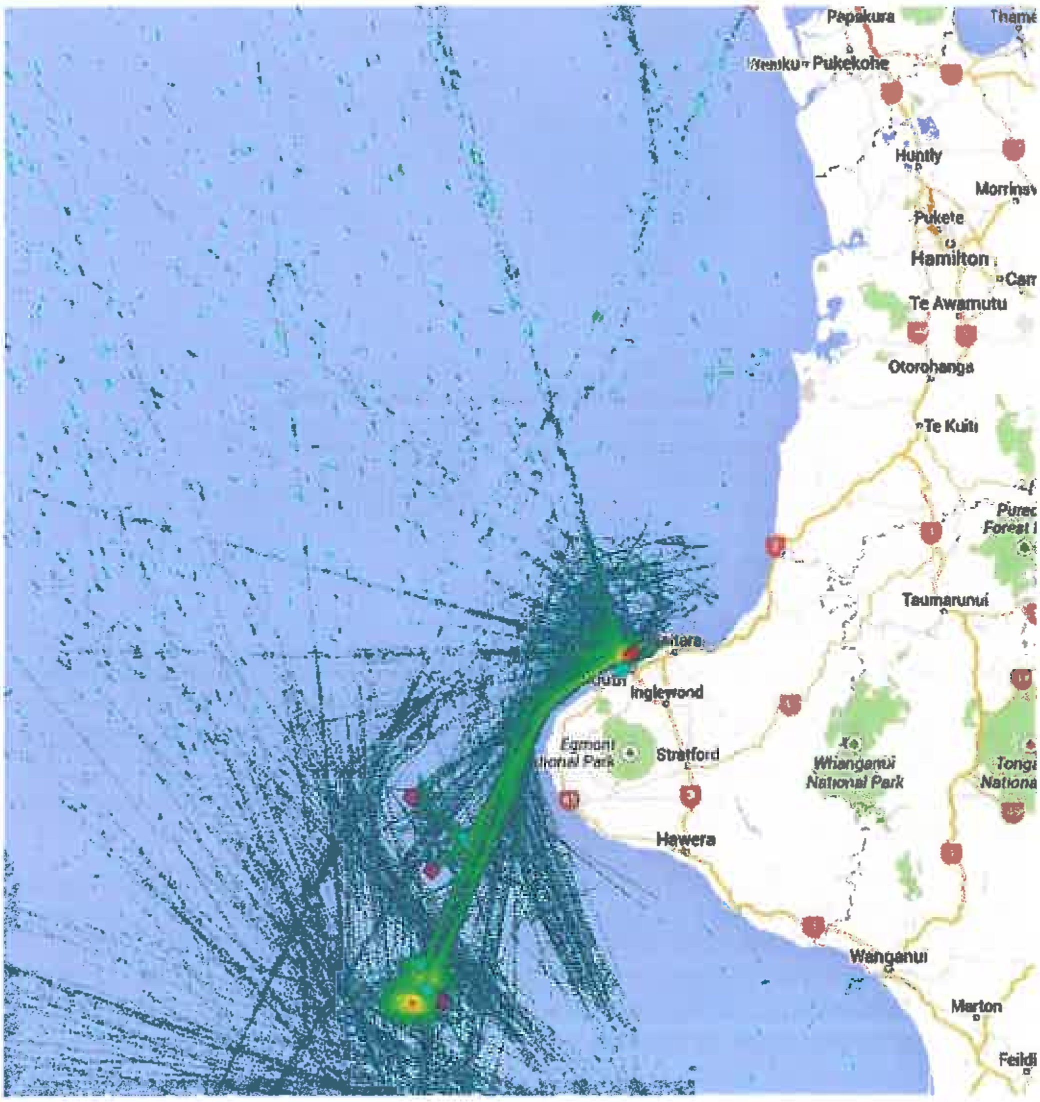

Figure 31: Marine traffic density map for the Vulcan Operational Area (source: www.marinetraffic.com)

Figure 32: General shipping routes surrounding the Vulcan Operational Area

Figure 33: Taranaki Precautionary Area and offshore installations

4.4.4 Petroleum Exploration

Exploration and production activities have occurred off the Taranaki coastline for more than 40 years and have increased in intensity in the last ten years. Taranaki is NZ's hydrocarbon province and is the only region where oil and gas has currently been found in sufficient quantities to be economically viable (Figure 34). As a result Taranaki and the associated petrochemical industry are very important to NZ's economy.

Petroleum exploration in Taranaki first began in 1865 with the Alpha-1 well in New Plymouth which is the first recorded well to produce oil in the British Empire. Petroleum activities in the Taranaki Basin have since increased to over 400 offshore and onshore exploration and production wells drilled (Figure 34). Over the years, there have been a large number of 2D and 3D MSSs in the Taranaki region. The proposed Vulcan 3D MSS will help gather more subsurface information to build onto the existing knowledge of the Taranaki Basin and underlying strata and tie in to the existing data from previously drilled wells.

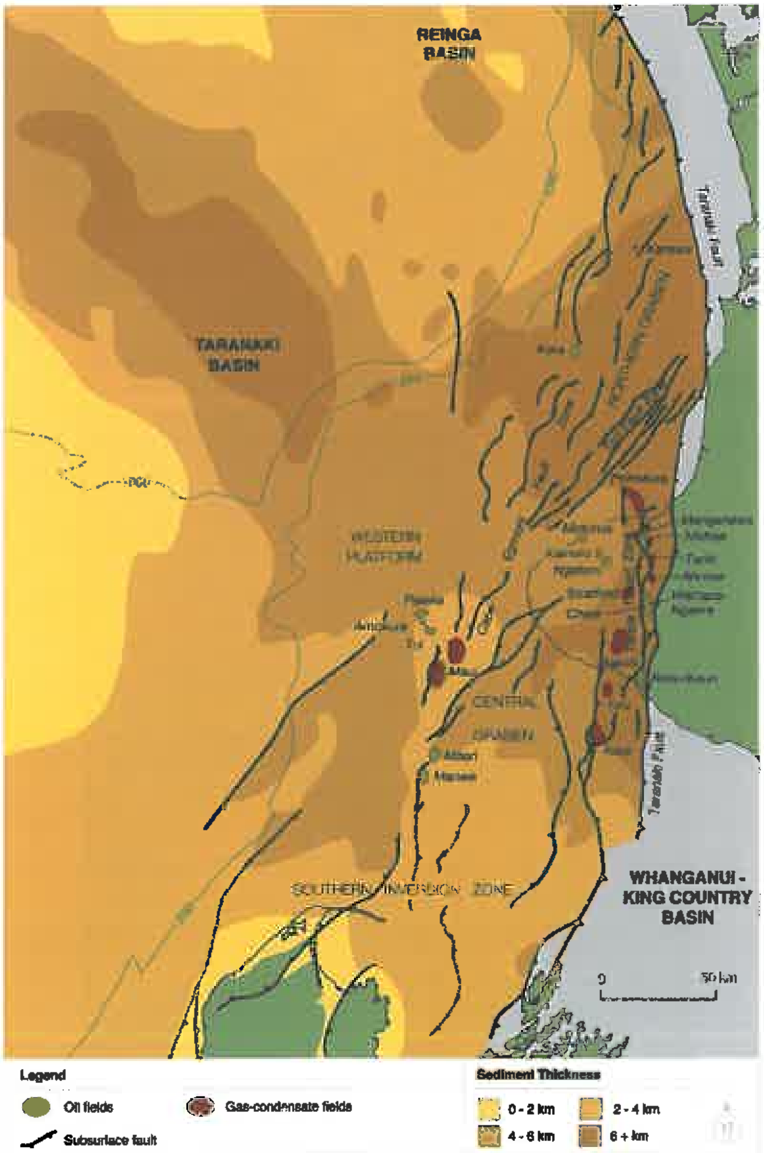

Figure 34: Taranaki oil and gas fields

5 Potential Environmental Effects and Mitigation Measures

This section presents an overview of the potential effects on marine mammals (and the wider marine environment) which may arise from the operation of the Vulcan 3D MSS programme.

An Environmental Risk Assessment (ERA) has been undertaken, using a risk matrix to identify the significance of each activity/environmental resource interaction based on a likelihood and consequence approach. This risk assessment is an essential component of this MMIA (Table 10).

A MSS has the potential to lead to environmental effects (e.g. physical disturbance) either under normal operating situations (planned activities) or during an incident (unplanned activities). Marine environmental resources provide ecosystem services that are important to society.

This assessment considers the consequence (Table 11) and likelihood (Table 12) of the potential environmental effect including its geographical scale (site, local and regional) and its duration in relation to the sensitivity of the key environmental receptors. A description of the risk matrix categories is provided in Table 13. A summary of the planned and unplanned activities with the consequence and likelihood scores as well as the overall risk ranking for the Vulcan 3D MSS is included in Appendix 6.

The joint Australian & NZ International Standard Risk Management – Principles and Guidelines, (ASNZS ISO 31000:2009) has been used to develop the framework in Table 10. ASNZS ISO 31000:2009 defines risk as 'the uncertainty upon objectives', while the effect is a deviation from the expected – either positive or negative.

The predicted effect in the ERA matrix (Table 10) is based on the assumption that standard mitigation measures to avoid, remedy or mitigate environmental effects are in place and these are discussed for each activity in the following sections.

The main steps used in the ERA can be summarised as follows:

- Identification of the marine seismic survey aspects (planned and unplanned) that might result in potential effects to marine mammals, marine fauna, the wider marine environment and existing users;
- Identification of the key potential environmental sensitivities vulnerable to those activities identified; and
- Detailed description of each identified potential environmental effect, including the measures which WEL will undertake to control and mitigate each potential effect.

Table 10: Environmental Risk Assessment

		4 - Negligible	3 - Minor	2 - Moderate	1 - Major
Likelihood Category	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: Marine effects – consequence definitions

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. Medium 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: Description of likelihood of environmental risk assessment matrix

Level - Descriptor	Likelihood of Exposure
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 WEL.
	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 & Mitigation Measures

5.1.1 Physical presence of *Polar Duke* and the Seismic Array

The *Polar Duke* and the associated seismic array have the potential to interfere with a number of commercial, recreational, social and environmental operations and resources. This potential interference is discussed further in the following sections.

5.1.1.1 Interference with the fishing community and marine traffic

There is the potential that the Vulcan 3D MSS could interfere with fishing activities due to the length of seismic array towed behind the *Polar Duke*. As a result, fishing vessels (mainly commercial) will be caused a temporary loss or reduction of access to fishing grounds within the Vulcan Operational Area during the survey (~35 days).

Commercial fishers who use the Vulcan Operational Area as part of their fishing grounds have been advised of the Vulcan 3D MSS and will be contacted closer to commencement with further details. The acquisition of the Vulcan 3D MSS could cause temporary displacement of fish stocks; however, most of the commercial fishing within the area is undertaken inshore of the Vulcan Operational Area.

It is assumed that any effect on fisheries is likely to be temporary, and it is unlikely that there will be any lasting harm to any fish populations.

Not all fishing methods will be impacted in the same way. Bottom longline is the most common method of commercial fishing in the waters within and surrounding the Vulcan Operational Area and involves fishing gear being deployed in one location generally for a few hours. However, most of this fishing activity is actually outside of the Vulcan Survey Area (Figure 29). Trawling is the second highest type of fishing method within the Vulcan Operational Area, it is a mobile method of fishing which leaves no gear deployed on the seabed and as a result will only suffer minor impacts from the Vulcan 3D MSS. In contrast, surface long-lining (which is not that common within the Vulcan Operational Area) provides the potential for heavier conflict. For this method of fishing, several kilometres of line can be set and left for a number of hours.

To ensure that the potential environmental effects are minimised, WEL will use the following mitigation measures:

- Operations will be 24 hours a day, 7 days a week (weather and marine mammal encounters permitting) to minimise the overall duration of survey;
- COLREGS (radio contact, day shapes, navigation lights etc.) will be complied with;
- A support vessel will be present at all times;
- Commercial fishers will be notified of the Vulcan 3D MSS and Vulcan Operational Area;
- Notice to Mariners and a coastal navigation warning will be issued; and
- A tail buoy will be attached to the end of each streamer to mark the overall extent of the seismic array and avoid any uncertainty to users of the marine environment.

With the mitigation measures in place, the environmental risk from the Vulcan 3D MSS to any fishing, commercial or private vessels is considered to be ***medium***.

5.1.1.2 Interference with Marine Archaeology, Cultural Heritage or Submarine Infrastructure

The seismic array used for the Vulcan 3D MSS will not come into contact with the seabed or coastline inshore of the Vulcan Operational Area. The Vulcan 3D MSS will use solid streamers with self-recovery devices fitted which release once the streamer reaches a certain depth (~50 m) bringing the streamer back to the surface for retrieval should they be severed and start sinking. In addition, most of the areas that are culturally significant are on the intertidal and shallow subtidal reefs located inshore of the Vulcan Operational Area. Consequently, it would only be a rupture to the vessel's fuel tank that could cause these areas to be impacted. WEL have mitigation measures in place to avoid a collision or prevent a spill of fuel to the marine environment. These measures are discussed in Section 5.2.2. Therefore, it is considered that the potential interference with any marine archaeology, cultural heritage or submarine infrastructure arising from the physical presence of the *Polar Duke* and the seismic array during the Vulcan 3D MSS is ***low***.

5.1.1.3 Changes in Seabird Behaviour

Numerous species of seabirds occur in within the Vulcan Operational Area (see Section 4.2.7) as a result the chances of encounter of sea birds by the survey vessel is high. Seabirds frequently interact with vessels at sea. Some of these interactions are harmless (i.e. birds using vessels as perching opportunities that would not otherwise be available) and others are negative and can result in injury or death (i.e. collision or entanglement in vessel rigging especially at night).

Research has shown that artificial lighting can cause disorientation in seabirds, although this is mainly true for fledglings and novice flyers, particularly when vessels are operating close to shore (Telfer *et al.*, 1987) and at night. It is believed seabirds use starlight to navigate, hence the potential for artificial lights to interfere with their ability to navigate (Black, 2005; Guynup, 2003).

There is limited experimental data on the reaction of seabirds to MSS operations. A study undertaken in the Wadden Sea (intertidal zone of the North Sea) concluded that bird counts showed no significant deviation in the numbers and seasonal distribution of shorebirds and waterfowl as a result of a seismic survey (Webb and Kempf, 1998). Although temporary avoidance of individual areas of distances up to 1 km was observed due to the activities of the boats and crew.

Overall, temporary disruption of potential feeding and resting could occur due to presence of vessel and associated streamers of the 3D MSS. However, prey items such as bait fish may display avoidance behaviour which could potentially reduce the interactions of bird species in the area. Seabird presence disturbance would be temporary in nature and given only a portion of the Operational Area will be affected at any given time and the mobile nature of the seabird species reduces possible interactions during the 3D MSS.

A number of factors will reduce the potential for any long term interference or damage to seabirds during the Vulcan 3D MSS. The *Polar Duke* will always be underway while acquiring the Vulcan 3D MSS and any diving birds in close proximity to the acoustic source are unlikely to do so since their prey (baitfish) are likely to have fled the immediate area around the operating acoustic source (see Section 5.1.2.2.2). As a result, the physical presence of the *Polar Duke* and the seismic array during the Vulcan 3D MSS is considered to have a ***low*** risk to seabirds.

5.1.1.4 Introduction of Invasive Marine Species

Ballast water discharges, sea chests and hull fouling on vessels has the potential to introduce and spread marine pests or invasive species to NZ waters.

As part of the environmental management commitments for the proposed Vulcan 3D MSS, WEL has committed to manage the risk of introducing Invasive Marine Species (IMS) by requiring that survey vessels are inspected by qualified IMS inspectors. Based on the outcomes of each IMS inspection, management measures will be implemented to ensure vessels meet the Part 2.1 "clean" hull requirement of the recently released Craft Risk Management Standard – Biofouling on Vessels Arriving to NZ.

Therefore, the potential to introduce marine pests or IMS as a result of the Vulcan 3D MSS is considered ***low***.

5.1.1.5 Interaction of Polar Duke with Marine Mammals

The physical presence of the *Polar Duke* has the potential to cause disruption to behaviour or even harm marine mammals present within the survey area. The level of potential impact ranges from disruption of behaviour caused by an attraction to the vessel (i.e. wake/bow riding), interruption of sensitive behaviours (i.e. feeding, breeding, resting etc.), to injury and death through ship strike or entanglement in streamers.

It is generally accepted that the presence of a vessel in proximity to marine mammals can cause some disturbance and alteration of behaviour. This is of concern especially in cases of prolonged disturbance of sensitive behaviours such as feeding, breeding and resting. It is possible that the physical presence of the *Polar Duke* could cause some temporary and localised modification in behaviour. However, this disturbance will be very limited in time (given that the vessel will be progressing steadily throughout the Vulcan Operational Area without concentrating in a given area) and space (marine mammals must be in close proximity to the vessel in order to be affected by its physical presence).

A study which considered a total of 292 records of confirmed or possible ship strikes to large whales identified 11 different species as potential ship-strike victims (Jensen and Silber, 2003). Nine of these species are among those which are likely to occur within the Vulcan Operational Area (i.e. blue whale, Bryde's whale, fin whale, humpback whale, killer whale, minke whale, sei whale, southern right whale, sperm whale). The study highlighted the fin whale (75 records) and the humpback whale (44 records) as the most commonly reported victims of ship strike.

Jensen & Silber (2003) also demonstrated that vessel-type plays a role in the likelihood of mortality from any vessel interaction. Out of the 292 fatal strikes considered in the study, vessel type was only known in 134 cases and the majority of these cases were navy vessels and container/cargo ships/freighters. Seismic vessels (described as research) accounted for only one of the 134 known vessel marine mammal strikes.

The vessel's speed is also known to impact the likelihood of mortality from ship strike. Jensen & Silber (2003) reported a mean speed of 18.6 kts for vessels involved in lethal ship strike. During acquisition, the *Polar Duke* will only be travelling at ~4.5 kts, less than four times slower than the mean speed reported in the Jensen & Silber (2003) study.

Given the information detailed above, it is considered that the risk to marine mammals arising from the physical presence of the *Polar Duke* and the seismic array during the Vulcan 3D MSS is ***low***.

5.1.2 Acoustic Source Sound Emissions

As mentioned previously, low frequency sound sources produced during MSSs are directed downwards towards the seafloor and propagate efficiently through the water with little loss due to attenuation (absorption and scattering). Attenuation depends on propagation conditions. In good conditions, 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).

When an acoustic source is activated, most of the emitted energy is low frequency (0.01 – 0.3 kHz), but pulses also contain small amounts of higher frequency energy (0.5 – 1 kHz) (Richardson *et al.*, 1995). The low frequency component of the sound spectrum attenuates slowly while the high frequency sound attenuates rapidly to levels similar to those produced from natural sources.

The acoustic pulse associated with a MSS produces a steep-fronted wave which is transformed into a high-intensity pressure wave (shock wave with an outward flow of energy in the form of water movement). This results in an instantaneous rise in maximum pressure, followed by an exponential pressure decrease and drop in energy. The environmental effects on marine mammals and other fauna associated with MSSs focus on these sound waves generated from the acoustic source.

A high intensity external stimulus (the acoustic source emissions in this case) will cause animals to produce an adaptive behavioural response. Depending on the species, this can take the form of displacement, avoidance or flight response, or a change in behaviour type or intensity. The nature (continuous or pulsed), source (visual or auditory) and the intensity of the stimulus, as well as the species, gender, reproductive status, health and age of the animal will impact the length and intensity of the observed response.

These behavioural responses are an instinctive survival mechanism aiming to preserve the organism from any physical or physiological damage. Consequently, animals may suffer temporary or permanent damage in cases when the external stimulus (threat) is too great or the organism is unable to provide sufficient behavioural adaptation (e.g. swim away fast enough) (see Section 5.1.2.3).

Depending on the level of exposure and the sensitivity thresholds of each species, the impact of acoustic emissions ranges from changes in behaviour and related population wide impacts (displacement, surfacing too quickly from deep dives which can result in 'decompression sickness', disruption of feeding, breeding or nursery activities, interference in communication) to physiological effects such as a change in hearing threshold or damage to sensory organs. Indirect effects can also be felt throughout the whole ecosystem with behavioural changes in prey species affecting other species higher up the food chain.

However, the potential behaviour or physiological effects discussed above will be minimised during the Vulcan 3D MSS, through the adoption of the Code of Conduct and associated mitigation measures. Adherence to these operational procedures (i.e. MMO's, PAM operators, soft starts, pre-survey observations, mitigation zones) will reduce the risk of marine mammals being exposed to dangerous levels of noise.

More specifically, the requirements and mitigation measures for a Level 1 MSS will be adhered to for the Vulcan 3D MSS and the acoustic source will either be shut down or the soft-starts delayed if any marine mammals are within the relevant mitigation zones and as a result keeping all impacts to a minimum level. WEL has undertaken source modelling to ensure the *Polar Duke* is using the appropriate acoustic source volume required to achieve the objectives of the Vulcan 3D MSS while minimising the effects on the marine environment.

The following sections detail the emitted sound levels that will be produced by the Vulcan 3D MSS and discuss the predicted potential impacts on marine mammals and other fauna.

5.1.2.1 Sound Transmission Loss Modelling

WEL commissioned Curtin University to conduct STLM in accordance with the Code of Conduct, even though the Vulcan Operational Area is located beyond the AEI. Acoustic propagation modelling was used to predict received SELs from the Vulcan 3D MSS to assess for compliance with the mitigation zones in the Code of Conduct (Appendix 5). The modelling methodology to produce the results summarised below accurately deals with both the horizontal and vertical directionality of the acoustic array and with the different water column and seabed variations in depth and range found throughout the Vulcan Operational Area (Galindo-Romero and Duncan, 2014).

The Vulcan Operational Area spans an area of complex bathymetry (see Section 4.1.3) so four different geoacoustic regions representing different bottom substrate types were chosen to represent the probable benthic sediment compositions and sub-bottom layering (Figure 35). The information was obtained from published literature on NZ regional seabed geology and the acoustic properties of marine sediments. The five regions referred to are differentiated by the likely geoacoustic properties of their seabeds and a description is provided below, while the full geoacoustic properties for the regions are defined in Galindo-Romero and Duncan (2014):

- R1:Taranaki – Northland Continental Shelf (Fine sand);
- R2: Taranaki – Northland Continental Slope (Silt – Clay);
- R3: Southern New Caledonia Basin – Reinga Basin – Challenger Plateau (Pelagic Sediments, Mud-Oozes); and
- R4: Veining Meinez Fracture Zone – Reinga Ridge (Carbonate Sediments).

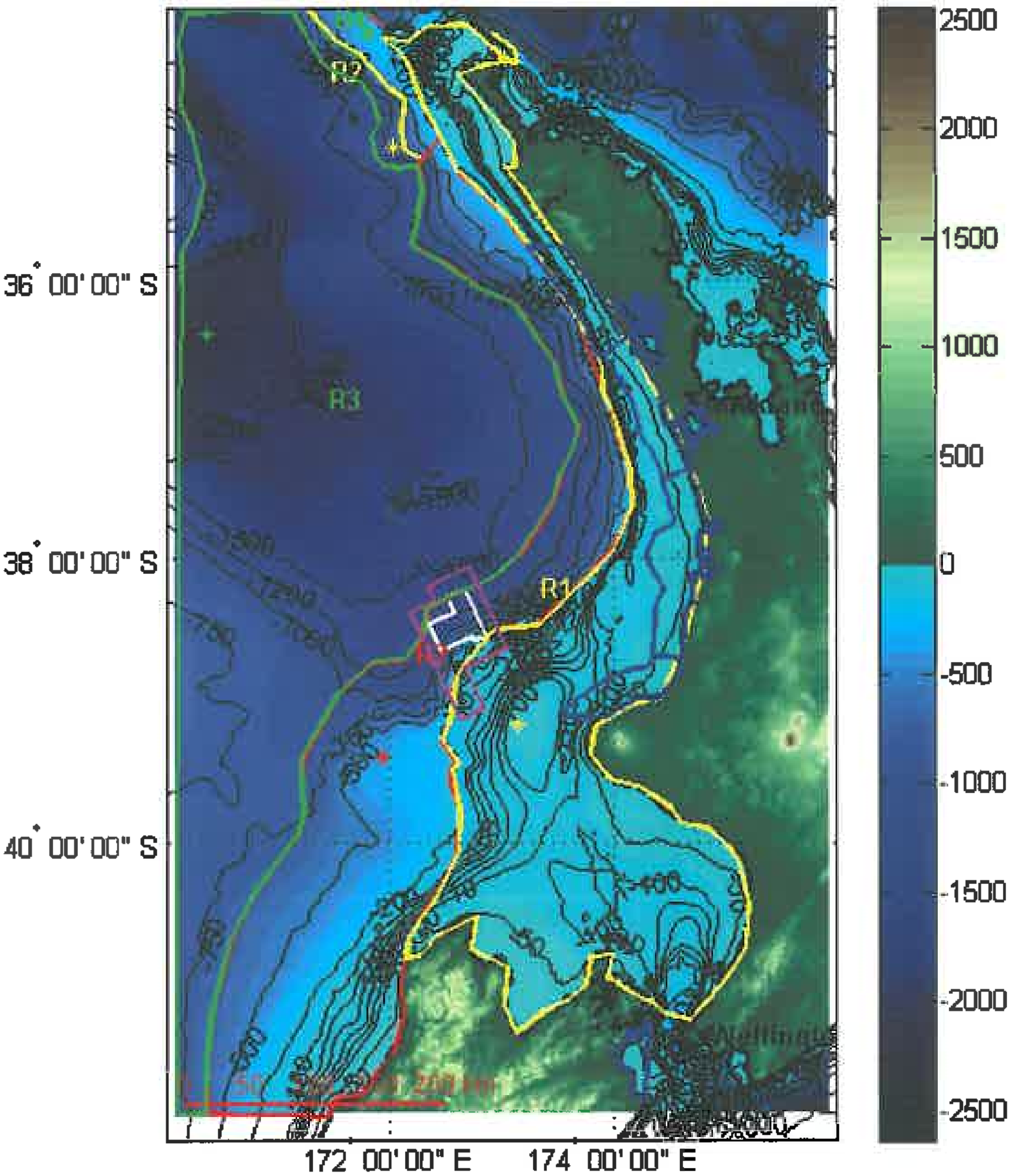

Figure 35: Geoacoustic regions surrounding the Vulcan Operational Area

The STLM was conducted at two modelling locations within the Vulcan Operational Area. Short range modelling was undertaken at S1, while long range modelling was undertaken at S2 (Figure 36). The modelling was based on the proposed Vulcan 3D MSS acoustic source (3,460 in^3). The modelling locations were selected based on the greatest potential for sound and energy propagation. The acoustic source was modelled to be operating 7 m below the sea surface - received sound levels in the water column increase with increasing array depth.

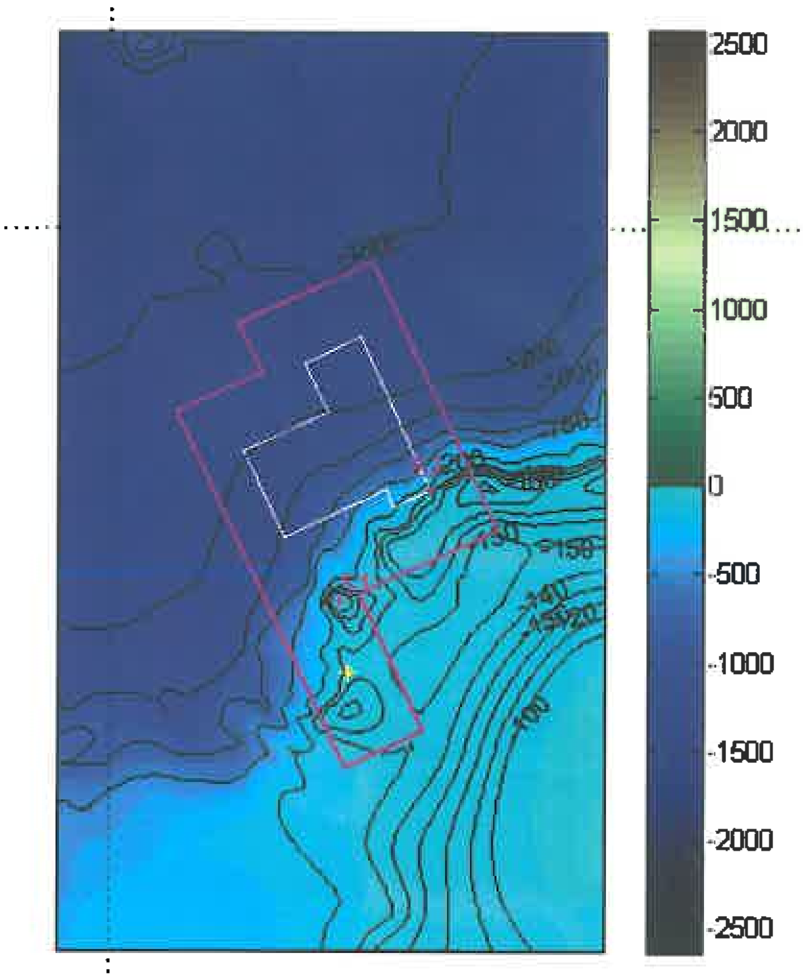

Figure 36: Modelling location for the Vulcan Operational Area (S1 – short range and S2 – long range) with the yellow dot showing the Tane-1 well

5.1.2.1.1 Short Range Modelling

The STLM used vertical and horizontal cross-sections through the frequency dependent beam pattern of the array to demonstrate the strong angle and frequency dependence of the sound radiation from the acoustic source array. The horizontal beam pattern shows that in the horizontal plane a large amount of the energy is radiated in the cross-line direction (azimuths of 90° and 270°) and a significant amount of energy is also radiated in the in-line direction (azimuths of 0° and 180°) as a result of the acoustic source configuration (Figure 37). A significant amount of energy is radiated in the cross-line direction. These beam patterns are characteristic of an acoustic array with wide spacing between elements or in the case of the Vulcan 3D MSS, wide spacing between the sub-arrays.

Figure 37 indicates the maximum received SELs at location S1 within the Vulcan Operational Area. The mitigation zones within the Code of Conduct are shown in Figure 37 and are indicated by a solid black circle (200 m), dashed black circle (1.0 km) and dash-dot black circle (1.5 km) relative to the maximum received SELs.

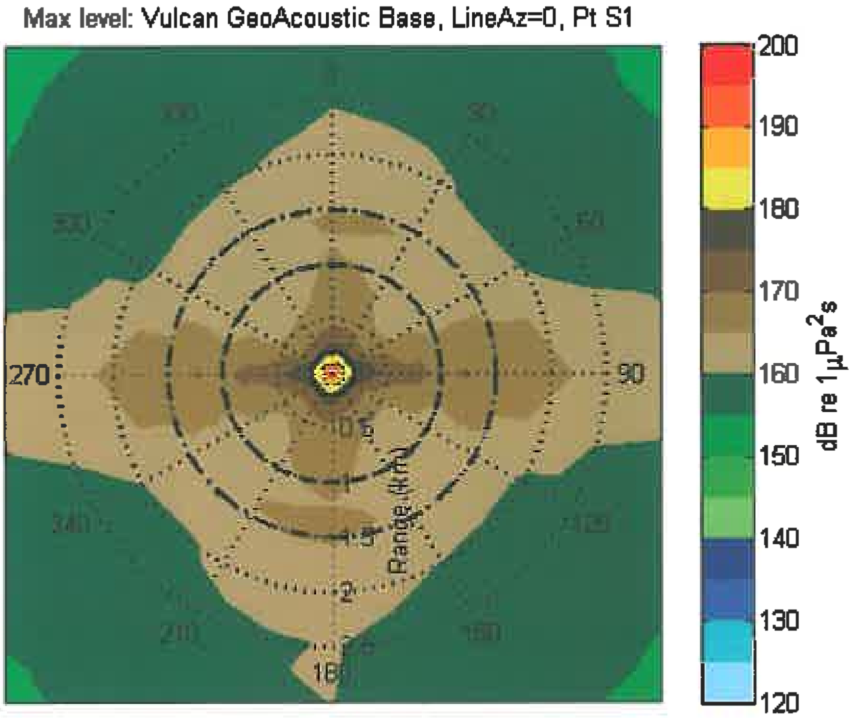

Figure 37: Maximum received SELs at any depth from the *Polar Duke* 3,460 in^3 acoustic source at S1

The modelling conducted in by Galindero-Romero and Duncan (2014) indicates that 100% of SELs lie below the threshold of 186 dB re 1 μPa^2.s (injury criteria) at distances of 200 m or greater from the source and below 171 dB re 1 μPa^2.s (behaviour criteria) at distances equal or above 1,000 m from the source (Table 14).

Table 14: Maximum SELs as a function of range from source location S1 in the Vulcan Operational Area

Range (m)	Maximum Sound Exposure Level (re 1 μPa^2.s)
200	180.7
1,000	168.5
1,500	168.2

An assessment was undertaken to determine the percentage of received SEL's below the standard thresholds within the Code of Conduct as a function of range. The percentage levels are plotted in Figure 38. These results show that 100% of SELs will be below 171 dB re 1 μPa^2.s and 186 dB re 1 μPa^2.s at the relevant mitigations distances.

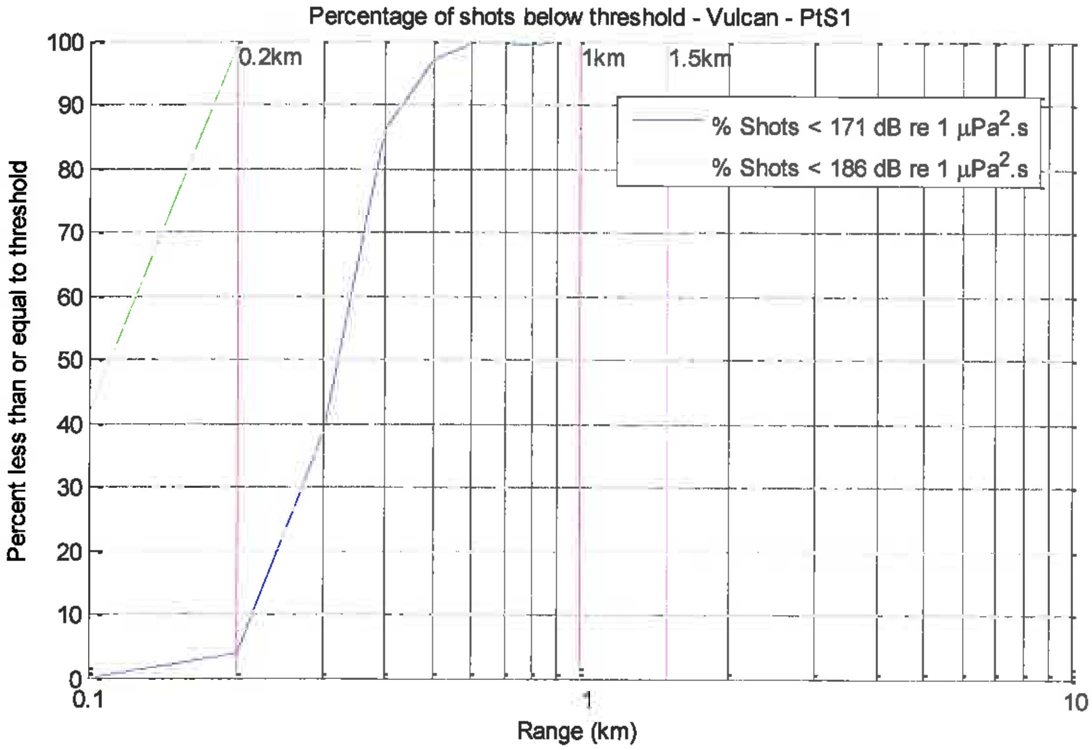

Figure 38: Percentage of received SELs below thresholds of 186 dB re 1 μPa².s (green) and 171 dB re 1 μPa².s (blue) as a function of range for source S1. Percentages are calculated over all azimuths and depths

5.1.2.1.2 Long Range Modelling

Long range modelling was undertaken at S2 out to a 350 km radius (Figure 39), with the S2 location being selected on the assumption that it was the location most likely to produce the highest SEL's inshore of the Vulcan Operational Area and within the west coast North Island MMS. WEL have taken a conservative approach for the long range modelling, as the source location was selected to model worst case (i.e. 152 m), where in reality the acoustic source will only be operating in this location for a very small portion of the overall Vulcan 3D MSS duration.

For long range modelling, variations in topography, such as the presence of canyons, are automatically accounted for by the inclusion of the bathymetry along propagation path. There are some limitations to the accuracy of this approach however, within the inshore portion of the Vulcan Operational Area, the bathymetry does not drop away sharply so these potential limitations are not likely to present themselves from the modelled location at S2. In contrast, short range modelling procedure precludes taking variations in topography into account, but such variations would be expected to have minimal impact on predicted sound levels at the 200 m, 1 km and 1.5 km mitigation specified in the Code of Conduct.

The acoustic propagation modelling method used for the long range modelling is usually referred to as N x 2D because it involves running a two-dimensional (range-depth) model along multiple azimuths. This is a common method of acoustic propagation modelling and is usually of more than adequate accuracy; however, its accuracy is limited by ignoring out of plane effects and will be reduced in situations such where the bathymetry is very steep and sound is propagating almost parallel to the contours. Several research groups are experimenting with fully three-dimensional parabolic equation models but these have not yet reached a point of efficiency and maturity where they can be used for operational modelling.

The long range STLM results shown in Figure 39 identify the strong and complicated directionality of the SELs due to a combination of the directionality of the acoustic array which produces the maximum amount of radiated energy in the in-line direction and to a lesser extent in the cross line direction. The effect of variable bathymetry causes rapid attenuation upslope from the source and enhances propagation downslope (Galindo-Romero and Duncan, 2014). As sound levels travel downslope, direction rays are flattened on each subsequent seabed reflection, reducing the number of seabed interactions and therefore attenuation rate. A reduction in sound speed with increasing depth results in downward refraction, where the highest sound levels occur in the lower portion of the water column. For sound travelling upslope from the acoustic source, the rays steepen on each subsequent seabed reflection, increasing the attenuation rate and distributing the sound energy more evenly through the water column.

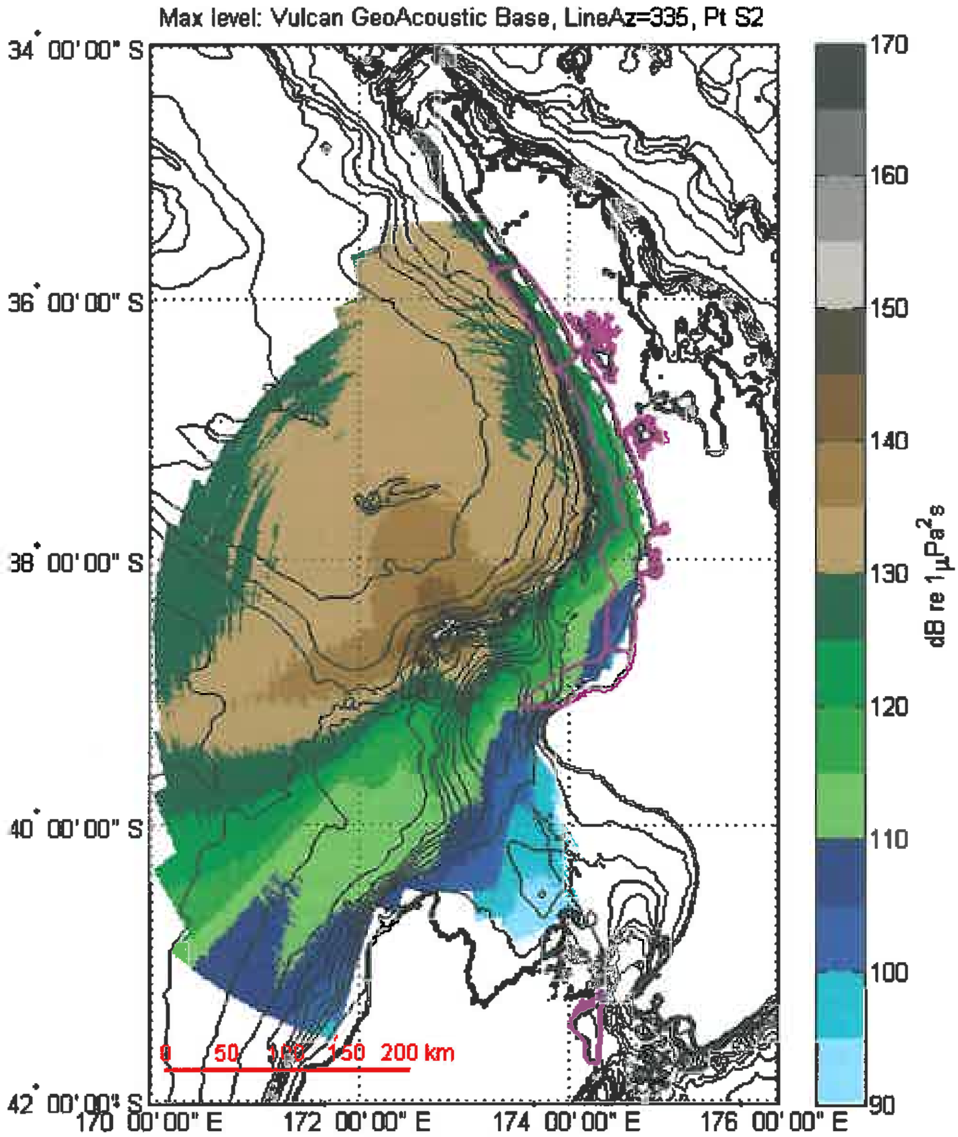

Figure 39: Geographical distribution of long range modelled SELs to a maximum range of 300 km at S2. Survey line azimuth is 335°T

This is illustrated in Figure 40 which shows a vertical cross-section through the sound field produced by the source modelled at the long-range modelling location S2 within the Vulcan Operational Area (along 160 °T and 340 °T). This cross-section shows the SEL emitted from the broadside of the array to the shore and into deep water (Galindo-Romero and Duncan, 2014). The highest SELs are transmitted vertically downward into the seabed; however, due to the total volume and frequency dependent beam pattern of the acoustic source array, energy is trapped in the ocean interior (Galindo-Romero and Duncan, 2014). The left hand side of the plot towards the northeast show the SEL's predicted to reach the west coast North Island MMS.

Figure 41 shows a second vertical cross-section through the sound field in the cross-line direction (along 70 °T and 250 °T) produced by an acoustic source at S2. Similar to the in-line direction the highest levels are transmitted vertically downwards into the seabed and sound is attenuated more inshore of S2 (left hand side of the plot – northeast).

To assess what SEL's could potentially reach the west coast North Island MMS, WEL took a conservative approach as part of the STLM, including modelling at the location likely to create the highest SEL's and using water column parameters for spring sound speed profile to capture worst-case conditions that could be encountered at the start of the Vulcan 3D MSS. The STLM indicated that the maximum SEL's at the offshore west coast North Island MMS boundary was predicted to be 133 dB re 1 μPa2.s which is well below the 171 dB re 1 μPa^2.s stated within the Code of Conduct (DOC, 2013).

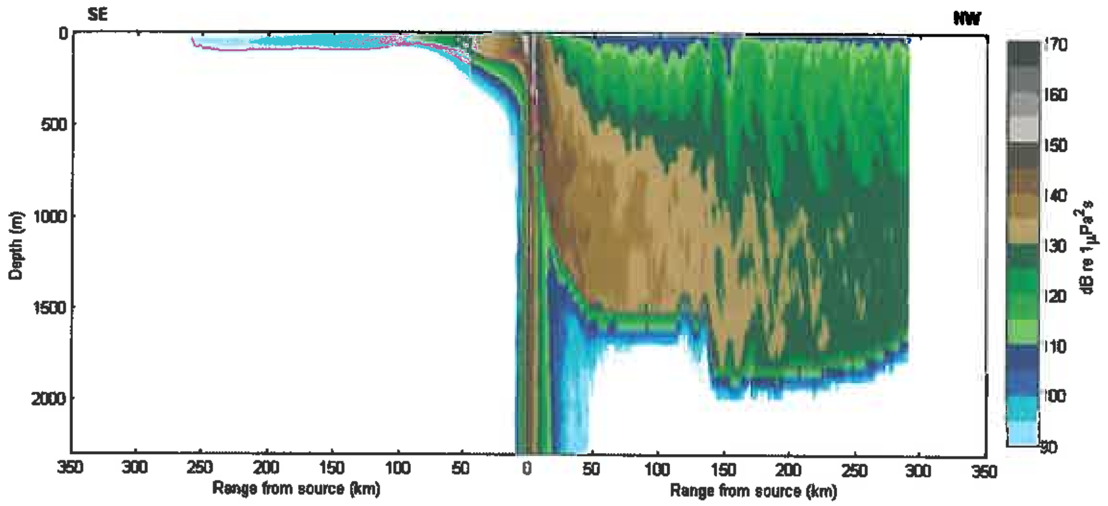

Figure 40: Vertical cross-section through the sound field in the in-line direction (160°T and 340°T), centred on S2. The magenta line is seabed.

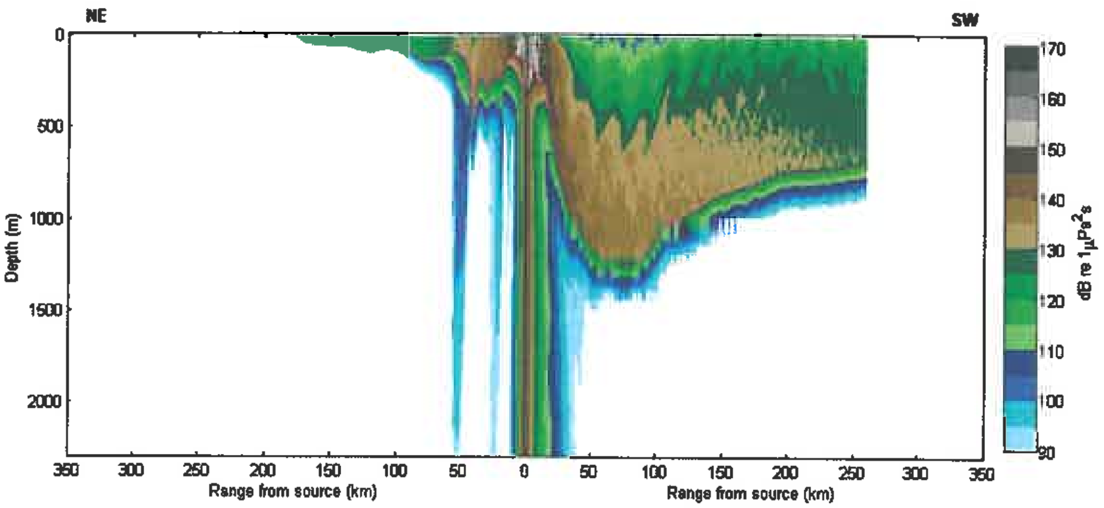

Figure 41: Vertical cross-section through the sound field in the cross-line direction (70°T and 250°T), centred on S2. The magenta line is seabed.

5.1.2.2 Behavioural Effects on Marine Mammals and Fauna

5.1.2.2.1 Avoidance and changes in distribution

The implications of movement or displacement of individual animals or a population depend on the temporal nature of the displacement. Short-term movement out of an area is thought to have very limited or no long term implications for a population. In contrast, long-term avoidance of an area could lead to displacement into sub-optimal or high-risk habitats resulting in additional exposure to predators as well as the loss of foraging or mating opportunities and therefore severely impacting the population.

Additionally, any changes in abundance and distribution of prey species (fish) will have a wide effect both on their predators (i.e. seabirds, marine mammals, fish etc.) and potentially also on fishing activities (both commercial and recreational).

5.1.2.2.1.1 Fish

Overall, studies of the impact of seismic surveys on fish can be separated into two main categories: experiments during which caged fish are exposed to an acoustic source and studies which rely on field data such as catch-effort data in an area before and after a seismic survey. Particular caution must be exercised when interpreting (and potentially extrapolating) results from existing peer-reviewed and grey literature on the impact of seismic source emission on fish. Variability in the characteristics of the experimental design (source properties, line spacing, timescale and spatial extent of data collection etc.) and the subjects (wild or farmed, demersal or pelagic, migrant or site-attached, age etc.) make it difficult to draw overall conclusions. Furthermore, tank behavioural studies only provide information on the very short term reaction of fish during and immediately after the onset of noise (Popper and Hastings, 2009). Beyond this, all behaviour is biased by the fact that the subjects are constrained to the tank and unable to flee.

The studies on the behavioural effects of acoustic sources on fish reviewed for this report gave little indication of long-term behavioural disruption. Short term responses in fish include C-starts and startle responses (Boeger *et al.*, 2006; Hassel *et al.*, 2004; Pearson *et al.*, 1992; Wardle *et al.*, 2001); modifications in schooling patterns and swim speed (Fewtrell and McCauley, 2012; McCauley *et al.*, 2000; Pearson *et al.*, 1992); freezing (Sverdrup *et al.*, 1994); and changes in fish distribution in water column (Fewtrell and McCauley, 2012; Pearson *et al.*, 1992). Furthermore, habituation and a resulting decrease in startle response has been documented in fish (Hassel *et al.*, 2004). This is also likely to occur during the Vulcan 3D MSS due to the use of soft-starts and the fact that the survey vessel will be moving slowly through the survey area. Overall, there is little indication of disturbance of the "day-to-day" behaviour of the animals (Wardle *et al.*, 2001; Woodside Petroleum Ltd, 2007a).

As mentioned above, MSS acquisition has been noted to cause both vertical and horizontal displacement in fish away from the acoustic source (Colman *et al.*, 2008; Handegard *et al.*, 2013; McCauley *et al.*, 2000; Pearson *et al.*, 1992; Woodside Petroleum Ltd, 2007a). Fish which have a pelagic lifestyle (rockfish, cod, haddock, blue whiting) tend to dive deeper (McCauley *et al.*, 2000), whereas site-attached coral reef species have been observed to swim into the reef for shelter on approach of the seismic survey and to resume normal activity swiftly after the vessel has passed (Colman *et al.*, 2008; Woodside Petroleum Ltd, 2007a).

It has long been considered by commercial fishers that MSSs can be disruptive to their fishing operations, and this is a view widely held around the world (Jakupsstovu *et al.*, 2001; McCauley *et al.*, 2000). Additionally, a number of studies have demonstrated a reduction in catch per unit effort in close proximity to MSSs (Bendell, 2011; Engas *et al.*, 1996; Handegard *et al.*, 2013; Skalski *et al.*, 1992). In an unpublished review (Gausland, 2003), the results of the Engas *et al* study (1996) were contested based on the fact that natural fluctuations in fish stocks had not been taken into consideration and that a long term negative trend could explain the reduction in catch rate. Additionally, although these studies have documented an effect on catch rates, these have only been short term investigations (up to five days after the exposure to the seismic source in the case of Engas *et al* (1996)) and no evidence of long term displacement was noted.

In the North Sea, geophysical surveys have been conducted continually over the last 40 years and during recent years MSS vessels have operated on fishing grounds in the Norwegian and Barents Seas. 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. The study showed that catch rates reduced by 55-80% within the survey area and for a distance up to 5 km. However, once the MSS ceased, catch rates returned to normal within 24 hours (Bendell, 2011).

In Lyme Bay (UK), the distribution of bass was documented during a seismic survey using a peak source of 202 dB re 1µPa@1m over a period of three and a half months. No long term changes in distribution where noted and importantly, data from tagged fish demonstrated that there were no large scale emigrations from the survey area (Pickett *et al.*, 1994).

In the Adriatic Sea, no changes in pelagic biomass where observed following emissions from an acoustic source with a peak of 210 dB re 1µPa@1m which indicates that catch rates would also remain unaffected (Labella *et al.*, 1996).

In the Faroes, a large scale study of catch rates was undertaken based on fishing vessel logbooks. Despite a majority of fishers reporting a decrease in catch caused by seismic surveys, the analysis of logbook records showed no significant effect of seismic activity in the area (Jakupsstovu *et al.*, 2001).

Based on these findings, it is likely that fish will undertake avoidance behaviour resulting in the displacement of stocks within the Vulcan Operational Area. Crucially, this displacement is predicted to be temporary and of an extent which falls within the normal geographic range of each particular species (Bendell, 2011). Short term repercussions include a possible increase in fishing effort if fishing is harder and a displacement of predator species/disruption of feeding activities (see Section 5.1.2.2.2). However, it is most likely that fishing vessels (commercial and recreational) would avoid the general Vulcan Operational Area fur the 30 day MSS duration.

Given the potential for displacement or avoidance of fish stocks to occur, it is considered that the risk to fish stocks and their natural habitat preferences in close proximity to the *Polar Duke* within the Vulcan Operational Area is ***medium***.

In order to keep impact to a minimum, mitigation measures will be implemented. The Vulcan 3D MSS will operate 24 hours a day, 7 days a week (weather and marine mammal encounters permitting) to ensure the survey period will be as short as possible (~35 days).

Commercial fishers who use the Vulcan Operational Area as part of their fishing grounds have been advised of the Vulcan 3D MSS and will be contacted closer to commencement with further details.

5.1.2.2.1.2 Crustaceans

As in the case of fish, behavioural responses of crustaceans to acoustic sources has the potential to impact their availability for capture by predator species and fishing operations. Although literature on the subject is limited, there is no indication of an effect of this nature on these species.

The most well-known crustacean species with NZ is the crayfish. Crayfish are found in coastal waters around NZ where rocky subtidal reefs are present. They are an important species within NZ from a commercial, cultural and recreational perspective. The Vulcan Operational Area lies within commercial Cray Fishing Area 9 (CRA 9) although the statistical areas for quota management only extend out to the CMA. CRA 9 is geographically large but has the smallest Total Allowable Commercial Catch (TACC) of the CRA fishery management areas within NZ. Most of the commercial catch of crayfish within CRA 9 comes from the northwest coast of the South Island and the area between Patea and Kawhia, in particular the Taranaki coastline. The TACC for CRA 9 is 60.8 tonnes which allows 20 tonnes for recreational catch and 30 tonnes for customary take.

Catch rates of three species of shrimp (southern white shrimp, southern brown shrimp and Atlantic seabob) showed no variation as a result of a seismic survey with a peak emission of 196 dB re 1 µPa at 1 m, indicating no short term effect on these species (Andriguetto-Filho *et al.*, 2005).

Similarly, no effect was detected in an extensive review of catch data from a lobster fishery spanning 25 years during which 28 2D and five 3D MSSs had been acquired (Parry and Gason, 2006). In this study, the number of seismic pulses were correlated to catch per unit effort data over 12 depth stratified regions (0-50 m, 51-100 m, 101-150 m) in the Western Rock Lobster Zone (Western Victoria, Australia). Catch per unit effort data showed no significant change in the weeks and years following seismic surveys leading authors to conclude a lack of apparent impact on rock lobster fisheries.

As a result, the impact of the acoustic source on these species is deemed to be **low**.

5.1.2.2.1.3 Cephalopods

Although startle responses have been observed in caged cephalopods exposed to acoustic sources, studies addressing noise-induced morphological changes in these species have been limited (Andre *et al.*, 2011).

In the McCauley *et al.* (2000) study, squid showed avoidance of the acoustic source by keeping close to the water's surface at the cage end furthest away from the acoustic source, at the surface where a sound shadow of almost 12 dB re 1 µPa exists. While alarm responses were consistent above 151-161 dB re 1 µPa, ramp-up of the acoustic source was seen to decrease startle response in these animals (McCauley *et al.*, 2000).

A later study corroborated these findings and further demonstrated that a source level of 147 dB re 1 µPa was necessary to induce an avoidance reaction in squid. Throughout this experiment, other reactions were also observed including alarm responses (inking and jetting away from the source), increased swimming speed and aggressive behaviour. It was noted that the reaction of the animals decreased with repeated exposure to the sound suggesting either habituation or impaired hearing (Fewtrell and McCauley, 2012).

As mentioned previously, it is not straightforward to use caged studies such as these as indicative of real world situations. However, it can be concluded that cephalopods will exhibit some form of avoidance response to the acoustic source.

Based on the information detailed above, the risk of the acoustic emissions from the Vulcan 3D MSS on cephalopod species is considered to be ***low***.

5.1.2.2.1.4 Marine Mammals and other Megafauna

Marine mammals are widely believed to stay away or avoid operating acoustic sources used during MSS (Goold, 1996; Stone and Tasker, 2006; Thompson *et al.*, 2013a; Thompson *et al.*, 2013b). These responses vary between species. In a large scale review of the impact of 201 seismic surveys conducted across the UK, researchers found that odontocetes were more likely to show lateral response (within the limits of visual observations), killer whales and mysticetes generally demonstrated a more limited movement sufficient to increase distance to the acoustic source, long-finned pilot whales simply changed their orientation, whereas as sperm whales showed no reaction.

In cases where avoidance has been observed, marine mammals have recorded swimming away from an acoustic source with some observed instances of rapid surface swimming and breaching (McCauley *et al.*, 2003a; McCauley *et al.*, 1998). This behaviour has been interpreted as a way of reducing their exposure to the higher sound levels.

Depending on the species considered, the level of sound needed to initiate a behavioural response can vary. Humpback whales exposed to seismic surveys, consistently changed course and speed to avoid any close encounters with an operating seismic array (McCauley *et al.*, 2000). In the McCauley *et al* (2003) study, the SPLs which initiated this avoidance response was estimated at 160 – 170 dB re 1 µPa peak to peak. From the Vulcan 3D MSS STLM, these sound levels are estimated to be present within ~1.5 km from the acoustic source (Figure 37).

Harbour porpoises exposed to a 470 in^3 acoustic source array over ranges of 5 – 10 km, at received peak-to-peak sound pressure levels of 165-175 dB re 1 µPa and SELs of 145 – 151 dB re 1µPas^{-1} were temporarily displaced. However, the animals were typically detected again at affected sites a few hours after the exposure. Moreover, the level of response declined throughout the 10 day survey period (Thompson *et al.*, 2013b). Thompson *et al* (2013b) concluded that prolonged seismic surveys did not lead to broad-scale displacement of marine mammals and that impact assessments should focus on sub-lethal effects of the acoustic emissions. It should, however, be highlighted that the acoustic source used for the Thompson *et al* (2013b) study was far smaller than the source to be used in the Vulcan 3D MSS. It is surmised that the potential implication of this in the Vulcan 3D MSS Operational Area will be the displacement of animals over a larger distance and for a longer period.

As mentioned above (see Section 4.2.4), both resident and migratory or vagrant species are expected to be encountered within the Vulcan Operational Area. Although it would appear that displacement of animals is only temporary, it is important to consider the implications on large scale patterns such as migrations. During the proposed Vulcan MSS there are no migrations expected through the Vulcan Operational Area. McCauley *et al* (2003) did not detect any changes in migratory patterns caused by seismic survey and it is therefore considered that with no migrations expected during the Vulcan MSS this can also be applied to the Vulcan Operational Area through the adherence to the Code of Conduct and associated mitigation measures.

Patterns of avoidance have also been observed in other species of megafauna. A study which exposed captive sea turtles to an approaching acoustic source indicated that they display a general alarm response at ~2 km from the acoustic source with avoidance behaviour estimated to occur at 1 km (McCauley *et al.*, 2000).

In addition to these avoidance responses, there is also anecdotal evidence of marine mammals being attracted to the seismic vessel and acoustic source. Common dolphins have been known to repeatedly head towards a seismic vessel to bow ride as it entered shallow waters off the Taranaki coastline with an active source. There are also multiple records of pinnipeds approaching an active acoustic source running at full capacity, suggesting that their inquisitive nature may override any fright or discomfort these animals may experience. A desktop study focussing on pinniped behaviour around an operating seismic vessels is currently being finalised. The report has drawn data from all of the MMO reports in NZ waters and any interactions or behavioural responses observed and recorded for NZ fur seals around the seismic vessel. The results from this study are expected at some stage in 2014.

Based on the studies mentioned above, it is surmised that displacement of marine mammals will occur. However, given the mobile nature of the survey, the disturbance will only be temporary. Despite the noted instances where marine mammals have been attracted to seismic survey vessels, it is considered that acoustic emissions from the Vulcan 3D MSS have a ***medium*** risk to marine mammals and megafauna due to potential avoidance and displacement from the Vulcan Operational Area.

Mitigation measures against this type of impact on marine mammals include the adherence to the Code of Conduct and mitigation measures. In addition, the survey will be operating outside of migration seasons in order to keep the number of marine mammals impacted to a minimum (see Section 4.2.4.2).

5.1.2.2.2 Disruption to Feeding Activities

The potential disruption to feeding activities caused by the acoustic emissions of the Vulcan 3D MSS is linked to the displacement of prey species (see Section 5.1.2.2.1) and the displacement of the predators themselves away from feeding grounds (see Section 5.1.2.2.1.4). Either scenario could have effects which are felt throughout the food chain and lead to the cessation of feeding activities for a more or less prolonged period.

Seabird feeding activities are likely to be interrupted through both these mechanisms. Birds in the area could be alarmed as the seismic array passes in their vicinity, causing them to stop feeding (Macduff-Duncan and Davies, 1995). Additionally, the displacement of baitfish (pilchards, saurie, anchovies etc.) could lead to a reduction in the diving activity of birds such as the Australasian gannet.

Similarly, marine mammals could be forced to leave feeding grounds (e.g. large aggregations of krill or fish) as a result of the Vulcan 3D MSS acoustic emissions. A number of species are known to feed in and around the Vulcan Operational Area (see Section 4.2.4). As mentioned earlier (see Section 5.1.2.2.1.4), marine mammals tend to temporarily avoid areas in which a MSS is occurring. This deviation from their natural distribution could have an impact on their ability to capture prey easily, forcing them to temporarily expend more energy hunting food. Data on the potential offshore marine mammal feeding grounds is scarce and any sightings recorded during the Vulcan 3D MSS will greatly enhance the knowledge of marine mammal distribution in the area.

Once the seismic vessel and acoustic array has passed through an area, or once the Vulcan 3D MSS is complete, the sound level within the marine environment will dissipate and there will be no further environmental effects on any species residing there. Therefore, the potential disruption and disturbance to marine mammals feeding activities by the Vulcan 3D MSS acoustic source within or in areas adjacent to the Vulcan Operational Area is considered to be ***medium.***

Mitigation measures to prevent disruption to the feeding mechanisms of marine mammals include the adherence to the Code of Conduct and the requisite mitigation measures.

Once the Vulcan 3D MSS is complete, any resonant noise within the Vulcan Operational Area or surrounding marine environment would diminish allowing animals to return to their preferred habitat.

5.1.2.2.3 Modification of Reproductive Behaviour in Marine Mammals

Since there is potential for the acoustic source emissions of the *Polar Duke* to cause displacement of marine mammals, it should also be concluded the acoustic source emissions have the potential to interrupt sensitive behaviour such as mating, breeding and nursery activities. However, since no confirmed breeding or mating grounds have been identified within the Vulcan Operational Area the risk of impact on reproductive behaviour is limited to the encounter of travelling or feeding mother and calf pairs. This scenario is widely covered in the Code of Conduct which defines larger exclusion zones around the acoustic sources when a Species of Concern with calf is sighted. It is assumed that encounters of this type will not be sufficiently numerous to have any population wide impact.

Therefore, the measures imposed by the Code of Conduct are such that the overall risk to marine mammals reproductive behaviour is considered to be ***medium***.

5.1.2.2.4 Interference with Acoustic Communication Signals in Marine Mammals

Marine mammals use sound both actively and passively for foraging, navigation, communication, reproduction, parental care, avoidance of predators and overall awareness of the environment (Johnson *et al.*, 2009; Thomas *et al.*, 1992). Consequently, the ability to perceive biologically important sound is crucial to these animals. Any acoustic disturbance caused by a MSS emitting sound in the same frequency range as these biological signals (Table 15) could interfere with, or even obscure, sounds emitted by individual animals and potentially lead to significant environmental effects (Di Iorio and Clark, 2009; Richardson *et al.*, 1995). Adaptive responses to anthropogenic sound such as changes in vocalisation strength, frequency, and timing have been documented in numerous studies (Di Iorio and Clark, 2009; Lesage *et al.*, 1999; McCauley *et al.*, 2003a; McCauley *et al.*, 1998; Nowacek *et al.*, 2007; Parks *et al.*, 2011).

Table 15: Cetaceans communication and echolocation frequencies

Species	Communication Frequency (kHz)	Echolocation Frequency (kHz)
Bottlenose dolphin	0.8 – 24	40 – 130
Common dolphin	0.2 – 16	23 – 67
Killer whale	0.5 – 25	12 – 25
Long finned pilot whale	1 – 18	6 – 117
Sperm whale	0.1 – 30	2 – 30
Blue whale	0.0124– 0.9	N/A
Hector's dolphin	N/A	120-125
Fin whale	0.017 - 0.15	N/A
Humpback whale	0.025 - 4	N/A
Minke whale	0.06 - 0.85	N/A
Southern right whale	0.05 - 0.5	N/A
Sei whale	1.5 - 3.5	N/A
Beaked whales	25 – 50	16
Northern bottlenose whale	3 - 16	20 - 30
Dusky dolphin	N/A	30-130
Risso's dolphin	22.5 - 90	N/A
Pygymy sperm whale	90-150	N/A

As mentioned in Section 3.1, sound frequencies emitted by seismic acoustic sources are broadband, where most of the energy is concentrated between 0.01 kHz and 0.25 kHz.

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

- Low frequency cetaceans which have an auditory bandwidth of 0.007 kHz and 22 kHz

  Species from this group, which could be found inside or in the area surrounding the Vulcan Operational Area include (see Section 4.2.4.1): southern right whale, pygmy right whale, humpback whale, minke whale, sei whale, Bryde's whale, blue whale and fin whale.

- Mid-frequency cetaceans which have an auditory bandwidth of 0.15 kHz and 160 kHz

  Species from this group which could be found inside or in the area surrounding the Vulcan Operational Area include (see Section 4.2.4.1): rough-toothed dolphin, bottlenose dolphin, striped dolphin, common dolphin, dusky dolphin, southern right whale dolphin, Risso's dolphin, false killer whale, killer whale, long finned-pilot whale, sperm whale, Arnoux's beaked whale, Shepherd's beaked whale, southern bottlenose whale, Cuvier's beaked whale, Andrew's beaked whale, Hector's beaked whale, Blainville's beaked whale, Gray's beaked whale, strap-toothed beaked whale, pygmy beaked whale and True's beaked whale.

- High-frequency cetaceans which have an auditory bandwidth of 0.2 kHz and 180 kHz

  Species from this group which could be found inside the Vulcan Operational Area include (see Section 4.2.4.1): dwarf sperm whale and pygmy sperm whale.

The greatest potential for interference of a MSS with cetacean acoustic signals is at the highest end of the seismic spectrum and the lowest end of whales and dolphins communication spectrum (Table 15).

The low frequency cetaceans (mysticetes) are particularly affected since they have the most overlap with the frequencies of seismic survey acoustic sources (Figure 42).

It has been shown that blue whales will increase their calls (emitted during social encounters and feeding) when a MSS is operational in the area (Di Iorio and Clark, 2009). It is believed that this occurs in order to increase the probability that communication signals will be successfully received by conspecifics and compensate for the masking of communications by noise.

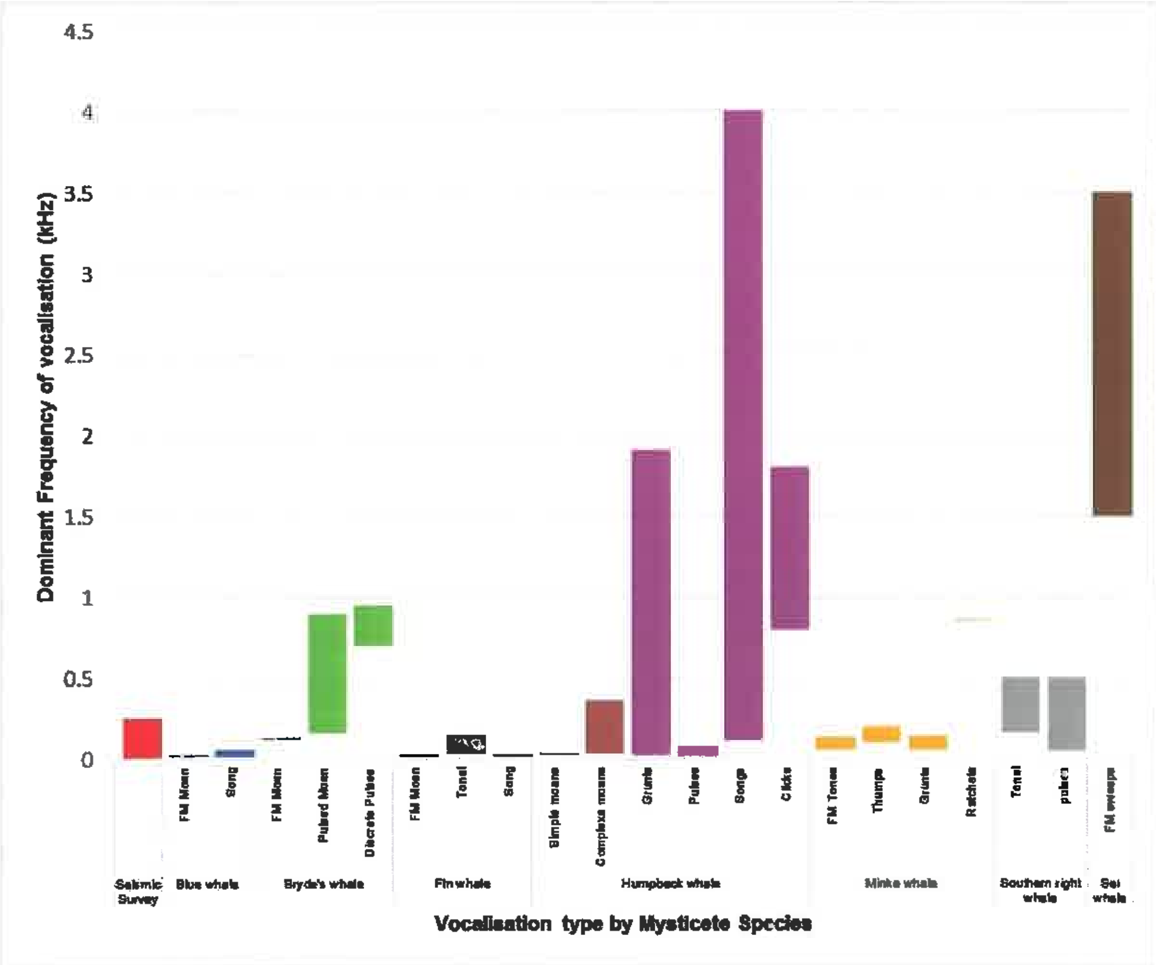

Figure 42: Dominant frequencies of vocalisations produced by mysticete species likely to occur in Vulcan Operational Area and overlap with MSS acoustic emissions

Mid and high frequency cetaceans are not likely to be detrimentally affected, as they generally operate at frequencies far higher than those generated by seismic acoustic sources (Table 15).

From the reviewed studies and available literature it is considered that there are no resident cetacean populations or critical habitat, so any potential impact on transiting cetaceans and the nature of these impacts would be temporary. It is considered that the acoustic source emission from the Vulcan 3D MSS could have a ***medium*** risk to marine mammal's use of naturally produced acoustic signals.

5.1.2.3 Physiological Effects on Marine Fauna

5.1.2.3.1 Larvae

Early larval stages of fish and invertebrates generally have a pelagic lifestyle. It is in this phase of their life cycle that the larvae could be exposed to noise if a MSS is being conducted in close proximity. Studies have shown that mortality of plankton communities can occur if they are within 5 m of an active acoustic source (DIR, 2007; Payne, 2004).

In a study of stage II zoeal Dungeness crab, no significant effect in terms of survival or time of moult was detected in individuals exposed to acoustic source (peak 231 dB re 1 µPa).

A study conducted in NZ at the Leigh Marine Laboratory exposed scallop larvae (*Pecten novaezelandiae*) to seismic pulses in tanks to assess the effect of noise on the early development stages of scallop larvae (Aguilar de Soto *et al.*, 2013). Scallop larvae were placed in noise flasks in a thin plastic mesh and suspended at a depth of 1 m in a tank filled with seawater (2 m diameter and 1.3 m deep). The noise flasks were suspended 5-10 cm in front of a sound transducer emitting a pulse every 3 seconds. Noise exposure started immediately after the flasks were put into the tank, which was within one hour after fertilisation. Control samples were also used with no acoustic source present. A total of 4,881 scallop larvae were utilised in the study and were sampled at seven fixed intervals (24, 30, 42, 54, 66, 78, and 90 hours) in order to document the development through several larval stages.

At completion of the Aguilar de Soto *et al.* (2013) study, 46% of the noise-exposed larvae showed abnormalities in the form of malformations including localised bulges in the soft body of the larvae, but not in the shell. In the control tanks, no malformations were found.

The study concluded that the observed damage was related to particle motion rather than the pressure component of the noise exposure. Recordings within the tank showed that the sound levels within the tank during the experiment were 160 dB re 1 µPa at 1m, but the particle velocities experienced by the larvae resulted in far-field pressure levels of 195-200 dB re 1 µPa. The report further concluded that given the strong disruption of larval development, weaker but still significant effects could be expected at lower exposure levels and shorter exposure durations.

These results are the first evidence that continual sound exposure can cause growth abnormalities in larvae and it is assumed that the exposure results of Aguilar de Soto *et al.* (2013) could be applied to other shellfish and fish in early developmental stages.

However, these results must be treated with caution when applying them to industry standard MSSs. The Aguilar de Soto *et al.* (2013) study, considers newly fertilised larvae, exposed to high intensity sounds with a short shotpoint interval (3 seconds) for an extended duration (between 24 and 90 hours). In contrast, industrial standard MSS apply a shotpoint interval of 8-11 seconds and exposure time is much shorter since the source is constantly moving at a speed of 4.5 kts. Furthermore, the Aguilar de Soto *et al.* (2013) study used a pulse duration of 1.5 seconds whereas the pulse duration for a seismic array is approximately 30 milliseconds. Additionally, given that the Vulcan 3D MSS will be operating at approximately 115 km from the Taranaki coastline, it is unlikely that recently fertilised shellfish larvae will be affected a, as fertilisation generally takes place in coastal waters..

Due to the distance offshore, the continual movement of the vessel, and the widespread and seasonal nature of larval production, the population level risk to fish and shellfish larvae is considered to be ***low***. In addition, the timing of the survey will be key in determining its effect on specific life-stages of key species such as longfin eels. The Vulcan 3D MSS is likely to be completed by the start of northward migration of adult eels; however, there is uncertainty of this migration period, but given the large size of these eels when they migrate there is likely to be very little interference from the Vulcan 3D MSS. The adult longfin eel migration path is also unknown, i.e. along the coast or further offshore as the eels travel towards Tonga. The most sensitive stage of the longfin's life cycle would be the return of the larvae and glass eels. As mentioned above, the eel larvae would have to be <5 m from the acoustic source for them to incur any negative effects. However, given the proposed timing of the Vulcan 3D MSS (January) it should not interfere with the return of the longfin eel larvae (July-December).

5.1.2.3.2 Fish

The potential physiological impact of sound on fish is variable. Depending on the source level and species considered, it can take the form of increased stress levels (Buscaino *et al.*, 2010; Santulli *et al.*, 1999; Smith, 2004), temporary or permanent hearing threshold shifts (Popper *et al.*, 2005; Smith, 2004), or damage to sensory organs (McCauley *et al.*, 2003b).

Studies undertaken on fathead minnows (*Pimephales promelus*) have shown that a threshold shift in hearing is directly correlated to the frequency and duration of sound exposure (Scholik and Yan, 2002). Temporary threshold shift (less than 24 hours) was observed after one hour of exposure to white noise at >1 kHz, but no threshold shift occurred at 0.8 kHz. The frequency of the acoustic sound for the Vulcan 3D MSS is between 2 – 250 Hz, and the sound emissions will only occur every 8 seconds during acquisition.

Another study in which northern pike (*Esox lucius*), broad whitefish (*Coregonus nasus*) and lake chub (*Couesius plumbeus*) were exposed to a 730 in^3 acoustic source (significantly smaller than the Vulcan 3D MSS acoustic source) found varying degrees of threshold shift, but recovery occurred within 24 hours of exposure (Popper *et al.*, 2005).

These experimental results should be considered in conjunction with results of behavioural studies (see Section 5.1.2.2.1.1) which demonstrate that fish will generally move away from a loud acoustic source in order to minimise their exposure. Consequently these data can be interpreted as a "worst case scenario" for fish which remain in close proximity to the seismic source. Additionally, even in close proximity to the source, not all species will be affected in the same manner. When considering three species of fish exposed to received levels of 193 dB re 1 µPa, Popper *et al* (2005) found that two species experienced a temporary threshold shift while the third showed no impact whatsoever.

In 2006, WEL applied to the regulator in Australia (Environmental Protection Authority) to undertake the 340 km^2 Maxima 3D MSS around Scott Reef in Western Australia. Prior to the survey an extensive scientific field validation survey costing over $10 million was conducted to assess the effects of a seismic survey on coral reef fish and coral species. The experiment involved 123 people from a variety of scientific organisations, including the Australian Institute of Marine Science, who conducted pre-, during and post seismic survey field experiments. The Maxima MSS Area water depths ranged from 20 – 1,100 m with the scientific study taking place within the southern lagoonal waters of Scott Reef. The study involved the exposure of faunal communities to acoustic source emissions using the actual survey vessel and acoustic array (2,055 in^3) to be used in the Maxima MSS. The monitoring work consisted of shallow water fish diversity and abundance data collection, coral monitoring, deep-water fish diversity and abundance data collection, collection of fish samples for pathology studies, and physiological studies. Sub-surface equipment was also deployed including sound loggers, remote underwater video and fish exposure cages with captured reef fish. The key finding of these studies was that there was no temporary or permanent hearing threshold shift in any species after exposure to the acoustic source and, crucially, that there were no long term impacts on fish populations (Colman *et al.*, 2008; Miller and Cripps, 2013; Woodside Petroleum Ltd, 2007b).

It has been concluded that during the Vulcan 3D MSS there is potential for the acoustic source to induce temporary effects on fish species that are in close proximity to the acoustic source, but the risk of any lasting physiological effects resulting in population level consequences on fish species caused by the acoustic source emissions during the Vulcan 3D MSS is considered to be ***low***.

5.1.2.3.3 Crustaceans and Molluscs

There is currently little information on how marine organisms process and analyse sound, which makes assessments of the impacts of artificial sound sources in the marine environment difficult (Andre and Kamminga, 2000). Research has shown that the effects of noise produced by a MSS on macroinvertebrates (scallop, sea urchin, mussels, periwinkles, crustaceans, shrimp, gastropods) result in 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). Sound levels required to cause mortality, based on the STLM would only be reached in very close proximity to the acoustic source (Andre *et al.*, 2011).

Moriyasu *et al.* (2004) undertook a literature review of studies on the effects of noise on invertebrate species. One 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. Results showed there was no discernible effects on the mussels or amphipods as a result of the acoustic sound at these short distances. A study in the Wadden Sea exposed brown shrimp to a sub-array of 15 acoustic sources with a source level of 190 dB re 1 µPa at 1 m from the source in a water depth of 2 m and found no mortality of the shrimp or any evidence of reduced catch rates. This result was attributed to the absence of gas-filled organs in these species.

From the summary above and based on the fact that the Vulcan 3D MSS will largely be conducted in waters greater than 150 m in depth, it is considered that the Vulcan 3D MSS would have ***low*** physiological effects on marine benthos.

5.1.2.3.4 Cephalopods

Situated in the food chain between fish and marine mammals, cephalopods are key bio-indicators for balance in vast and complex marine ecosystems (Andre *et al.*, 2011). Both squid and octopus occur in waters surrounding or inshore of the Vulcan Operational Area. Octopus live a cryptic lifestyle around reef structures and generally closer to shore. Squid can be found from coastal waters up to the edge of the continental shelf (Figure 30). They are a very short-lived but fast growing species which only live for one year and spawn in May and July (MPI, 2014a).

It is believed that if cephalopods are in close proximity (<1.5-2 km) to the operating acoustic source there is the potential for trauma to these species (Andre *et al.*, 2011).

The chances of octopus being within 1.5-2 km from the acoustic source is low given the Vulcan 3D MSS will be conducted in water depths of greater than 150 m and the closest point to land of the Vulcan 3D MSS is approximately 115 km.

Given their pelagic lifestyle, there is a chance that squid could come within 1.5-2 km of the acoustic source resulting in potential physical damage. However, squid are generally short-lived but fast growing species with high fecundity rates which spawn between May and July (MPI, 2014g). As a result, there is not anticipated to be any overall significant effects on the squid populations on the west coast North Island of NZ.

In Andre *et al.* (2011), four cephalopod species were exposed to low frequency sounds (50-400 Hz sinusoidal wave sweeps with a 1 second sweep period for two hours). The study identified the presence of lesions in the statocysts, which are believed to be involved in sound reception and perception. The received sound levels from these waves were of 157 ± 5 dB re 1 µPa, with peak levels at 175 re 1 µPa. It was therefore concluded that the effects of low frequency noise for a long period of time could induce severe acoustic trauma to cephalopods (Andre *et al.*, 2011).)

Based on the information detailed above, the mobile nature of the Vulcan 3D MSS, the wide distribution of pelagic cephalopod species and high population turn-over, the risk of the acoustic emissions of the Vulcan 3D MSS on cephalopod species is considered to be ***low***.

5.1.2.3.5 Marine Mammals

Sound intensities that would result in physiological effects are largely unknown for most marine animals, with current knowledge based on a limited number of experiments (Gordon *et al.*, 2003; Richardson *et al.*, 1995). Marine mammals are a protected species so they cannot be sacrificed for physical examinations and the size of most marine mammals does not generally allow captive studies to occur. However, it is believed that to cause immediate serious physiological damage to marine mammals, SELs need to be very high (Richardson *et al.*, 1995) and these are only found close to the acoustic source. The STLM showed that the SELs for injury criteria for cetaceans are likely to be at a range of less than 150 m from the source for the modelling location S1. SEL thresholds relating to injury of cetaceans are expected at much closer distances to the source based on the thresholds outlined by Southall *et al.* (2007).

Elevated SELs can lead to a hearing threshold shift, which in most cases is believed to only be temporary, while exposure to an extreme SEL could cause a permanent threshold shift.

In adherence to the Code of Conduct, pre-start observations, soft start and shut-down procedures will help minimise the risk to marine mammals to as low as reasonably practicable (ALARP) during the Vulcan 3D MSS. It should, however, be noted that most free-swimming marine mammals have been observed to swim away from an acoustic sound well before they are inside the range within which any physiological effects could occur (see Section 5.1.2.2.1.4).

Based on the information above, it is considered that the acoustic source emissions during the Vulcan 3D MSS could have ***medium*** physiological effects on marine mammals in close proximity to the *Polar Duke*.

5.1.2.3.6 Birds

Acoustic damage to birds could arise if one was to dive in very close proximity to the acoustic source while it was active. Although there is potential for some birds to be alarmed as the seismic array passes by them, any effects are likely to be beyond any harmful range (Macduff-Duncan and Davies, 1995). Additionally, once the acoustic source is operating, it is not likely that birds will be in the water close to the array.

Movement of baitfish away from an operating acoustic source means that there will be very little feeding by birds in close proximity to the acoustic source and therefore the risk to seabirds is ***low***.

5.1.2.3.7 Deepwater Benthic Communities

The potential effects of noise on benthic communities such as corals are not well understood and there is a notable lack of literature on the topic. It has been suggested that sound emissions from seismic sources could either remove or damage polyps on the coral calcium carbonate skeleton, or potentially impact the larval stages of the coral in the same way that larval stages of fish and invertebrates can be affected (see **Section 5.1.2.3.1**).

The Woodside Petroleum Ltd (2007) study was significant as it detected no signs of lethal or sub-lethal effects of a seismic survey on warm water corals in shallow water. This study was the world's first scientific study of this kind and demonstrated that MSS's can be undertaken in sensitive coral reef environments with no detrimental impact (Colman *et al.*, 2008). In addition, a study of hard coral communities within the southern lagoon of Scott Reef (45-60 m depth) considering condition of the reef 'before' and 'after' seismic survey, indicates no impact (Heyward *et al.*, in prep).

Based on the Woodside Petroleum Ltd (2007) study and given that there are no scientific publications of this type available for deepwater corals, it is also assumed that there would be no detectable effects on any of the deepwater coral species potentially present in waters surrounding the Vulcan Operational Area. These deepwater corals (e.g. black coral) are generally found at depths of >200 m (except in Fiordland) and so at a sufficient distance from the acoustic source to be unharmed by its emissions.

It is thought that deepwater corals' reproductive strategies could also mitigate against the potential impact of seismic sources. Mortality of pelagic or planktonic coral larvae is known to occur if the acoustic source is within close range (< 5 m) (DIR, 2007). This type of close interaction between the source and larvae is highly improbable for black coral. Despite having very low levels of fecundity and recruitment (making them vulnerable to any mortality), black coral are assumed to be protected from any close contact with the acoustic sources by the fact that their larvae are negatively buoyant and do not disperse very far from the mature coral (Consalvey *et al.*, 2006; Parker *et al.*, 1997).

Given that the larvae are negatively buoyant and that black coral generally live a great depths (>200 m – apart from Fiordland) there is very little chance that the larval stages will come in close proximity to the acoustic source used during the Vulcan 3D MSS. As a result, it is considered that the acoustic emissions from the Vulcan 3D MSS will pose a ***low*** risk to the deepwater corals.

5.1.3 Solid and Liquid Wastes

During the Vulcan 3D MSS various types of waste will be produced (sewage, galley waste, garbage and oily water) and if inappropriate management occurred there is the potential for an environmental effect. Each type of waste requires correct handling and disposal; the volume of waste generated will depend on the number of crew onboard each vessel and the MSS duration. All wastes that are produced during the Vulcan 3D MSS will be controlled in accordance to WEL standard practice and international standards.

5.1.3.1 Generation of Sewage and Greywater

The liquid wastes that will be generated during the Vulcan 3D MSS will include sewage and greywater (wastewater from washrooms, the galley and laundry). The *Polar Duke* and *Sanco Sky* have onboard sewage treatment plants which ensure a high level of treatment before the waste is discharged. All vessels involved in the Vulcan 3D MSS also have an International Sewage Pollution Prevention Certificate (ISPPC) where applicable to vessel class.

As a result of the high level of treatment the sewage generated by the vessels involved in the Vulcan 3D MSS receives, it is considered that the risk to the marine environment is ***low***.

5.1.3.2 Generation of Galley Waste and Garbage

In accordance with the NZ Marine Protection Rules, only biodegradable galley waste, mainly food scraps, will be discharged to sea at distances greater than 12 Nm from the nearest land. Comminuted waste (<25 mm) can be discharged beyond 3 Nm from shore. Given the high energy offshore marine environment, these discharges will rapidly dilute to non-detectable levels very quickly.

All solid and non-biodegradable liquid wastes will be retained onboard for disposal to managed facilities ashore through the waste management contractor.

For all disposal options MARPOL Annex V stipulations will be followed with records kept detailing quantity, type and approved disposal route of all wastes generated and will be available for inspection. All wastes, including hazardous returned to shore will be disposed of in strict adherence to local waste management requirements with all chain of custody records retained by WEL.

As a result of these operating procedures in place and adherence to MARPOL the risk from galley waste and garbage to the marine environment is considered to be ***low***.

5.1.3.3 Generation of Oily Waters

Oily waters on any vessel is generally derived from the bilges. The *Polar Duke* has a bilge water treatment plant that achieves a discharge that is below the NZ and MARPOL requirements of 15 ppm.

All vessels involved in the Vulcan 3D MSS have approved International Oil Pollution Prevention Certificates (IOPPC) where applicable to vessel class and have a Shipboard Oil Pollution Emergency Plan (SOPEP) in place.

As a result of operating in compliance to the above procedures, the environmental risk of any discharges to the marine environment is considered to be ***low***.

5.1.3.4 Atmospheric Emissions

Exhaust gasses from the *Polar Duke's* engines, machinery and air compressor generators are the principle sources of air emissions (combusted exhaust gasses) likely to be emitted to the atmosphere. Most of these gaseous emissions will be in the form of carbon dioxide, although smaller quantities of other gasses (oxides of nitrogen, carbon monoxide and sulphur dioxide) may be emitted. The *Polar Duke* has an International Air Pollution Prevention Certificate (IAPPC) which ensures that all engines and equipment are regularly serviced and maintained. Low sulphur fuel is also used by the *Polar Duke* which will further reduce emissions.

Potential adverse effects from these emissions are related to the reduction in ambient air quality in populated areas and potential adverse effects/health effects on personnel. However, given the distance offshore and exposed nature of the Vulcan Operational Area and the anticipated low level of emissions, the environmental risk arising from the Vulcan 3D MSS is considered to be ***low***.

5.2 Unplanned Activities – Potential Effects & Mitigation Measures

Unplanned activities are rare during MSS operations; however, if they were to occur, would likely be a result of a streamer break or loss, fuel/oil spill or a vessel collision. All marine operations have some risk, no matter how low and this assessment has covered the potential of this occurring.

5.2.1 Streamer Break or Loss

The potential damage to a seismic streamer could result from snagging with floating debris; or rupture from abrasions, shark bites or other vessels crossing the streamer.

The acquisition streamers to be used in the Vulcan 3D MSS are solid streamers. Therefore, if an acquisition streamer was to break or be severed, there is little potential for an effect on the marine environment. The solid streamers are negatively buoyant and require movement to maintain depth so if a streamer was severed it would start sinking. The acquisition streamers have Self Recovery Devices (SRD) fitted which deploy for retrieval once the streamer sinks below approximately 50 m depth. This will prevent any potential for crushing or damage to the benthic communities.

The Vulcan 3D MSS will be undertaken by experienced personnel and as a result of the streamer type to be used for the Vulcan 3D MSS, if a streamer was severed or lost the environmental risk would be ***low***.

5.2.2 Hydrocarbon Spills

The potential for a fuel or oil spill during the Vulcan 3D MSS could arise during an accidental spill during refuelling operations, leaking equipment or storage containers, or hull/fuel tank failure due to a collision or sinking. An accidental spill during refuelling or hydrocarbon spills caused by a collision or sinking are the most likely to cause and environmental effect. Other types of spills would be generally be contained on the vessel.

If a spill from the *Polar Duke'* fuel tank did occur, the maximum possible volume spilt would be 244 m^3. However, for this to occur, there would have to be a complete failure of the vessel's fuel containment system or catastrophic hull integrity failure. The high-tech navigational systems onboard, adherence of the COLREGS and operational procedures to international best practice will ensure that these risks are kept to a minimum.

All vessels involved in the Vulcan 3D MSS have an approved and certified SOPEP and IOPPC where applicable to vessel class (as per MARPOL 73/78 and the Maritime Protection Rules Part 130A and 123A) which are onboard the vessels at all times. In addition, the *Polar Duke* has a HSE Management Plan and Emergency Response Plan which would be used in the event of any emergency, including fuel spills.

Refuelling will be undertaken at sea approximately every three weeks from the support vessel accompanying the *Polar Duke*. The *Polar Duke* has a detailed refuelling protocol and procedures in place which are designed to prevent any incidents during a refuelling process. Spills caused by fuel handling mishaps are rare due to tried-and-true monitoring and management systems and procedures for such activities. Potential causes for a spill during refuelling could include hose rupture, coupling failures or tank overflow.

During refuelling operational procedures and equipment will be in place and implemented on board the seismic and support vessels and will be subject to the following Woodside requirements:

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

Should a spill occur during a refuelling operation, a spill response will initially be undertaken in accordance with the *Polar Duke* and support vessels SOPEPs. Notifications will be provided to Maritime NZ as per the requirements of the HSE Management Plan and Emergency Response Plan onboard the *Polar Duke*.

However, due to the safety, environmental and maritime requirements that will be implemented throughout the Vulcan 3D MSS, the risk of a fuel or oil spill occurring is considered to be ***low***.

5.2.3 Vessel Collision or Sinking

If a collision occurred whilst the *Polar Duke* was at sea, the biggest threat to the environmental would be the vessel reaching the sea floor and the subsequent release of hazardous substances, fuel, oil or lubricants. However, this is very unlikely as the risks are mitigated through the constant presence of a support vessel and adherence to the COLREGS. As a result, the risk for a vessel collision or sinking is considered to be ***low***.

5.3 Mitigation Measures

WEL will adhere to the mitigation measures identified in the Code of Conduct for operating a Level 1 MSS to minimise any adverse effects to marine mammals from the MSS operation (DOC, 2013). While undertaking the Vulcan 3D MSS, if there are any instances of non-compliance to the Code of Conduct and the mitigation measures identified below, the Director-General will be notified immediately.

The operational procedures that WEL will follow will be detailed in the MMMP (Appendix 4) and circulated among the MMO's and crew, with a summary of these operating procedures and mitigation measures listed in the following sections.

5.3.1 2013 Code of Conduct Mitigation Measures

The 2013 Code of Conduct was updated following the 2012 – 2013 summer period during which several MSSs were conducted in the Taranaki Basin, with operators voluntarily adhering to the 2012 Code of Conduct. During these surveys a number of operational issues were identified and led to a review of the 2012 Code of Conduct before the next MSS season (2013 – 2014 summer period). For the Vulcan 3D MSS, the requisite mitigation measures specific to a Level 1 MSS are identified in Section 2.3.1. However, WEL will implement additional mitigation measures and these are discussed in Section 5.3.2.

5.3.2 Additional Mitigation Measures for the Vulcan 3D MSS

5.3.2.1 Sound Transmission Loss Modelling

As discussed in Section 5.1.2.1 STLM has been undertaken to predict SEL's at the Code of Conduct specified distances from the *Polar Duke*. The STLM was based on the specific configuration of the acoustic source to be used for the Vulcan 3D MSS and the environmental conditions (i.e. bathymetry, substrate and underlying geology) of the Vulcan Operational Area.

Results were used to validate the mitigation zones identified for a Level 1 MSS in the Code of Conduct and as a result the STLM results were within the confines of the Code of Conduct. For MSSs undertaken in an AEI, the Code of Conduct requires that the STLM should provide the relative distances from the acoustic source at which behavioural criteria (171 dB re 1μPa^2-s SEL) and injury criteria (186 dB re 1μPa^2-s SEL) could be expected. Even though the Vulcan Survey Area is located beyond the AEI, WEL decided to undertake STLM as an additional mitigation measure. The STLM results showed that the SEL's produced from the Vulcan 3D MSS will be below the behaviour and injury criteria thresholds within the Code of Conduct.

5.3.2.2 Additional marine mammal observations outside Vulcan Operational Area

The *Polar Duke* will travel to the Vulcan Operational Area. On transit to the Vulcan Operational Area, a MMO will be on the bridge to observe for any marine mammals thus contributing to the understanding and distribution data of marine mammals around NZ.

Any marine mammal observations outside the Vulcan Operational Area will be recorded in the 'Off Survey' forms developed by DOC.

5.3.2.3 Necropsy of stranded marine mammals

If any marine mammals are stranded or washed ashore during or within two weeks after the Vulcan 3D MS and inshore of the Vulcan Operational Area, a discussion between DOC and WEL will occur to determine where the seismic vessel had been operating and whether a necropsy will be undertaken. DOC will be responsible for all aspects of the necropsy and coordination with pathologists at Massey University in order to determine the cause of death and whether it was a result of any pressure-related or auditory injuries, WEL will consider covering the costs directly associated with Massey University undertaking a necropsy.

5.3.2.4 Notification of any marine mammal carcass observed at sea

If a marine mammal carcass is observed at sea during the Vulcan 3D MSS, the location and species (where possible) and any other useful information will be recorded and the lead MMO will notify and provide this information to DOC at the earliest opportunity.

5.4 Cumulative Effects

Anthropogenic activities such as shipping and fishing occurring in the offshore Taranaki and Waikato waters all contribute to an increased level of underwater noise. The cumulative effect of shipping and seismic survey noise was investigated in the Di Iorio & Clark (2009) study and it was concluded in that study that shipping noise did not account for any changes in the acoustic behaviour of blue whales (Di Iorio and Clark, 2009). Given the amount of maritime shipping through the Vulcan Operational Area is relatively low (Figure 31) noise from shipping traffic has not been considered in this cumulative effects assessment.

At the time of preparation of this MMIA and through consultation with DOC National Office, there are likely to be two other MSSs being undertaken to the north and northwest of the Vulcan Operational Area.

When SEL's from two different seismic surveys combine it is actually counter-intuitive; the largest difference between the combined and individual SEL's will be 3 dB re 1µP^{2}s, and this will only occur at locations where both surveys produce the same SEL's.

In other words, 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 at the same location of 163 dB re 1µP2s (Alec Duncan pers. comm.).

However, if one survey produces a higher SEL than the other survey, then the higher SEL will dominate to the point where if Survey A produces a 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 SEL (Survey A). This combination of SEL's for two seismic sources operating is shown in Figure 43.

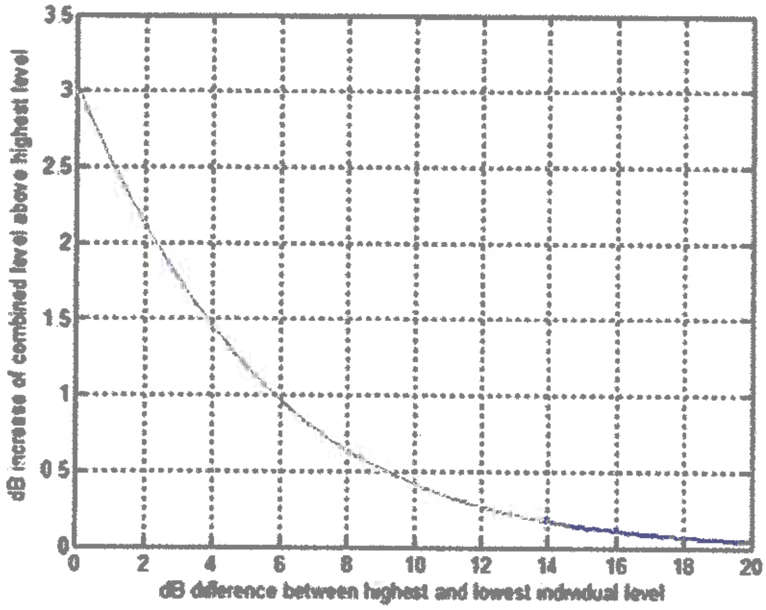

Figure 43: Sound exposure levels when two seismic sources operate together

The STLM shows that 100% of the SELs are below 171 dB re $1\mu P^2s$ at 1,000 m from the source. When the Vulcan 3D MSS and the other MSS are operating at the same time, they will be many km's apart. The distance between the survey areas will reduce the potential for any cumulative effects.

Cumulative impacts are much more likely to occur when two surveys are operating close together in both time or space or both. It is considered 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; however, this is still unproven.

The potential for cumulative impacts are also more 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, whereas open coastline allows the sound to dissipate more rapidly and therefore the risk is lower. Resident populations (i.e. Maui's/Hector's dolphins) are going to be more sensitive to cumulative impacts than for migratory or non-resident populations (i.e. humpback whales). Given the Vulcan 3D MSS is more than 115 km away from the coastline, the likelihood that any marine mammals residing in close proximity to the Vulcan Operational Area will be impacted by cumulative impacts from the MSS's conducted over January-February 2015 is low.

Therefore, given there will be significant distance between the Vulcan 3D MSS and those surveys further to the north of NZ and with the mitigation measures in place; the potential cumulative effects on marine mammals, marine fauna or the marine environment from the Vulcan 3D MSS will be ***low***.

5.5 Summary of Environmental Effects and Mitigation Measures

The potential environmental effects and associated mitigation measures that will be implemented for the Vulcan 3D MSS as identified in this MMIA are summarised in Table 16. WEL will operate in accordance to the Code of Conduct and implement mitigation measures to ensure any potential effects from the Vulcan 3D MSS are to ALARP.

Table 16: Vulcan 3D MSS planned and unplanned activities and the potential effects and mitigation measures to be implemented

Aspect or Source	Potential Environmental Effect	Likelihood of Occurrence	Consequence of Occurrence	Proposed Mitigation Measures to Avoid, Remedy or Mitigate Environmental Effects	Risk Category Ranking
Planned Activities					
Physical presence of *Polar Duke*, acoustic array and streamer.	Interference with the fishing community and marine traffic.	Possible	Minor	24/7 operations to minimise overall duration of MSS. Compliance with COLREGS. Support vessel present at all times. Notification to commercial fishing companies and representatives. Notification to sportfishing clubs. Notice to mariners issued.	Medium
	Interference with marine archaeology, cultural heritage or submarine infrastructure.	Unlikely	Negligible	Solid streamer with SRD. Compliance with COLREGS. Support vessel present at all times.	Low
	Changes in seabird behaviour.	Negligible	Negligible	No mitigation options available. MMOs will record any seabird strikes with the vessel that are witnessed.	Low
	Introduction of invasive marine species.	Negligible	Minor	WEL's IMS standards. Adherence to Import Health Standard for ballast water exchange. Adherence to Craft Risk Management Strategy for biofouling.	Low
	Interaction with marine mammals.	Possible	Negligible	Compliance with the Code of Conduct and mitigation zones. Two MMOs and two PAM operators will be observing for marine mammals 24 hours/day. Pre-survey observations, soft-start and delayed start/shut down procedures will be followed for duration of Vulcan 3D MSS. STLM to validate mitigation zones used against sound exposure thresholds for behaviour criteria and injury criteria.	Low
Acoustic sound source emissions – behavioural effects	Changes in abundance or behaviour of fish	Possible	Minor	24/7 operations to minimise overall duration of Vulcan 3D MSS. Soft-start procedures. Acoustic source and vessel always moving at approximately 4.5 knots. Any exposure will only be temporary.	Medium
	Avoidance and startle responses in marine mammals and other marine megafauna	Possible	Minor	Compliance with the Code of Conduct and mitigation zones. Two MMOs and two PAM operators will be observing for marine mammals 24 hours/day. Pre-survey observations, soft-start and delayed start/shut down procedures will be followed for duration of Vulcan 3D MSS. STLM to validate mitigation zones used against sound exposure thresholds for behaviour criteria and injury criteria. Survey Area located beyond the AEI (except tie lines).	Medium
	Disruption to feeding activities.	Possible	Minor	Compliance with the Code of Conduct and mitigation zones. Two MMOs and two PAM operators will be observing for marine mammals 24 hours/day. Pre-survey observations, soft-start and delayed start/shut down procedures will be followed for duration of Vulcan 3D MSS. STLM to validate mitigation zones used against sound exposure thresholds for behaviour criteria and injury criteria.	Medium

Aspect or Source	Potential Environmental Effect	Likelihood of Occurrence	Consequence of Occurrence	Proposed Mitigation Measures to Avoid, Remedy or Mitigate Environmental Effects	Risk Category Ranking
				Survey Area located beyond the AEI (except tie lines).	
	Disruption of reproductive behaviour in marine mammals	Unlikely	Minor	Compliance with the Code of Conduct and mitigation zones. Two MMOs and two PAM operators will be observing for marine mammals 24 hours/day. Pre-survey observations, soft-start and delayed start/shut down procedures will be followed for duration of Vulcan 3D MSS. STLM to validate mitigation zones used against sound exposure thresholds for behaviour criteria and injury criteria. Survey Area located beyond the AEI (except tie lines).	Low
	Interference with acoustic communication signals.	Possible	Minor	Compliance with the Code of Conduct and mitigation zones. Two MMOs and two PAM operators will be observing for marine mammals 24 hours/day. Pre-survey observations, soft-start and delayed start/shut down procedures will be followed for duration of Vulcan 3D MSS. STLM to validate mitigation zones used against sound exposure thresholds for behaviour criteria and injury criteria. Survey Area located beyond the AEI (except tie lines).	Medium
Acoustic sound source emissions – physiological effects	Physiological effects on marine mammals	Possible	Minor	Compliance with the Code of Conduct and mitigation zones. Two MMOs and two PAM operators will be observing for marine mammals 24 hours/day. Pre-survey observations, soft-start and delayed start/shut down procedures will be followed for duration of MSS. STLM to validate mitigation zones used against sound exposure thresholds for behaviour criteria and injury criteria. Survey Area located beyond the AEI (except tie lines).	Medium
	Physiological effects on seabirds	Unlikely	Negligible	Vessel is underway for the duration of the Vulcan 3D MSS. 24/7 operations to minimise overall duration of Vulcan 3D MSS.	Low
	Physiological effects on fish	Unlikely	Minor	Vessel is underway for the duration of the Vulcan 3D MSS. 24/7 operations to minimise overall duration of Vulcan 3D MSS.	Low
Acoustic sound source emissions – physiological effects on Invertebrates	Physiological effects on larvae	Unlikely	Minor	Vessel is underway for the duration of the Vulcan 3D MSS. 24/7 operations to minimise overall duration of Vulcan 3D MSS. Survey Area is located a long way from shore.	Low
	Physiological effects on benthos	Unlikely	Minor	Vessel is underway for the duration of the Vulcan 3D MSS. 24/7 operations to minimise overall duration of Vulcan 3D MSS. Survey area is located in deep water.	Low
	Physiological effects on deepwater corals	Unlikely	Negligible	Vessel is underway for the duration of the Vulcan 3D MSS. 24/7 operations to minimise overall duration of Vulcan 3D MSS.	Low
	Physiological effects on cephalopods	Unlikely	Minor	Vessel is underway for the duration of the Vulcan 3D MSS. 24/7 operations to minimise overall duration of Vulcan 3D MSS.	Low
Solid and liquid wastes.	Generation of sewage and greywater.	Possible	Negligible	On-board sewage treatment plant, Adherence to MARPOL	Low

Aspect or Source	Potential Environmental Effect	Likelihood of Occurrence	Consequence of Occurrence	Proposed Mitigation Measures to Avoid Remedy or Mitigate Environmental Effects	Risk Category Ranking
				Approved ISPPC where applicable to vessel class.	
	Generation of galley waste and garbage.	Possible	Negligible	Biodegradable waste discharged overboard beyond 12 Nm from the nearest land or 3 Nm if comminuted. Adherence to MARPOL Annex V.	Low
	Generation of oily waters.	Unlikely	Negligible	Adherence to MARPOL. Oily-water separators. Approved IOPPC where applicable to vessel class. Approved SOPEP.	Low
Atmospheric emissions.	Atmospheric emissions.	Unlikely	Negligible	Approved IAPPC where applicable to vessel class. Regular maintenance of motors, equipment and generators.	Low
Cumulative Effects	Cumulative sound exposure on marine mammals from two seismic surveys	Unlikely	Negligible	Compliance with the Code of Conduct and mitigation zones. Two MMOs and two PAM operators will be observing for marine mammals 24 hours/day. Pre-survey observations, soft-start and delayed start/shut down procedures will be followed for duration of Vulcan 3D MSS. If another survey is to be acquired, the vessels would communicate so that the MSS's were acquired as far apart as possible to minimise disturbance to marine environment and also prevent interference with the received signals from each source.	Low
Unplanned Activities					
Streamer break or loss.	Water or seabed impact.	Unlikely	Negligible	Solid streamers with SRD fitted. Support vessel present at all times.	Low
Fuel or oil spills.	Water and coastal impact.	Unlikely	Negligible	Compliance with COLREGS. Approved SOPEP. Approved IOPPC where applicable to vessel class. Bunkering only occurs during daylight hours and suitable sea conditions. Bunkering operations manned with constant visual monitoring of gauges, hoses, fittings and sea surface. Radio communication between seismic and support vessel. All equipment (transfer hose and dry break couplings) are visually checked for integrity. JHA (or equivalent) in place and reviewed before each fuel transfer.	Low
Vessel collision or sinking.	Water and coastal impact.	Unlikely	Minor	24/7 operations to minimise duration of survey. Compliance with COLREGS. Support vessel present at all times. Notice to Mariners issued and broadcast on Maritime Radio. All users have been advised of the Vulcan 3D MSS operation.	Low

6 Environmental Management Plan

The management of environmental risks associated with WEL's activities is integral to their business decision-making processes. Environmental risks and hazards are identified during planning stages and throughout operations, and their associated risks are assessed and managed via a structured management system. These mechanisms ensure that WEL's high environmental standards are maintained, the commitments specified in this MMIA are achieved and that any unforeseen aspects of the proposed Vulcan 3D MSS are detected and addressed.

The Environmental Management Plan (EMP) is essential for the successful implementation of the Vulcan 3D MSS; highlighting the key environmental objectives, the mitigation measures and monitoring programmes to be followed as well as the regulatory and reporting requirements and commitments outlined in this MMIA.

The mitigation measures for the Vulcan 3D MSS will be implemented to eliminate, offset, or reduce any identified environmental effects to ALARP.

The *Polar Duke* also has its own independent EMP which documents the implementation of their environmental management system as part of their Health, Safety and Environmental Quality Planning process for their operations, waste accounting system, waste management plan and emergency response plan, including for small oil and fuel spills.

The EMP for the Vulcan 3D MSS is provided in Table 17 and will be undertaken in conjunction with the MMMP (Appendix 4).

The Vulcan 3D MSS will be conducted in accordance to (but not limited to) the Code of Conduct, all relevant Maritime regulations, Marine Protection Rules, Environmental Best Practice Guidelines for the Offshore Petroleum Industry (MfE, 2006) and the Health and Safety in Employment (Petroleum Exploration and Extraction) Regulations 2013 (Mateparae, 2013). As a result of compliance with the Code of Conduct, if any marine mammals are observed within the relevant mitigation zones, the four qualified observers onboard the *Polar Duke* have the authority to delay or shut down an active seismic array.

Table 17: Vulcan 3D MSS Environmental Management Plan

Environmental Objectives	Parameters to be Controlled	Control Frequency	Proposed Actions	Legislation and Protocols to be Applied
Minimise interference with fisheries community.	Presence of fishing boats.	Pre-survey. Continuous.	24/7 operation to minimise MSS duration. Information provided to fishing authorities, fishing and boating clubs. Support boat investigation, coastal navigation warning and Notice to Mariners issued.	COLREGS. International best practice.
Minimise introduction of invasive marine species.	Hull fouling. Ballast water discharge.	Continuous.	WEL's IMS standards. Adherence to Import Health Standard for ballast water exchange. Adherence to Craft Risk Management Strategy for biofouling. Regular maintenance undertaken.	International best practice. Import Health Standard for Ships' Ballast Water from All Countries (Biosecurity Act 1993). Draft Craft Risk Management Strategy for Vessel Biofouling.
Minimise disruption and physiological effects to marine mammals and marine fauna.	Presence of marine mammals within mitigation zones while acoustic source is active.	Continuous observation 24 hours per day by four qualified observers. Use of PAM 24/7.	Compliance with Code of Conduct and Section 5.3.2. 24/7 operation to minimise MSS duration. Presence of two qualified MMOs and two qualified PAM operators (PAM used 24/7). Pre-start observations, soft start and delay start/shut down procedures.	The Code of Conduct. Marine Mammals Protection Act 1978 & Marine Mammals Protection Regulations 1992.
Minimise effects on sea water quality.	Liquid wastes.	Continuous.	Discharge to sea in accordance with MARPOL and NZ regulations.	MARPOL 73/78. NZ Maritime Transport Act 1994.
	Oil and other waste.	Continuous.	Disposed at an approved shore reception facility in compliance with legal procedures and maintain a waste disposal log. Approved SOPEP and IOPPC where applicable to vessel class.	MARPOL 73/78. NZ Maritime Transport Act 1994.
	Bio-degradable wastes.	Continuous.	Can be discharged overboard beyond 12 Nm from the coastline or 3 Nm if comminuted.	MARPOL 73/78. NZ Maritime Transport Act 1994.
Solid waste management.	Solid waste.	Continuous.	Dispose at an approved shore reception facility in compliance with local regulatory requirements. Waste disposal log will be kept.	MARPOL 73/78. NZ Maritime Transport Act 1994.
	Bio-degradable wastes.	Continuous.	Discharged overboard from seismic and support vessels, will be comminuted so can occur beyond 3 Nm from coastline.	MARPOL 73/78. NZ Maritime Transport Act 1994.
Minimise effects on air quality.	Atmospheric emissions.	Continuous.	Proper maintenance of equipment and generators. Approved IAPPC where applicable to vessel class and regular monitoring of fuel consumption.	Best practice.
Minimise accidental events.	Streamer break or loss. Collisions. Fuel/oil spills.	Continuous.	24/7 operations to minimise survey duration. Solid streamer used with SRD's fitted. COLREGS and presence of a support vessel. Approved SOPEP in place. Bunkering only occurs during daylight hours and suitable sea conditions. Bunkering operations manned with constant visual monitoring of gauges, hoses, fittings and sea surface. Radio communication between seismic and support vessel. All equipment (transfer hose and dry break couplings) are visually checked for integrity. JHA (or equivalent) in place and reviewed before each fuel transfer.	Best Practice. COLREGS.

7 Conclusion

Within the petroleum industry, a MSS is considered a routine activity and a requirement to discover and further develop oil and gas fields. Well established standard operating procedures are in place within the petroleum industry to reduce any potential environmental effects that could arise from a MSS to ALARP.

WEL will comply with the Code of Conduct, NZ Maritime Rules, NZ Marine Protection rules, WEL's internal HSE documents and implement international best practice to ensure there is no harm to any marine mammals, marine fauna, the marine environment or any personnel.

As well as adhering to the Code of Conduct, WEL will implement additional mitigation measures as part of the Vulcan 3D MSS, even though the Vulcan Operational Area is beyond the AEI. The mitigation zones within the Code of Conduct for a Level 1 MSS were validated by STLM and were within the SEL thresholds stated in the Code of Conduct. Adhering to the Code of Conduct mitigation zones there should be no injury to marine mammals. WEL will have two independent and suitably qualified MMO's and two independent and suitably qualified PAM operators on board the *Polar Duke*, and with the use of PAM, observations will be carried out 24/7 while the acoustic source is active.

There is a long history of MSS's around the NZ coastline and to date there has been no significant environmental effects on marine mammals or the marine environment which have been recorded by independent MMO's.

The *Polar Duke* is a specialised MSS vessel that has advanced seismic acquisition technology and environmentally sensitive operational equipment onboard in order to reduce any environmental effects on marine mammals or the marine environment to ALARP.

This MMIA identifies and discusses the potential environmental effects from the Vulcan 3D MSS and the mitigation measures that will be implemented to ensure that any potential effects are ALARP.

From the information provided in this MMIA, and the environmental risk assessment undertaken, it is considered that the potential for any adverse effects on the marine environment or marine mammals are ***low***. This assessment is based on the Vulcan 3D MSS being undertaken in compliance with the Code of Conduct and the mitigation measures discussed in this MMIA.

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Appendices

This report contains the following appendices.

Number	Title
1	Vulcan 3D MSS Information Sheet
2	Consultation Register with Key Stakeholders
3	Technical Details of the PAM system
4	Marine Mammal Mitigation Plan for the Vulcan 3D MSS
5	Sound Transmission Loss Modelling
6	Vulcan 3D MSS Environmental Risk Assessment Summary

APPENDIX 1

Vulcan 3D MSS Information Sheet

ENVIRONMENTAL OFFSHORE SERVICES LIMITED

Woodside Energy Limited
Vulcan 3D Marine Seismic Survey – Taranaki Basin
Information Sheet

Environmental Offshore Services Limited (EOS) has been engaged by Woodside Energy Limited to prepare a Marine Mammal Impact Assessment (MMIA) for a 3D Marine Seismic Survey (MSS), 115 km northwest of New Plymouth in the Taranaki Basin (Figure 1).

Survey Details

The 900 km² Vulcan 3D MSS will be located within Petroleum Exploration Permit 55793 to assess hydrocarbon prospectivity in the area. Figure 1 shows the Vulcan Survey Area which is bound by the Vulcan Operational Area to allow for line changes, acoustic source testing and soft-start initiation.

The Vulcan 3D MSS is scheduled to commence in early Q1 2015and is expected to take approximately one month to complete depending on weather constraints and marine mammal encounters.

Activity Summary

Seismic surveying is commonly used in the oil and gas industry to improve understanding of subsurface geology. For the Vulcan 3D MSS, seismic data will be collected using a purpose-built seismic survey vessel towing dual acoustic source arrays and hydrophone cables, also known as streamers.

The acoustic emissions from the source arrays will be detected by the hydrophone cables and recorded onboard the seismic vessel. The reflected sound is then processed to provide information about the structure and composition of geological formations below the seabed to identify potential hydrocarbon reservoirs (Figure 2).

Woodside intends to contract a specialist seismic vessel to undertake the Vulcan 3D MSS. The seismic vessel is expected to tow 12 streamers up to 8 km long and 100 m apart resulting in a 1,100 m spread of gear being towed that will restrict its ability to manoeuvre (Figure 3). The end of each streamer is marked with a tail buoy that can be observed day and night due to a flashing light and radar reflector. The seismic vessel will traverse the survey area in a series of pre-determined lines at a speed of approximately 4-5 knots or 7-9 km/hr.

A support vessel and a chase vessel will accompany the seismic vessel to ensure the survey area is clear of obstructions and inform other users of the presence of the seismic vessel if they cannot be contacted via VHF radio. A Notice to Mariners will be issued and a warning will be broadcast daily on maritime radio advising of the Vulcan 3D MSS for the duration of the survey.

Environmental Management

Woodside has a long history of successfully conducting marine seismic surveys. The Vulcan 3D MSS has been subject to rigorous environmental risk assessment and planning. An environmental risk assessment was conducted in preparation for the Vulcan 3D MSS. As a result, a number of mitigation measures and management measures will be implemented during the proposed survey, including:

- Measures to protect marine mammals, including using dedicated marine mammal observers and passive acoustic monitoring during survey activities;
- All routine discharges (sewage/grey water) will meet the relevant requirements of the International Convention of the Prevention of Pollution from Ships 73/78 (referred to as MARPOL (73/78);
- Appropriate spill response plans and equipment will be kept and maintained on vessels; and
- All vessels will be managed as appropriate to prevent the introduction of invasive marine species.

Environmental Approvals

Woodside will operate the Vulcan 3D MSS in accordance with the '2013 Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Operations' (Code of Conduct). Under the Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012, seismic surveys are classified as Permitted Activities where the operator complies with the Code of Conduct. This requires a MMIA to be prepared and that the mitigation measures for a Level 1 seismic survey under the Code of Conduct are adhered to in order to prevent any adverse effects on the marine environment or marine mammals. The Director-General of Department of Conservation is required to give formal sign off to the MMIA before the Vulcan 3D MSS can commence.

Contact Details

If you have any further questions or matters you would like to discuss or you would like any further information in regards to the Vulcan 3D MSS, please contact Dan Govier of EOS.

Dan Govier
Environmental Consultant
Environmental Offshore Services Ltd

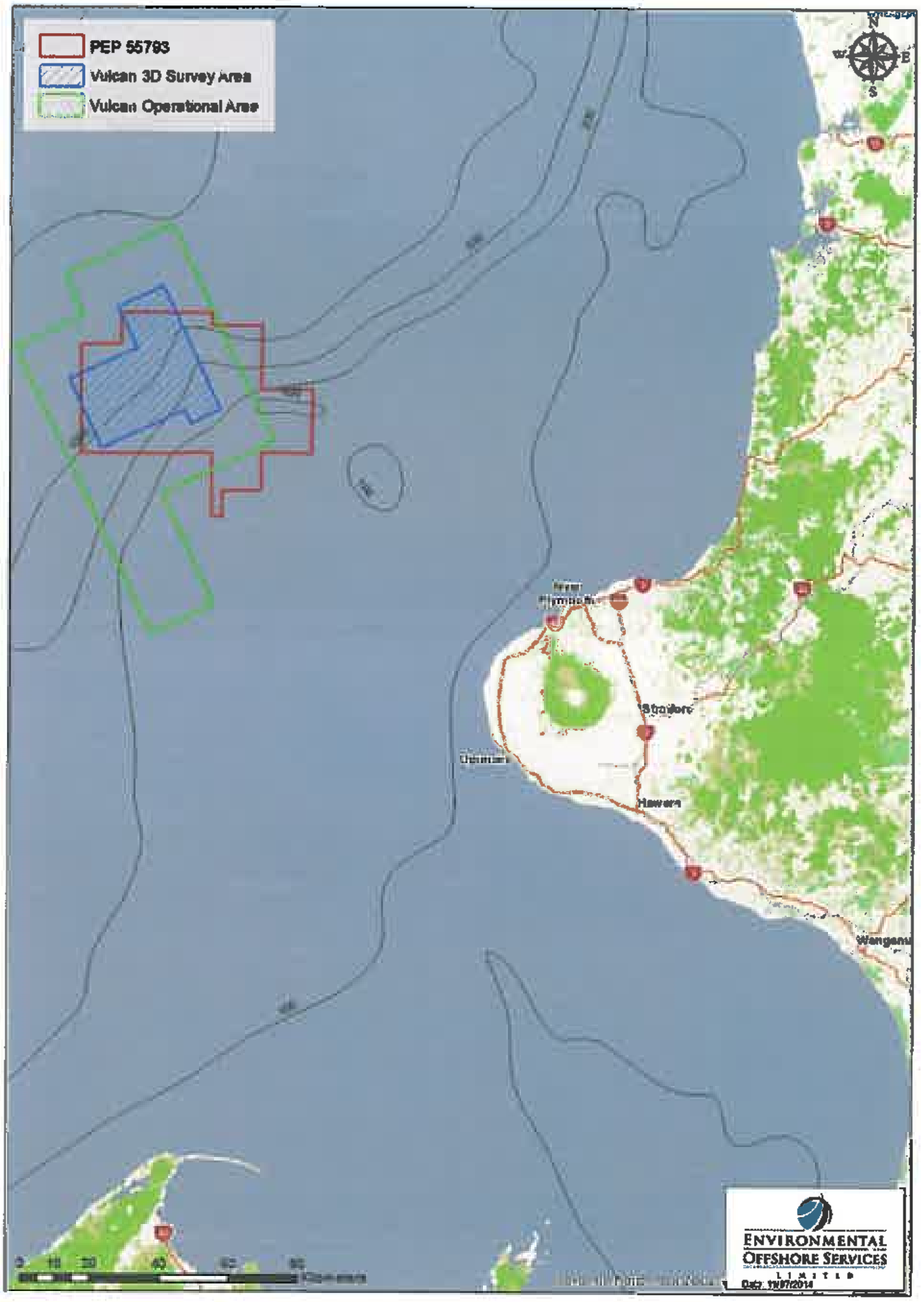


Figure 1: Vulcan 3D Survey Area and Vulcan Operational Area

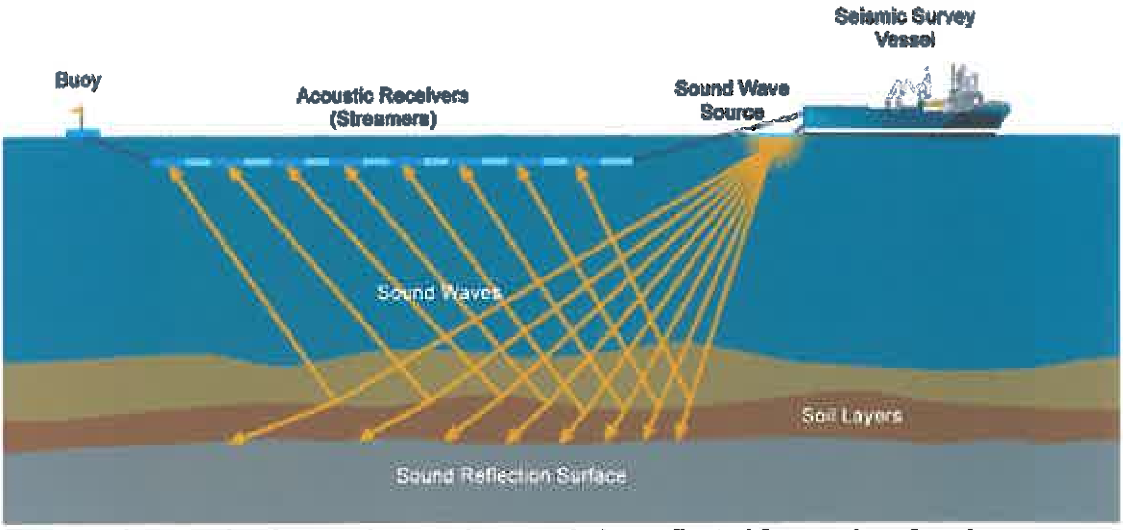


Figure 2: Schematic of acoustic sound source being reflected from subsurface layers

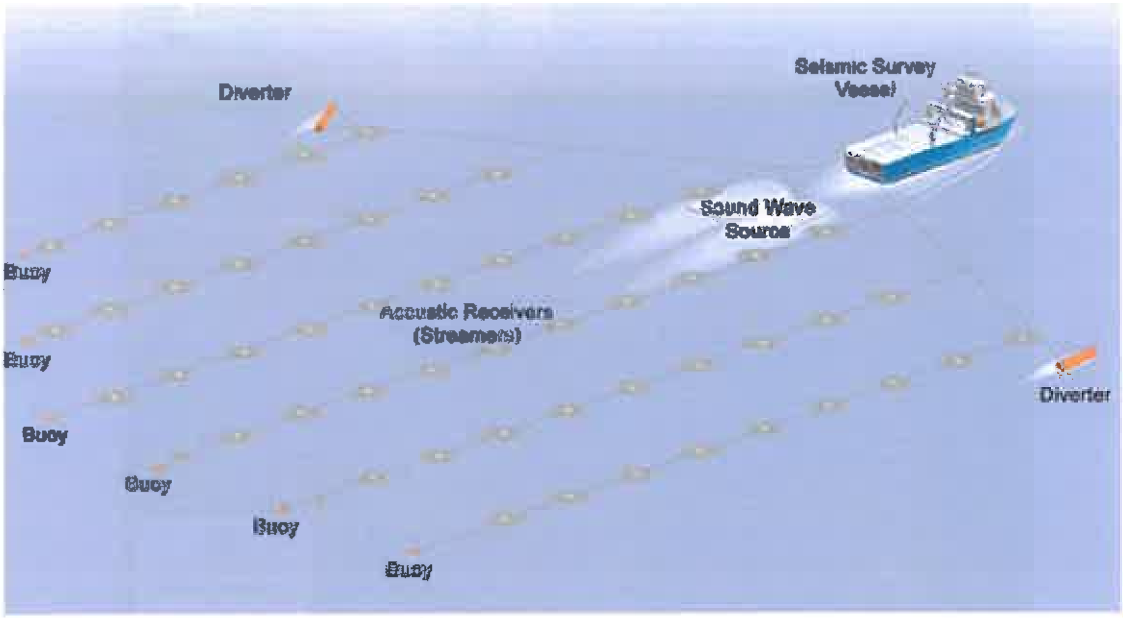


Figure 3: Schematic of a 3D seismic survey

APPENDIX 2

Consultation Register with Key Stakeholders

Stakeholder	Discussion Summary
EPA / DOC – Wellington 24 February 2014	An introductory meeting with EPA and DOC staff in Wellington, with WEL and NZOG in attendance. WEL provided a company overview and summary of the work program commitments attached to the exploration permit. EPA / DOC provided an overview of the governing regulations under the EEZ act and the requirement to comply with the seismic code of conduct. A discussion over the consultation process, and the need to engage broadly with iwi and community groups that have an interest in the area of operation.
Taranaki Regional Council 27 February 2014	An introductory meeting with the Taranaki Regional Council (TRC) in New Plymouth, with WEL and NZOG in attendance. The TRC confirmed seismic survey activities were taking place outside of its jurisdiction. A general discussion on the consultation process and assistance to identify parties to engage with was had.
Venture Taranaki 27 February 2014	An introductory meeting with Venture Taranaki in New Plymouth, with WEL and NZOG in attendance. Focus of discussions was on engaging with iwi and community groups with an interest in the area of operation.
Taranaki Iwi Trust 27 February 2014	An introductory meeting with the Taranaki Iwi Trust in New Plymouth, with WEL and NZOG in attendance. WEL provided a company overview and summary of the work program commitments attached to the exploration permit. The Trust provided a cultural context and overview of primary concerns Taranaki iwi may have with the proposed activities.
Ngati Mutunga Ngati Tama 5 April 2015	An introductory meeting with Ngati Mutunga and Ngati Tama trust officials in New Plymouth, with WEL and NZOG in attendance. WEL and NZOG provided company overviews and summary of the work program commitments attached to the exploration permit. Throughout the discussion the importance of protecting the environment was emphasised. A particular focus was oil spill response, given the Rena and Macondo incidents. Other concerns raised were the lack of benefits of oil and gas activities flowing back into the communities.
Ngati Maru 5 April 2014	Unfortunately this meeting did not happen due to non-attendance.
Te Atiawa 5 April 2014	Unfortunately this meeting did not happen due to non-attendance.
Ngati Maru Trust 28 May 2014	An introductory meeting with the Ngati Maru Trust in New Plymouth. WEL provided a company overview and summary of the work program commitments attached to the exploration permit. It was explained the iwi are in the initial stages of a Treaty settlement, which is high priority for the Trust. A general discussion about the concerns and potential opportunities followed with the potential impact an oil spill might have on estuarine systems and rivers emphasised. Opportunities for iwi participation in the oil and gas industry were also discussed, as were local content requirement for developments in New Zealand.
Tainui-a-whiro (including Ngati Tamainupo, Ngati Mahanga and Tainui) 28 May 2014	An introductory meeting with the Tainui-a-whiro hapu in Raglan. WEL provided a company overview and summary of the work program commitments attached to the exploration permit. A robust but respectful discussion followed where it was made clear the community feels quite strongly that the perceived benefits of oil and gas production are far less than the risks of oil spill and negative environmental impacts. Particular emphasis was placed on oil spill response and a perceived lack of transparency of the oil and gas

	industry.
Waikato Regional Council 28 May 2014	An introductory meeting with the Waikato Regional Council (WRC) in Hamilton. WEL provided a company overview and summary of the work program commitments attached to the exploration permit. The WRC provided an overview of business and industry in the Waikato region, including the key industries of dairy, sheep, beef, energy generation (hydro, geothermal, coal), tourism, mining (coal, iron sand). The WRC advised WEL of their involvement in emergency response (led by Maritime NZ) for oil spill response, noting the Council coastal plan is to be revised in 2015. WEL has undertaken to keep the Council informed of exploration activities. Community perceptions were also discussed, in particular how local communities feel they assume oil and gas exploration and production risk, without any direct benefit.
Waikato Tainui 29 May 2014	An introductory meeting with the Waikato Tainui in Hamilton. WEL provided a company overview and summary of the work program commitments attached to the exploration permit. The focus of the following discussion was on maintaining the health of the Waikato waterways, including the protection of eel fisheries.
Maniapoto Trust Board 29 May 2014	An introductory meeting with the Maniapoto Trust Board in Te Awamutu. WEL provided a company overview and summary of the work program commitments attached to the exploration permit. In the following discussion the potential for iwi participation in the oil and gas industry and improving industry transparency were emphasised. The applicability of agreements made in other jurisdictions, such as Native Title in Australia, was also raised, and whether WEL would look to do something similar in New Zealand. Other concerns raised included the likelihood and response (across the industry) to an oil spill, in the context of the Macondo event in the Gulf of Mexico. The Trust was also interested in why oil and gas exploration in New Zealand has increased in recent years.
Deep Water Group	A meeting was held with the Deepwater Group (DWG) to introduce the proposed survey area and to listen to any concerns that may result from the fishers relating to the proposed survey. A fisheries assessment was underway but the results were not yet available. DWG requested that as soon as the fisheries assessment was available if they could receive a copy and they would distribute it to all the relevant parties that fish in that area. The DWG subsequently distributed the fisheries assessment to the fishing industry and no questions were asked over the survey. This was also supported by the Information Sheet providing more details of the survey.
DOC – Taranaki 4 August 2014	WEL met with DOC-Taranaki to introduce WEL and the proposed seismic activities in the Taranaki Basin. A summary was provided on the survey, who was being engaged with, what measures would be in place, proposed timing. A general discussion was held over Maui's dolphins, and although it is very unlikely they will be in the survey area, when the vessel is heading to or from Port Taranaki a MMO will be on the bridge for any observations. WEL will keep DOC Taranaki informed during the MMIA and seismic process.
Ngati Mutunga 4 August 2014	WEL met with Ngati Mutunga to provide some project specific details of the proposed seismic survey in the Taranaki Basin. WEL provided a summary on the survey and MMIA process. The Chief Executive of Ngati Mutunga was aware of Woodside from previous engagements (April 2014) and this meeting was to discuss more specifics around the survey

	area and MMIA process. The key aspects of extractive industry activities foremost in the minds of members are the oil spill from the Rena grounding, Macondo accident and the proposed seabed mining in the South Taranaki Bight. A summary of the Ngati Mutunga Treaty Settlement was provided and gave WEL an understanding of where the iwi are at. WEL are to keep Ngati Mutunga informed of any changes to the timing of the survey.
Maniapoto Trust Board 4 August 2014	WEL met with the Maniapoto Trust Board (MTB) to provide some project specific details of the proposed survey, as The MTB had an understanding of who WEL are from a previous meeting on 29th May 2014. An overview was provided on the proposed survey, the regulatory process, seismic acquisition. One of the members in attendance had been out on a support vessel during a seismic survey in Taranaki waters and was able to get a first-hand experience at what a seismic survey involved and the mitigation measures which get implemented. Discussion was held over the MMO training provided course that was being proposed for iwi members. Questions were asked about the potential impact of the survey on fish and crayfish. WEL provided an overview of their significant involvement in research at Scott Reef on pelagic and site attached fish. A draft copy of the MMIA is to be provided to the Maniapoto Trust Board. The MTB also asked whether it is possible to put for some of their people to visit the vessel during the survey to gain experience and first-hand experience of what a seismic survey looks like. WEL informed that while that was unlikely due to limited space, the distance offshore and the logistics of crew changes there was the potential for a vessel tour while in port.
Taranaki Iwi Trust 5 August 2014	WEL met with Taranaki Iwi Trust to provide some further details regarding the proposed seismic survey and follow up on the initial meeting held in February 2014. A general discussion was held which covered a general lack of understanding in the general community about how seismic works, which can often lead to wrong conclusions being drawn. A discussion was held over what takes place during a necropsy and what the pathologists are looking for when the do the necropsy to assess cause of death. It was raised that the Taranaki Iwi Trust that their main concern is the cetaceans that wash ashore dead that have died offshore for unknown reasons, a 20 m pygmy blue whale had just recently washed ashore within their rohe. A draft copy of the MMIA is to be provided to the Taranaki Iwi Trust. The MMO training course which is being proposed was discussed and WEL were asked about the ability to provide sea time to course members.
Ngati Maru 5 August 2014	Unfortunately this meeting did not happen due to non-attendance.
Ngati Tama 5 August 2014	This was a follow up meeting between WEL and Ngati Tama which was held in April 2014. WEL reintroduced themselves and a provided a summary of the proposed survey and the regulatory process. An overview of seismic surveys was provided. Ngati Tama indicated that the issues at the forefront of iwi's minds relate to oil spills and their duty to protect the coastline. The question of potential employment for iwi was raised, while a discussion was also held over the MMO training programme.
Waikato Tainui 7 August 2014	Follow up meeting between WEL and Waikato Tainui from May 2014. A summary of Waikato Tainui was provided and the different roles of the Waikato Tainui trusts to provide a background into their role within the region. WEL gave a summary of the proposed survey and its timing as

well as the regulatory process required. The hapu that were not available to meet with WEL in the Waikato Region, Waikato Tainui were going to provide an update to those iwi as well following this engagement. WEL are to keep Waikato Tainui updated and provide a draft copy of the MMIA prior to submission.

Dan Govier

From: Gdq#Jryhu
Sent: Wxhvgd|/#55#Mxo|#5347#4=6:#sp1
To: *sdulqjdwd55C jp dlofrp *#Khdwkhu#Wkrp vrq*
Subject: IZ =#Z rrgvlgh#Hqhuj|#Vhlvp lf#Vxuyh|
Attachments: SHS#38:<61sgi

Kia ora
We have firmed up some of our meetings and was wondering whether we would be able to call in and meet with you on Wednesday 6th August?

If you could please let me know whether this works for us to come and visit you it would be greatly appreciated.

Nga mihi,
Dan

From: Dan Govier
Sent: Friday, 18 July 2014 10:03 p.m.
Subject: Woodside Energy Seismic Survey

Kia ora ,

I am working with a company called Woodside Energy who are proposing to undertake a seismic survey and I understand you have had some correspondence with previously.

I am preparing their Marine Mammal Impact Assessment and involved with the engagement process and was hoping that we could come and meet with you.

Woodside are going to be in the country the week of Monday August 4th until Friday 8th of August and have appointed a NZ country Manager who will be travelling with us also.

How would you be placed to meet on Wednesday 6th or Thursday 7th of August?

I have attached a map showing the permit area where the seismic survey will be conducted within.

The proposed survey is a 900 km^2 3D seismic survey and is anticipated to take 35 days.

At its closest point, the proposed survey area is 192 km southwest of the entrance to Raglan Harbour and 175 km southwest of Kawhia Harbour entrance.

If I can answer anything else please let me know, otherwise if you could please confirm whether you would be able to meet with us on one of those dates that would be appreciated.

Nga mihi,
Dan

Dan Govier

From: Gdq#Jryhu
Sent: Iulgd|/#58#Mxo|#5347#7=5:#sp1
To: *Dqjhdqh#Juhhqvlo*
Subject: UH=#Z rrgvlgh#Hqhuj|#Vhlvp lf#Vxuyh|
Attachments: Yxdfdq#5G#P VV#Frqvxodwlrq#lqirup dwlrq#Vkhhwisgi#
Z rrgvlghbFrusrudwhbEurfkxuh1sgi

Kia ora .

That is unfortunate our schedules do not align on the 6th.

The reason we have proposed that week is that Woodside staff will be in the country from Australia, along with the NZ Country manger so we were just trying to meet with as many people as we could while they were in the country.

In regards to the new information that we would provide, we are currently preparing the Marine Mammal Impact Assessment and Woodside are also wanting to continue building a relationship with iwi and hapu along the Taranaki and Waikato coastline. There will also be a bit more information on the details of the survey, survey area etc.

I have attached the information sheet for the proposed survey which shows the survey area and some further details on the survey. Also attached is a brochure on Woodside Energy, but you may have this already.

The only other time that we could potentially get to Raglan would be around 5-6pm on Tuesday 5th of August as we have meetings in New Plymouth on the afternoon of the 5th.

In regards to your question with what we hope to achieve, we are just wanting to have a good open discussion with where the project is currently at, discuss the details of the survey, the mitigation measures that will be in place, and to be able to answer any questions you may have around the seismic survey.

Nga mihi,

Dan

From.
Sent: Thursday, 24 July 2014 2:40 p.m.
To: Dan Govier
Subject: Re: Woodside Energy Seismic Survey

Kia ora Dan,
My calendar is fairly full at the moment with only Friday afternoon free. On the 6th I am attending a marine mammal observers workshop.. Are you able to forward information so I can discuss your request with our hapu. Why do you need to meet that week and what do you hope to achieve by meeting with us? Is there any new information apart form that given out at the marae meeting?

On Tuesday, 22 July 2014 11:06 AM, Dan Govier · · wrote:

> Kia ora .
> We are trying to organise/finalise our meetings for the week of August 4th and wondering whether you are able to confirm that you could meet with us or not to discuss the Woodside seismic survey?

At the moment we are trying to arrange flights and confirm meetings for the Woodside team in Australia so just trying to finalise our arrangements.

At this stage Wednesday 6th of August would work best for us if that suits?

Nga mihi,
Dan

From: Dan Govier [mailto:
Sent: Friday, 18 July 2014 9:06 p.m.
To:
Subject: Woodside Energy Seismic Survey

Kia ora
I am working with Woodside Energy whom I understand you have already met with previously.

I am preparing their Marine Mammal Impact Assessment and involved with the engagement process and was hoping that we could come and meet with you in early August.

Woodside are going to be in the country the week of August 4th and have also appointed a NZ country Manager who will be travelling with us also.

How are you placed to meet on Wednesday 6th or Thursday 7th of August?

I have attached a map showing the permit area where the seismic survey will be conducted within.

The proposed survey is a 900 km^2 3D seismic survey and is anticipated to take 35 days.

At its closest point, the proposed survey area is 192 km southwest of the entrance to Raglan Harbour.

If I can answer anything else please let me know, otherwise if you could please confirm whether you would be able to meet with us that would be appreciated.

Nga mihi,
Dan

Dan Govier
Environmental Consultant
+64 (0) 274 898 628
www.eosltd.co.nz
P.O. Box 2065
Nelson 7041

ENVIRONMENTAL OFFSHORE SERVICES LIMITED

Dan Govier

From: Vkluh|#Kxqw
Sent: Z hgqhvgd|/#9#Dxjxvw#5347#4=47#sp 1
To: Gdq#Jryhu
Subject: Uh=#Z rrgvlgh#Vhlvp lf#Vxuyh|#P hhwlqj

Hi Dan I must apologize for Tuesdays meeting I was called away for work , And completly forgot our arrangment to met . Dan I wil be away for some time and best contact at this stage will be Again I apologize for my none attendance, as I know I would have enjoyed the subjects we would have veiwed and discussed , Please continue to Email
On 24/07/2014, at 10:20 AM, Dan Govier wrote:

> Kia ora
>
> Thanks for talking to me just then, just to confirm we will meet with you at Gusto Restaurant on Tuesday 5th August at 11 am.
>
> I have also attached a map of Woodside Energy's exploration permit area which the seismic survey will be within.
>
> We can run you through the details of the survey, the mitigation measures that will be in place and the regulatory requirements that have to be adhered to for the survey to commence.
>
> I will look forward to meeting you.
>
> Nga mihi,
> Dan
> <image001.jpg>
>
> ### <PEP 55793.jpg>

Dan Govier

From: Gdq#Jrylhu
Sent: Wxhvgd|/#47#Rfwrehu#5347#<=84#dp1
To: Gdq#Jrylhu
Subject: IZ=#Sursrvhg#Vhlvplf#Vxuyh|
Attachments: Yxofdq#6G#PVV#Frqvxowdwlrq#Lqirupdwlrq#Vkhhw1sgi

From: Dan Govier [mailto:dan@eosltd.co.nz]
Sent: Monday, 15 September 2014 10:42 a.m.
To: '
'n
Subject: Proposed Seismic Survey

Tēnā koutou,

I am working with a company called Woodside Energy who are proposing to undertake a seismic survey off the west coast of the North Island in January 2014.

I am preparing their Marine Mammal Impact Assessment and involved with the engagement process.

The proposed survey is a 1,030 km^2 3D seismic survey and is anticipated to take approximately 35 days. I have attached an information sheet of the proposed survey providing you with further details.

At its closest point, the proposed survey area is 115 km northwest of New Plymouth.

If you are interested in finding more out about the proposed seismic survey, myself and Craig Barry (Woodside NZ Manager) can travel to New Plymouth for the day to meet with you. If this could be a combined hui on the same day it would work best.

We can provide you with further information on the proposed survey, the regulatory process and the mitigation measures that will be implemented during the survey, and then listen to any concerns you have or answer any questions you may have.

If anyone can provide a venue for the hui that would also be appreciated.

At this stage I would propose one of the following dates for the hui:

- 26th September
- 9th - 10th October
- 14th - 17th October

If I can answer anything else please let me know, otherwise if you could please confirm whether you would like to meet with us on one of the dates above that would be appreciated.

Otherwise if you do not require to meet with us, please let me know.

Nga mihi,
Dan

Dan Govier

From: Gdq#Jryhu
Sent: Vxqgd|/#45#Rfwrehu#5347#43=58#sp 1
To: *Ulfkdug#Zhov*##Dvrq#Kqgrui0Od|*##Vkdqh#Zdvk*##Qdwkdq#Uhlg*#
vwhyh1wdudqwC p rdqd1fr1q}##Grud#Vwdqj*##Elo#Khdo|*##Dqg|#Vp lwk*##hhp |*#
Fdurd#Vfrw##VDXQGHUVOORGHU/#Grxj*##Vdp#Shqzdughq#D#Edulqh*##EDUEDUIFK/#
P lod*##Gdu|q#Vkdz*##Vwhskhq#Elvkrs*##Mdvrq#Zlodp vrq*##Shwhu#Gdzvrq*##Wlp #
Odz*
Cc: *FOHDO/#Mrkq*##THKQNHU/#Dlvv|*
Subject: UH#Gdq#Jryhu#p hhwlqj#uh#vhlvp lf#vxuyh|v/#sodqqhg#dqg#srvvleoh#0#xsgdwh#zlwk#
p dsv#surylghg#e|#Zrrgvlgh1
Attachments: Yxcfdq#5G#P VV#Frqvxowdwlrq#Lqirup dwlrq#Vkhhw1sgi#Wrurd#5G#P VV#Frqvxowdwlrq#
Lqirup dwlrqbVkhhw1sgi

Hi all,
In additional to the email that Richard sent below back in August, I have attached an information sheet for the proposed seismic surveys that Woodside Energy will undertake early next year.

The seismic survey vessel *Polar Duke* has been contracted and will be accompanied by the support vessel *Sanco Sky*. It is likely that an additional chase vessel will be working with them as well although that has not yet been confirmed.

Both surveys are proposed to take approximately 35 days to complete.

The Taranaki survey will begin first at the start of January 2015, then following completion of this, the vessel will travel to the Great South Basin, with a port call along the way somewhere, so it is likely to be February/March by the time the vessel is in the Great South Basin.

If you have any questions or concerns relating to the attached information sheet or the proposed seismic survey please let me know.

Kind Regards,
Dan

Dan Govier
Environmental Consultant
+64 (0) 274 898 628
www.eosltd.co.nz
P.O. Box 2065
Nelson 7041
ENVIRONMENTAL OFFSHORE SERVICES LIMITED

From: F
Sent: Friday, 1 August 2014 8:43 a.m.
To: .
v;

Subject: RE: Dan Govier meeting re seismic surveys, planned and possible - update with maps provided by Woodside.

Dear All,

Following the email sent 25 July, I now attach the maps of the two areas discussed below.

There appears to be very little overlap in regard survey proposal 2 but some with proposal 1.

I suggest that if proposal 1 turns from proposal to plan, maximum warning of dates to be undertaken will be required to prevent any conflict with fishing operations.

If any wish further discussion on this matter please advise so I can confer with Dan Govier about how and when to do this.

Regards,

Fisheries Specialist

Deepwater Group Ltd
M
E
W www.deepwatergroup.org

From:
Sent: Friday, 25 July 2014 10:16 a.m.
To: ,

Cc: F
Subject: Dan Govier meeting re seismic surveys, planned and possible

Dear All,

1) There is a concept plan for a survey west of Taranaki in January 2015 in 500-1000 metres. This is still a plan in development. Dan has agreed to ask client if we can see the fisheries overlap data as soon as produced by MPI. Until this is complete we can only be on standby for this proposal. I will circulate information on arrival.
2) There is a concept plan for a survey in an area in deepwater ESE of Stewart Island (Feb-March 2015, ie after Taranaki above and by same vessel). There is likely to be little if any overlap but again as per 2) above, MPI will have information soon so we can determine who and to what extent we need to manage any conflict.

I reminded Dan that wrt seismic surveys we held four broad concerns:

1) Navigational conflict to fishing ops
2) Fish scaring increasing cost of catch
3) Fish scaring when research being undertaken
4) Impact on species eg potential for damage to spp such as scampi as previously advised

Communication well in advance best mitigation.

Any questions please advise.

Regards,

Fisheries Specialist

deepwater group

Deepwater Group Ltd

W www.deepwatergroup.org

Dan Govier

From: Gdq#Jryhu
Sent: Vxqgd|/#45#R fwrehu#5347#43=75#s1p 1
To: *Wdqld#Ebgrlv*
Subject: UH#Z rrgvlgh#Hqhuj |#Vhlvp lf#Vxuyh|
Attachments: Yxcfdq#6G#P VV#Frqvxowdwlrq#lqirup dwlrq#Vkhhwsgi

Kia ora
Please find attached the information regarding the proposed Woodside Energy Seismic Survey that is proposed for January 2015, northwest of New Plymouth.

If you have any further questions please do not hesitate to call me

Nga mihi
Dan

From:
Sent: Wednesday, 23 July 2014 2:36 p.m.
To: Dan Govier
Subject: RE: Woodside Energy Seismic Survey

On the 6th I'm in meetings from 11-4pm. Then I finish work to pick up my daughter.

Sorry!

From: Dan Govier [mailto:dan@eosltd.co.nz]
Sent: Wednesday, 23 July 2014 2:33 p.m.
To:
Subject: RE: Woodside Energy Seismic Survey

Hi
We may have time in the afternoon on the 6th of August, how are you placed for the 6th?

But yes we will have some electronic information shortly, it is just currently being finalised, so once that is approved I can send it through to you.

Thanks
Dan

From:
Sent: Wednesday, 23 July 2014 12:42 p.m.
To: Dan Govier
Subject: RE: Woodside Energy Seismic Survey

Hi Dan,

I am away in training all day on the 7th of August.

Are you able to send me the information please?

From: Dan Govier [mailto:dan@eosltd.co.nz]
Sent: Tuesday, 22 July 2014 7:31 p.m.

To:
Subject: Woodside Energy Seismic Survey

Kia ora

I am working with a company called Woodside Energy who are proposing to undertake a seismic survey off the west coast of the North Island in January 2014.

I am preparing their Marine Mammal Impact Assessment and involved with the engagement process and was hoping that we could come and meet with you.

Woodside are going to be in the country the week of August 4th and have also appointed a NZ country Manager who will be travelling with us also.

How are you placed to meet on Thursday 7th of August? We are meeting Tim Manukau at 9-30 am so could call in and see you at the Council after that if that works, maybe around 11-30am, otherwise we could make it 1pm if that suits better.

I have attached a map showing the permit area where the seismic survey will be conducted within.

The proposed survey is a 900 km^2 3D seismic survey and is anticipated to take 35 days.

At its closest point, the proposed survey area is 192 km southwest of the entrance to Raglan Harbour and 175 km southwest of Kawhia Harbour entrance.

If I can answer anything else please let me know, otherwise if you could please confirm whether you would be able to meet with us on one Thursday 7th that would be appreciated.

Nga mihi,
Dan

Dan Govier
Environmental Consultant
+64 (0) 274 898 628
www.eosltd.co.nz
P.O. Box 2065
Nelson 7041

ENVIRONMENTAL OFFSHORE SERVICES LIMITED

Dan Govier

From: Ur|#Z hdyhu
Sent: P rqgd|/#46#R fwrehu#5347#43=87#dp 1
To: G dq#J rylhu
Cc: Mrkq#Ehodqg#Q hlo#Dup lwdjh#Jx|#Jrshu
Subject: Z rrgvlgh#Hqhuj |#Surs rvhg#Vhlvp lf#Vxuyh|

Thanks for the heads-up Dan.
Roll on summer!
Best regards,

From: Dan Govier [mailto:dan@eosltd.co.nz]
Sent: Sunday, 12 October 2014 10:29 p.m.
To:
Cc:
Subject: Woodside Energy Proposed Seismic Survey

Hi
I am working with Woodside Energy whom I understand you have met previously regarding their proposed 3D Seismic Survey northwest of New Plymouth at the start of January 2015.

I have attached an information sheet for the proposed seismic survey. Woodside will utilise the seismic survey vessel *Polar Duke* and will be accompanied by the support vessel *Sanco Sky*. It is likely that an additional chase vessel will be working with them as well although that has not yet been cofirmed.

The survey is proposed to take approximately 35 days.

If you have any questions or concerns relating to the attached information sheet or the proposed seismic survey please let me know.

Cheers,
Dan

Dan Govier
Environmental Consultant
+64 (0) 274 898 628
www.eosltd.co.nz
P.O. Box 2065
Nelson 7041

ENVIRONMENTAL OFFSHORE SERVICES LIMITED

Dan Govier

From: Gdq#Jryhu
Sent: Z hgqhvgd|/#57#Vhswhp ehu#5347#<=39#s1p 1
To: *rwdudxd*
Subject: UH=#Sursrvhg#Vhlvp lf#Vxuyh|

Hi
We have not booked any flights yet as we were not certain you were available and I have not heard back from anyone else either.

So it might be easiest if we plan on the 9th or 10th of October instead? Will one of those dates suit?

Nga mihi
Dan

From:]
Sent: Wednesday, 24 September 2014 6:32 p.m.
To: Dan Govier
Subject: RE: Proposed Seismic Survey

Thank you
I don't mind waiting until October but if you have booked for this Friday please can you confirm this and we will see you then.

Nga mihi

Sent from Samsung Mobile

-------- Original message --------
From: Dan Govier
Date:09/18/2014 10:21 AM (GMT+12:00)
To:
Subject: RE: Proposed Seismic Survey

Kia ora

Thanks for your email.

That is fine we would like to meet with you to discuss the proposed survey.

The afternoon of September 26th would work best for us if possible.

I have not heard from anyone else yet that I sent the email to. Are you willing to have a combined hui if any of the other hapu would like to join? As we would like to have one hui with whoever is interested in attending.

Once I hear back from you we can confirm a venue and timings etc. if we come up on the 26th, we arrive at about 12-30pm, so we could meet at 1pm?

Nga mihi,

Dan

From:
Sent: Tuesday, 16 September 2014 12:23 p.m.
To: Dan Govier
Subject: Re: Proposed Seismic Survey

Tena koe Dan

Thank you for the above information,

On behalf of our Hapu we would like to meet with you on the above matter as we are very involved in all aspects of the Oil and Gas industry and have Hapu members that will be involved in the marine mamal survey course been held for the first time inNew Zealand in the next few months.

I am able to meet with you either in September 26th or the latter dates in October.

Nga mihi

OTARAUA HAPU
51 McLean Street
WAITARA
(06)754-8299 (Ph/Fax)
(027)7345209 (Cell)

On Monday, September 15, 2014 10:47 AM, Dan Govier <dan@eosltd.co.nz> wrote:

Tēnā koutou,

I am working with a company called Woodside Energy who are proposing to undertake a seismic survey off the west coast of the North Island in January 2014.

I am preparing their Marine Mammal Impact Assessment and involved with the engagement process.

The proposed survey is a 1,030 km^2 3D seismic survey and is anticipated to take approximately 35 days. I have attached an information sheet of the proposed survey providing you with further details.

At its closest point, the proposed survey area is 115 km northwest of New Plymouth.

If you are interested in finding more out about the proposed seismic survey, myself and Craig Barry (Woodside NZ Manager) can travel to New Plymouth for the day to meet with you. If this could be a combined hui on the same day it would work best.

We can provide you with further information on the proposed survey, the regulatory process and the mitigation measures that will be implemented during the survey, and then listen to any concerns you have or answer any questions you may have.

If anyone can provide a venue for the hui that would also be appreciated.

At this stage I would propose one of the following dates for the hui:

- 26th September
- 9th - 10th October
- 14th - 17th October

If I can answer anything else please let me know, otherwise if you could please confirm whether you would like to meet with us on one of the dates above that would be appreciated.

Otherwise if you do not require to meet with us, please let me know.

Nga mihi,

Dan

Dan Govier
Environmental Consultant
+64 (0) 274 898 628
www.eosltd.co.nz
P.O. Box 2065
Nelson 7041

ENVIRONMENTAL OFFSHORE SERVICES LIMITED

APPENDIX 3

Technical Details of the PAM System

Seiche Measurements Ltd
Bradworthy Industrial Estate
Langdon Road, Bradworthy
Holsworthy, Devon EX22 7SF
United Kingdom
Tel: +44 (0) 1409 404050
Fax: +44 (0) 1409 240276
Email: info@seiche.eu.com
Web: www.seiche.eu.com

Seiche Measurements LLC
10801 Hammerly Boulevard
Suite 114, Houston
Texas TX77043
USA
Cell: +1 (713) 201 5726
Fax: +1 (713) 984 9628
Email: bpadovani@seiche.eu.com
Web: www.seiche.eu.com

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.

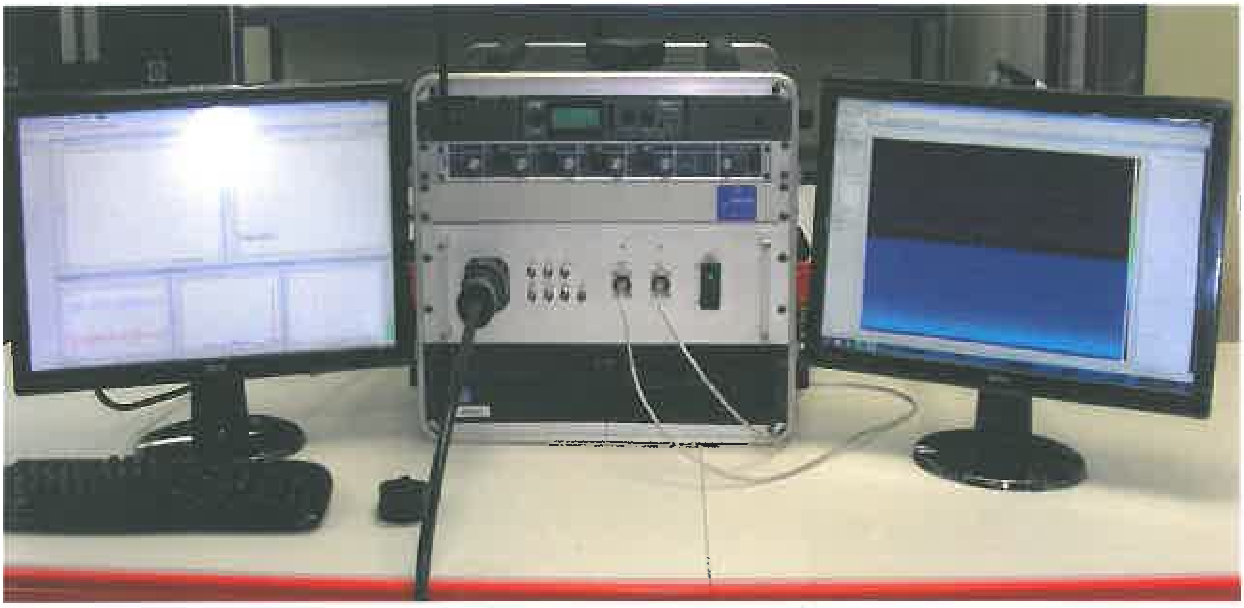


Figure 1: 8U Base unit with Rack-mounted PC and LF and HF monitors

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

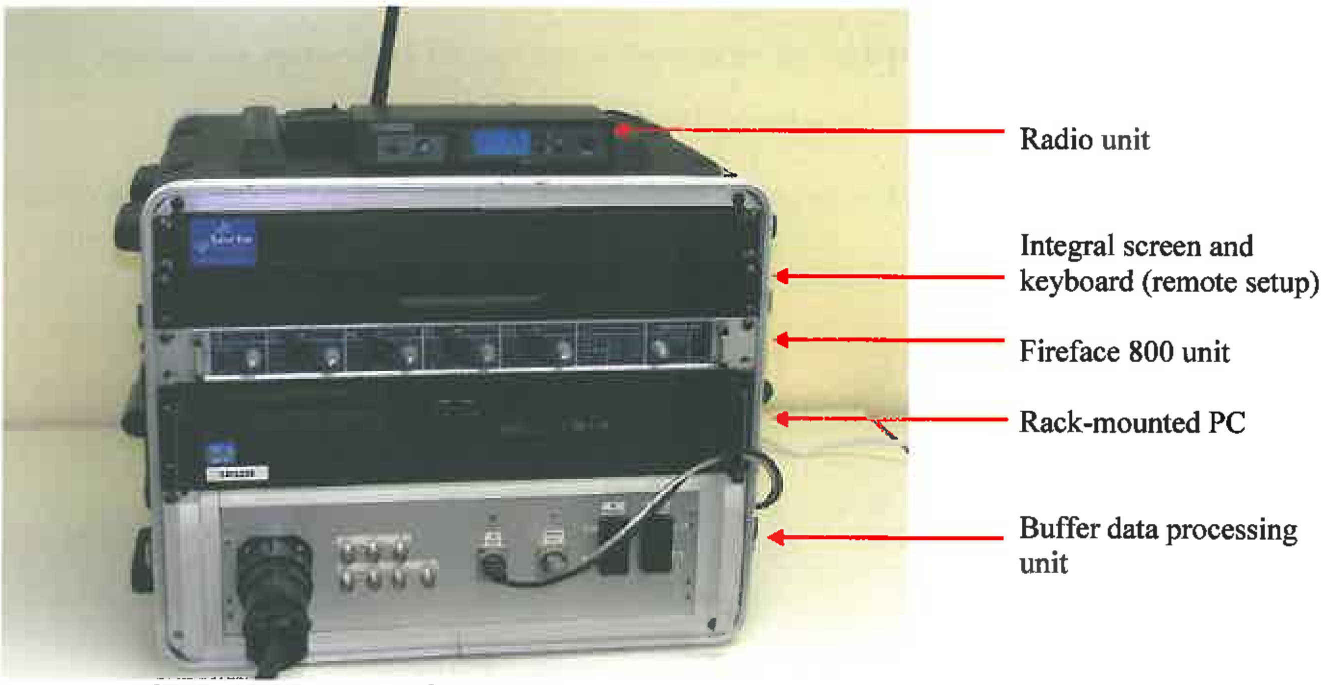


Figure 3: Electronics monitoring base unit

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.

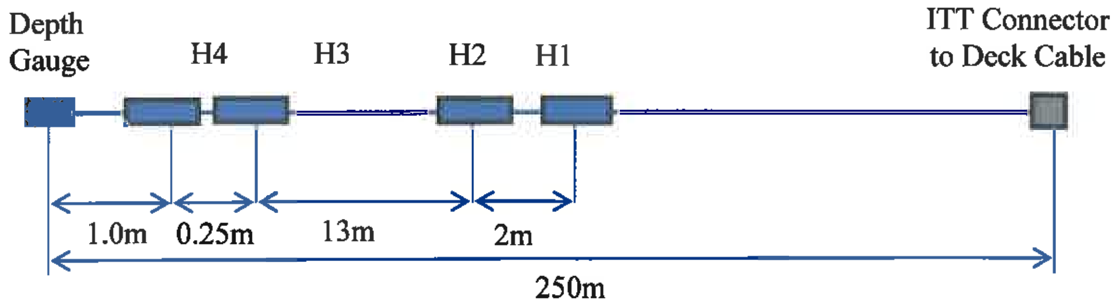
Rack-mounted PC
The rack-mounted PC system has an Intel quad core i5 processor with 8 GB of RAM. This custom built PC system has enough power to run both high and low frequency audio data through Pamguard simultaneously from up to 4 hydrophones.

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

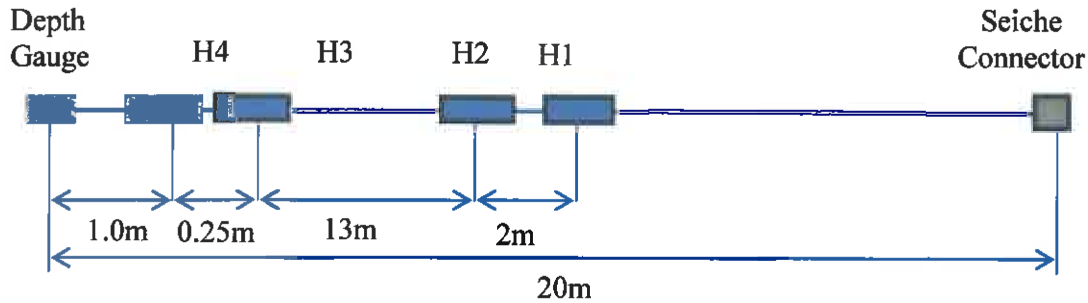
Length:	250m
Depth Rating:	100m (not connector)
Diameter:	14mm over cable, 32mm over mouldings, 64mm over connectors
Weight:	60kg
Connector:	ITT 19 pin
BS	500 kg

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

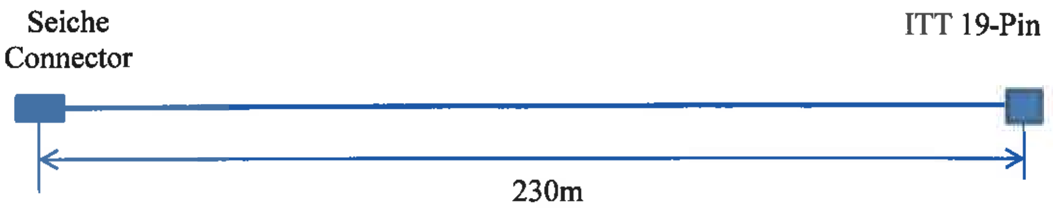
Length:	20m
Depth Rating:	100m (not connector)
Diameter:	14mm over cable, 32mm over mouldings, 45mm over connectors
Weight:	60kg
Connector:	Seiche
BS	500 kg

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

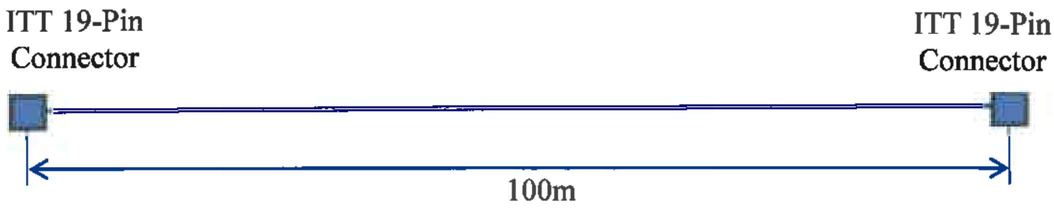


Mechanical Information

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

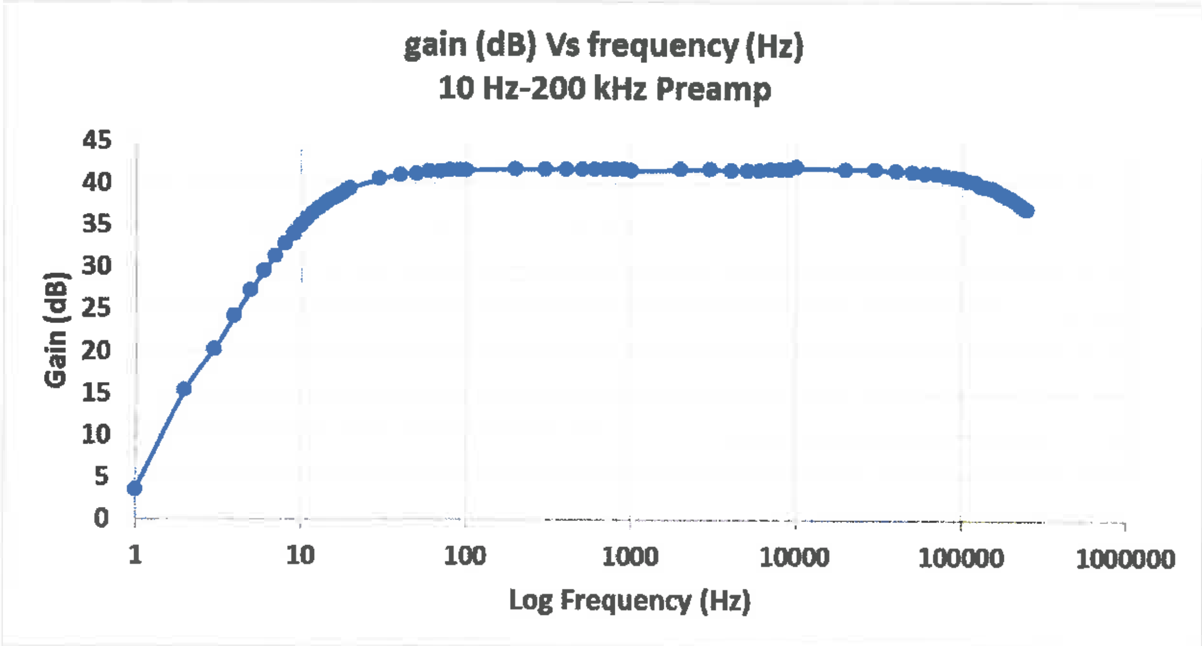


Figure 4: Hydrophone Sensitivity

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.

APPENDIX 4

Marine Mammal Mitigation Plan for the Vulcan 3D MSS

Marine Mammal Mitigation Plan:

Woodside Energy (New Zealand) Limited – Vulcan 3D Marine Seismic Survey

BPM-Woodside-Vulcan 3D MSS-MMMP-v1.2

16/12/2014

BLUE PLANET MARINE

Document Distribution List

Date: 16/12/2014

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Woodside	Country Manager New Zealand	2
Woodside	Environment Advisor Exploration	3
EOS/SLR	Environmental Consultant	4
BPM	, Senior Marine Scientist	5
BPM	Managing Director	6

Document Revision Record

Rev.	Date	Description	Prepared	Reviewed	Approved
1.0	01/12/2014	Version 1	LD	SC, DG, MH	
1.1	12/12/2014	Comments incorporated	LD	SC	SC
1.2	16/12/2014	Comments from DOC incorporated	LD	SC	SC

Document Reference Number: BPM-Woodside-Vulcan 3D MSS-MMMP-v1.2

Prepared by: l

Last updated: 16 December 2014

www.blueplanetmarine.com

Table of Contents

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1. Introduction

This document has been developed by Blue Planet Marine (BPM) for Woodside Energy (New Zealand) Limited (Woodside) in order to meet the requirements for a Marine Mammal Mitigation Plan (MMMP) for the Vulcan 3D Marine Seismic Survey (the survey).

This MMMP outlines the procedures to be followed by observers and crew in order to guide survey operations. It should be read in conjunction with the *2013 Code of Conduct for Minimising Disturbance to Marine Mammals from Seismic Survey Operations* (the Code) and the Woodside MMIA developed by Environmental Offshore Services Limited (EOS) specifically for this survey. The Code is the primary tool for describing mitigation and reporting required for seismic surveys consistent with NZ legislation. It should be the primary reference for Marine Mammal Observers (MMOs) and PAM operators (PAMOs) during a survey. This MMMP is specific to the survey and provides additional and supplemental information useful in the completion of MMO and PAM roles.

2. The Woodside Energy (New Zealand) Limited – Vulcan 3D Marine Seismic Survey

Information provided in the draft MMIA for the survey has been used by BPM in the development of this MMMP. EOS was engaged by Woodside to prepare a MMIA for an approximate 1,030 km^2 survey in the Taranaki Basin, scheduled to commence in January 2015. The survey area will be located largely within PEP 55793 and will be bound by an Operational Area allowing for line turns, acoustic source testing and soft start initiation (Figure 1). A well tie will take place from the Survey Area consisting of one swathe of seismic acquisition to the previously drilled Tāne-1 well to tie in the down hole stratigraphy data from the Tāne-1 well to the survey.

The primary objective of the survey is to assess hydrocarbon prospectivity within the area, and if successful, identify possible locations for an exploration well to target any potential reservoirs. It is anticipated that the survey will take approximately 35 days to complete, depending on weather constraints and marine mammal encounters. The current schedule anticipates a commencement date in January 2015. Operations will be conducted 24 hours per day, 7 days per week; also subject to suitable weather conditions and marine mammal encounters.

2.1 Seismic vessel and acoustic source

The survey will use the seismic vessel *Polar Duke* and will tow 12 solid streamers, 7 km in length and 100 m apart. The acoustic source will have an effective volume of 3,460 in^3 and will be comprised of three sub-arrays with seven acoustic sources on all but one of the sub-arrays, which has nine. The acoustic array will be located at a depth of 7 m below the sea surface and approximately 450 m behind the survey vessel. The depth of the sub-arrays will ensure that the volume used enables the survey to be run effectively in regards to data acquisition, but also to minimise the potential environmental disturbance. In the case of dropouts during acquisition, the gun array may operate at a slightly lower capacity for a short period of time.

The acoustic source will have an operating pressure of 2,000 psi and will be fired at a sourcepoint interval of 18.75 m apart. For a typical boat speed of 4.5 knots (kts), this equates to a sourcepoint activation every 8 seconds. Given the volume of the acoustic source being used, the survey is classified as a **Level 1** survey under the Code. The mitigation procedures set out in this MMMP will adhere to the requirements of a Level 1 survey as stipulated in the Code and any additional mitigation measures determined via the MMIA process and outlined in Section 5 of this document.

The *Sanco Sky* will act as support vessel and be in close proximity to the *Polar Duke* for the duration of the survey, except when required to go into port for supplies. A chase vessel will also be utilised for the duration of the survey.

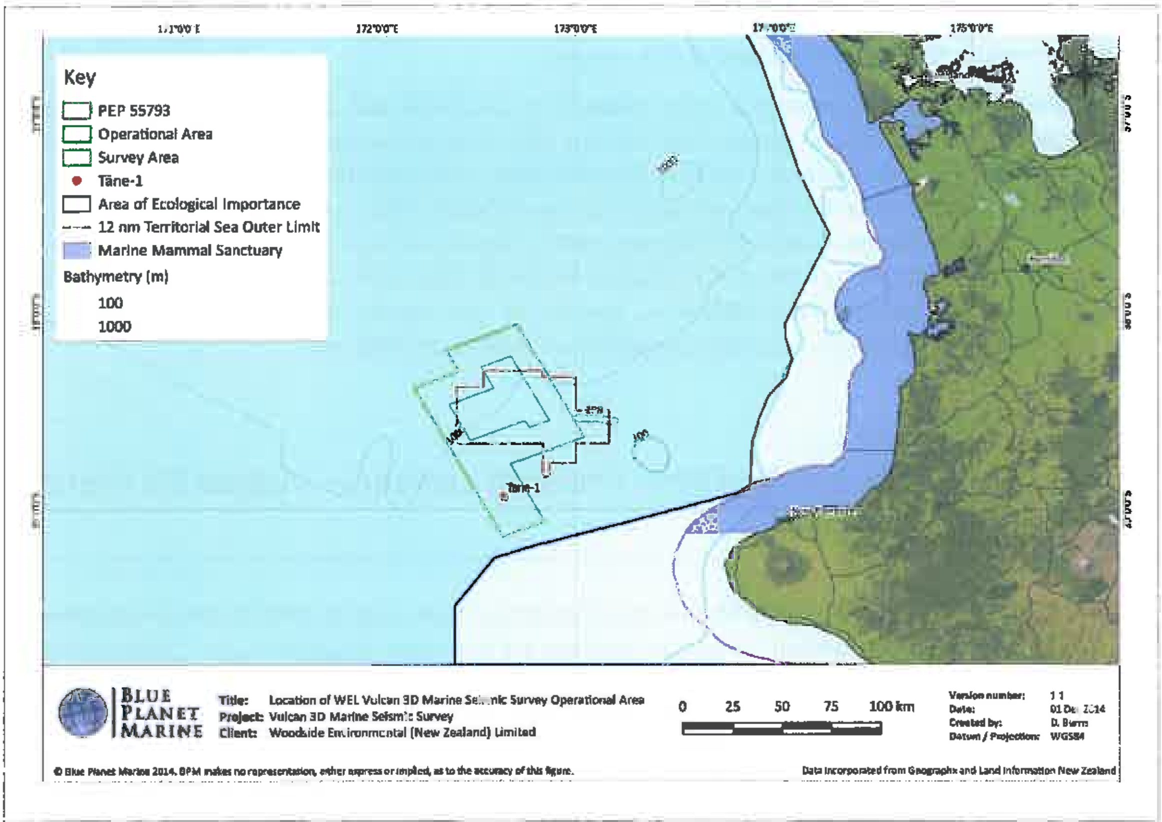

Figure 1: Location of the Woodside Vulcan 3D Marine Seismic Survey.

(Observers to refer to the VADAR system for the coordinates of the Operational Area.)

2.2 Operational Area

The Operational Area for the survey is beyond the 12 nautical mile Territorial Sea boundary, but within the New Zealand Exclusive Economic Zone (Figure 1). Amongst other legislation, the survey is required to comply with the Exclusive Economic Zone (EEZ) and Continental Shelf (Environmental Effects – Permitted Activities) Act and the Code.

When a MSS is proposed within Areas of Ecological Importance (AEI), the Code requires Sound Transmission Loss Modelling (STLM) to be undertaken in order to validate the standard mitigation zones specified in the Code. The Operational Area for this survey is located beyond AEI and so STLM is not required. Regardless, Woodside elected to undertake STLM.

Woodside's STLM was based upon the specific configuration of the acoustic array deployed from the *Polar Duke* and the environmental conditions within the Operational Area. The STLM predicted that the standard mitigation zones described in the Code will be adequate for the protection of marine mammals and that Sound Exposure Levels (SEL) will be equal to or below the behaviour and injury criteria thresholds specified for mitigation in the Code. There is no need, therefore, to either extend the radius of the mitigation zones or limit acoustic source power.

The West Coast North Island Marine Mammal Sanctuary (MMS) is located 75 km inshore of the Operational Area. The MMS extends from Oakura Beach in the south to Maunganui Bluff in Northland

and offshore to 12 nautical miles. It was gazetted to protect the 'nationally critical' Māui dolphins. Due to its distance offshore, it is unlikely that Māui dolphins will be sighted within the Operational Area.

3. Record Keeping and Reporting

The observers (MMOs and PAMOs) are responsible for maintaining records of all marine mammal sightings/detections and mitigation measures taken throughout the survey. Observers are also required to monitor and record seismic operations, the power output of the acoustic source while in operation, observer effort and sighting conditions. These and other reporting requirements are detailed in Appendix 2 of the Code. Sections 4.2.4.3; 4.2.4.4 and 4.2.5 of the MMIA present a summary of the most commonly occurring or protected marine mammal species known to occur in the Operational Area.

Observers are to accurately determine distances/bearings and plot positions of marine mammals whenever possible throughout the duration of sightings. Positions of marine mammals should be plotted in relation to the vessel throughout a detection. GPS, sextant, reticle binoculars, compass, measuring sticks, angle boards, or any other appropriate tools should be used to accurately determine distances/bearings and plot positions of marine mammals.

The operator will ensure that information relating to the activation of an acoustic source and the power output levels employed throughout survey operations is readily available (e.g. in a place of convenience for the qualified observers while conducting their normal duties) to support the activities of the qualified observers in real time by providing a display screen for acoustic source operations.

Please review Appendix 2 of the Code carefully. Note that you are required to record the power levels (and timing) of at least one random soft start per swing[1].

Note: the Code is mandatory within the NZ EEZ, as such record keeping should be of a high standard as it may form the basis of compliance or enforcement action by the authorities.

All data must be recorded in a standardised Department of Conservation (DOC) Reporting Form. Datasheets are available from www.doc.govt.nz/notifications and are in Excel format. With regard to these forms please note the following advice from DOC:

- Always save the forms in MS Excel 2003 version, with macros enabled;
- Do not attempt to use the forms on a Macintosh device; and
- Do not cut/paste within the document (copy/paste should be okay, but cutting and pasting causes problems with formulas and validation).

It is recommended that observers test the functionality of the datasheets prior to mobilisation and become familiar with their use. In particular, note that macros <u>must</u> be enabled.

All raw datasheets shall be submitted by the qualified observer directly to the Director-General (refer Appendix 5 of the Code for postal and email addresses) within 14 days of a completed MMO/PAMO rotation or end of the survey. Prior to submission to DOC, these data sheets are to be reviewed by the BPM Project Manager so please ensure that sufficient time is made for that.

A written report will be submitted to the Director-General of DOC at the earliest opportunity, but no longer than 60 days after completion of survey.

[1] Note: Text in blue boxes are recommendations or further explanations to observers from BPM and/or DOC.

There are a number of situations that require immediate notification to DOC. These are listed in Table 1, in Section 6. Where uncertainty or ambiguity in application of the Code arises, clarity can be sought from the Director-General.

In addition to the recording and reporting requirements of the Code, Woodside has committed to the following:

- A MMO will be on watch and recording marine mammal sightings during transit to and from the Operational Area during daylight hours and in good sighting conditions; and
- DOC will be notified as soon as possible of any sightings of Māui dolphins.

The Team leader is responsible for compiling an end of survey summary report based on the data collected throughout each survey. The contents of this report are summarised in Appendix 2 of the Code.

DOC have requested the following:

- DOC have requested that the MMO's make note of any observations of hammerhead sharks in Taranaki waters during the Vulcan MSS or on transit to or from port to further understand the movement and distribution of these sharks within NZ waters.

3.1 Māui dolphin sightings

The survey is being acquired in waters 75 km beyond the West Coast North Island MMS. Due to its distance offshore, it is highly unlikely that Māui dolphins will be sighted within the Operational Area. If a Māui dolphin sighting is made during the survey, DOC should be notified immediately. Refer to Section 6 for notification details.

3.2 Contact details for the Department of Conservation

During the survey, the first point of contact within DOC is Ian Angus (or iangus@doc.govt.nz). If a response is required urgently then telephone communications are recommended but in all other circumstances email correspondence should suffice. Should Ian Angus be unavailable, please phone 0800DOCHOT (0800-362-468) and state the following:

1) You wish to provide information to the Marine Species and Threats Team, National Office;
2) The name of the MMO/PAMO, the seismic survey and boat you are currently on;
3) The time and date;
4) The issue/enquiry they wish to pass on to Ian Angus; and
5) Where you can be contacted with a reply (if appropriate).

3.2.1 Communication protocol

The communication protocol to be followed for reporting to DOC is as follows:

For **general reporting of non-urgent issues** to DOC the communication protocol is:

- MMO Team Leader to contact BPM Project Manager ashore);
- BPM to contact Woodside ; and
- Woodside to contact DOC (Ian Angus or other).

For **urgent communications**, any qualified MMO can contact DOC directly either by email or by phone under the following conditions:

- Qualified MMO undertaking direct communication with DOC must inform the MMO Team Leader, Party Chief (or nominated Woodside person) and the Client Reps of the issue and intention to contact DOC, and keep these people informed of discussions and associated events;
- The BPM Project Manager, onshore Woodside Project Manager (and WEL Environment) must be kept informed;
- If the contact is by email, then the Team Leader should consider making a phone call advising DOC of the situation; and
- All direct contacts to DOC via phone must be followed up by an email to DOC and Woodside at the earliest opportunity to provide written confirmation of the message.

4. Mitigation Measures Required Under the Code

The survey is classified as a Level 1 survey under the Code. Within the Operational Area, the marine mammal impact mitigation measures required can be divided into three principal components:

1) The use of dedicated observers (i.e. MMOs and PAMOs);
2) The mitigation measures to be applied; and
3) The mitigation actions to be implemented, should a marine mammal be detected.

4.1 Dedicated observers (MMOs and PAMOs)

As this is a Level 1 survey, there will be two MMOs and two PAMOs on board the seismic survey vessel for the duration of the survey. The training and experience of the observers will meet the requirements stipulated in Section 3.4 of the Code. **There will be at least one MMO (during daylight hours) and one PAMO on watch at all times while the acoustic source is in the water in the Operational Area.**

If the acoustic source is in the water but inactive, such as while waiting for bad weather conditions to pass, the qualified observers have the discretion to stand down from active observational duties and resume at an appropriate time prior to recommencing seismic operations. This strictly limited exception must only be used for necessary meal or refreshment breaks or to attend to other duties directly tied to their observer role on board the vessel, such as adjusting or maintaining PAM or other equipment, or to attend mandatory safety drills.

It is recommended that:

• MMOs conduct daylight observations from half an hour before sunrise to half an hour after sunset;

• Fatigue and effective watch-keeping be managed by limiting watches to a maximum of 4 hours; and

• The maximum on-duty shift duration must not exceed 12 hours in any 24-hour period.

The primary role of the observers is to detect and identify marine mammals and guide the crew through any mitigation procedures that may be required. Any qualified observer on duty has the authority to delay the start of operations or shut down an active survey according to the provisions of the Code and MMIA. In order to work effectively, clear lines of communication are required and all personnel must understand their roles and responsibilities with respect to mitigation.

It is recommended that:

- Where possible, both MMOs are on watch during pre-start observations and soft starts;
- While in transit to the prospect the observers deliver a presentation to crew members detailing observer roles and mitigation requirements;
- The observers hold briefings with key personnel prior to the commencement of seismic operations, and
- The observers provide posters detailing mitigation procedures and communications protocols and display these in the instrument room, at the PAM station and on the Bridge (refer Addenda 1, and Addenda 2).

Undertaking work-related tasks, such as completing reporting requirements, while monitoring equipment is allowed during duty watch, but PAMOs must not be distracted by non-work activities such as listening to music or watching TV/DVDs etc.

4.1.1 Safety drills

Attendance at a safety drill at least once during each rotation is typically mandatory (e.g. the vessel HSE plan will specify the number). Although not specified in the Code, safety of personnel takes priority over mitigation. Safety drills may be conducted when the acoustic source is active. In this case, endeavours should be made to arrange rosters such that observers attend alternate drills, thus enabling mitigation to be maintained. In all cases, observers must comply with the mandatory safety code of the vessel.

4.1.2 PAM not operational

Section 4.1.2 of the Code states: "*At all times while the acoustic source is in the water, at least one qualified MMO (during daylight hours) and at least one qualified PAM operator will maintain watches for marine mammals*".

The Code defines PAM as "*calibrated hydrophone arrays with full system redundancy*". BPM has provided full redundancy for this survey by providing two full sets of PAM equipment plus an additional backup PAM hydrophone cable. However, there may be occasions where PAM is not operational.

The Code was first implemented in 2012. In 2013 it was updated. One update relates to times when PAM is not operational. Section 4.1.2 of the Code states that:

"*If the PAM system has malfunctioned or become damaged, operations may continue for 20 minutes without PAM while the PAM operator diagnoses the issue. If the diagnosis indicates that the PAM gear must be repaired to solve the problem, operations may continue for an additional 2 hours without PAM monitoring as long as all of the following conditions are met:*

- *It is 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 2 hours*
- *Two MMOs maintain watch at all times during operations when PAM is not operational*
- *DOC is notified via email as soon as practicable with the time and location in which operations began without an active PAM system*
- *Operations with an active source, but without an active PAM system, do not exceed a cumulative total of 4 hours in any 24 hour period.*"

It is recommended that MMOs and PAMOs familiarise themselves with this revision to the Code, including the conditions. For clarity, the period that a survey may operate without PAM is a maximum of 2 hours 20 minutes and only when the conditions identified in Section 4.1.2 of the 2013 Code are satisfied. Once this time is exceeded, the source must be shut down until PAM is operational again.

4.2 Crew observations

As per Section 3.8.6 of the Code:

"If a crew member on board any vessel involved in survey operations (including chase or support vessels) observes what may be a marine mammal, he or she will promptly report the sighting to the qualified MMO, and the MMO will try to identify what was seen and determine their distance from the acoustic source.

In the event that the MMO is not able to view the animal, they will provide a sighting form to the crew member and instruct on how to complete the form. Vessel crew can relay either the form or basic information to the MMO. If the sighting was within the mitigation zones, it is at the discretion of the MMO whether to initiate mitigation action based on the information available. Sightings made by members of the crew will be differentiated from those made by MMOs."

4.3 Mitigation procedures

The proponent will observe the following mitigation practices:

4.3.1 Operational Area

Under the Code, an Operational Area must be designated outside of which the acoustic source will not be activated. This includes testing of the acoustic source and soft starts. The Operational Area is defined by the coordinates provided in Addenda 3. These have been loaded into VADAR for real time monitoring of vessel location and marine mammal detections relative to the Operational Area.

4.3.2 Operational capacity

The operational capacity of the acoustic source is notified in the MMIA and outlined in Section 2.1 of this MMMP. This operational capacity should not be exceeded during the survey, except where unavoidable for source testing and calibration purposes only[2]. All occasions where activated source volume exceeds notified operational capacity must be fully documented in observer reports. It is the responsibility of the operator to immediately notify the qualified observers if operational capacity is exceeded at any stage[3].

4.3.3 Sighting conditions

Good sighting conditions means in daylight hours, during visibility of more than 1.5 km, and in a sea state of less than or equal to Beaufort 3.

Poor sighting conditions means either at night, or during daylight visibility of 1.5 km or less, or in a sea state of greater than or equal to Beaufort 4.

[2] D Lundquist, DOC (25 March 2014): "Please note that if the operational capacity is exceeded at any other time (including soft starts), this is a non-compliance incident and should be reported as such."
[3] D Lundquist, DOC (25 March 2014): "qualified observer should be able to monitor this via a dedicated screen as described in section 3 above"

Beaufort 3

- Gentle breeze: 7–10 kts
- Wave height: 0.5–1 m
- Large wavelets. Crests begin to break; scattered whitecaps

BEAUFORT FORCE 3
WIND SPEED: 7-10 KNOTS

SEA: WAVE HEIGHT .6-1M (2-3FT), LARGE WAVELETS, CRESTS BEGIN TO BREAK, ANY FOAM HAS GLASSY APPEARANCE, SCATTERED WHITECAPS

Beaufort 4

- Moderate breeze: 11-16 kts
- Wave height: 1–2 m
- Small waves with breaking crests. Fairly frequent whitecaps.

BEAUFORT FORCE 4
WIND SPEED: 11-16 KNOTS

SEA: WAVE HEIGHT 1-1.5M (3.5-5FT), SMALL WAVES BECOMING LONGER, FAIRLY FREQUENT WHITE HORSES

4.3.4 Transit

Though not required by the Code it is encouraged that a MMO be on watch while the seismic survey vessel is in transit to and from the Operational Area. If a marine mammal is sighted during transit, the sighting must be recorded in the standardised DOC Off Survey Reporting Form.

Woodside has committed to a MMO being on watch and recording marine mammal sightings during daylight hours and good weather for transits to and from the Operational Area

4.3.5 Outline of mitigation procedure

A diagram outlining the general components of the mitigation procedure is shown in Figure 2. Addenda 4 outlines a checklist to be completed by the MMO and/or PAMO on watch prior to the acoustic source being put into the water.

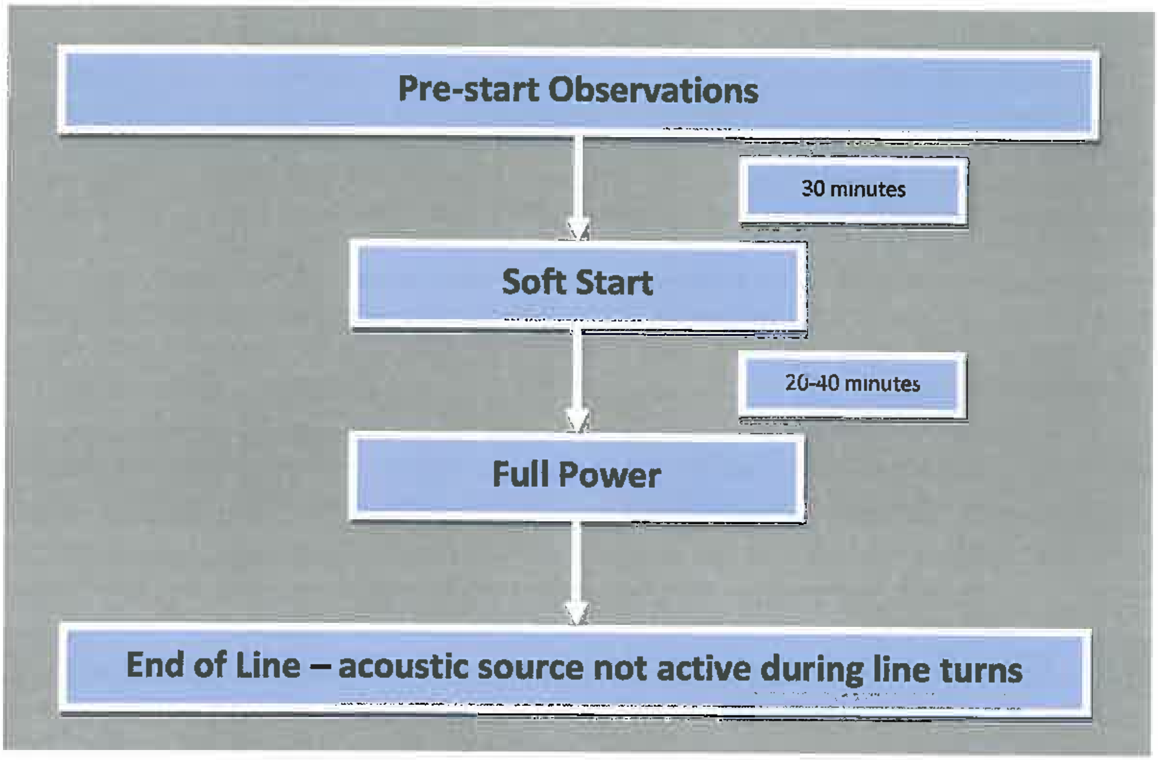

Figure 2: Seismic operations mitigation procedure.

4.3.6 Pre-start observations

A Level 1 acoustic source can only be activated if it is within the specified Operational Area, and no marine mammals have been observed or detected in the relevant mitigation zones as outlined in Section 4.5.

The source cannot be activated during daylight hours unless:

- At least one qualified MMO has continuously made visual observations all around the source for the presence of marine mammals, from the bridge (or preferably an even higher vantage point) using binoculars and the naked eye, and no marine mammals (other than fur seals) have been observed in the relevant mitigation zone for at least 30 minutes, and no fur seals have been observed in the relevant mitigation zones for at least 10 minutes; and
- Passive Acoustic Monitoring for the presence of marine mammals has been carried out by a qualified PAMO for at least 30 minutes before activation and no vocalising cetaceans have been detected in the relevant mitigation zones.

It is recommended that MMOs and PAMOs are notified at least 45 minutes prior to activation of the source to ensure that the 30 min of pre-start observations can be conducted.

The source cannot be activated during night-time hours or poor sighting conditions unless:

- Passive Acoustic Monitoring for the presence of marine mammals has been carried out by a qualified PAMO for at least 30 minutes before activation, and
- The qualified observer has not detected vocalising cetaceans in the relevant mitigation zones.

Note: If a marine mammal is observed to move into a relevant mitigation zone during pre-start observations and then observed to move out again there is no requirement to delay soft start (providing that at least 30 minutes of pre-start observations have been completed). The important criterion is that there are no marine mammals inside the relevant mitigation zones when the acoustic source is activated at the beginning of soft start and that at least 30 minutes of pre-start observations had been undertaken immediately prior.

Another update to the Code in 2013 relates to commencement of operations in a new location in the survey programme for the first time (Section 4.1.3). When arriving at a new location for the first time, the initial acoustic source activation must not be undertaken at night or during poor sighting conditions unless either:

- MMOs have undertaken observations within 20 nautical miles of the planned start up position for at least the last 2 hours of good sighting conditions preceding proposed operations, and no marine mammals have been detected; or
- Where there have been less than 2 hours of good sighting conditions preceding proposed operations (within 20 nautical miles of the planned start up position), the source may be activated if[4]:
    - PAM monitoring has been conducted for 2 hours immediately preceding proposed operations, and
    - Two MMOs have conducted visual monitoring in the 2 hours immediately preceding proposed operations[5], and
    - No Species of Concern have been sighted during visual monitoring or detected during acoustic monitoring in the relevant mitigation zones in the 2 hours immediately preceding proposed operations, and
    - 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.

It is recommended that MMOs and PAMOs familiarise themselves with this revision to the Code including the conditions.

Woodside will adhere to the requirements of Section 4.1.3. This includes when the seismic vessel leaves and returns to the Operational Area following a crew change or port call.

[4] D Lundquist, DOC (25 March 2014): "Please note that this option may only be used if there have not been two hours of good sighting conditions preceding operations. It cannot be used if there were 2 or more hours of good sighting conditions and marine mammals were sighted (i.e., the second option may only be used if weather conditions prevented the first condition being met, not if marine mammal presence prevented the first condition being met)"

[5] D Lundquist, DOC (3 November 2014): "... this requirement means that night time starts are not allowed, since visual observation cannot be undertaken immediately prior to start-up."

4.3.7 Soft starts

The soft start procedure will be followed every time the source is activated. That is: the gradual increase of the source's power to the operational power requirement over a period of at least 20 minutes and no more than 40 minutes, starting with the lowest power acoustic source in the array. The MMIA for the survey (Section 2.3.2.3) describes the soft start procedures to be conducted as:

"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 capacity defined in this MMIA (3,460 in^3) is not to be exceeded during the soft start period."

Soft starts will also be scheduled so as to minimise the interval between reaching full power and commencing data acquisition.

The only exception to the requirement to use the soft start procedure is when the acoustic source is being reactivated after a single break in firing of less than 10 minutes (not related to an observation of marine mammal), immediately following normal operations at full power (see Section 3.8.10 of the Code). However, it is not permissible to repeat the 10-minute break exception from soft start requirements by sporadic activation of acoustic sources at full or reduced power within that time.

Note: for each swing, at least one random sample of a soft-start should be recorded in the standard form and submitted to DOC for every rotation (see Appendix 2 of the Code).

4.3.8 Acoustic source testing

The Code requires that all testing of the acoustic source occurs within the Operational Area. Notified operational capacity should not be exceeded during the survey, except where unavoidable for source testing and calibration purposes only.

Seismic source tests are subject to soft start procedures (Section 4.3.7), though the 20-minute minimum duration does not apply. Where possible, power should be built up gradually to the required test level at a rate not exceeding that of a normal soft start. Acoustic source tests cannot be used for mitigation purposes, or to avoid implementation of soft start procedures.

4.3.9 Line turns

There will be no acquisition during line turns and the acoustic source will not be active (unless soft start procedures are in effect).

4.4 Species of Concern

The full list of Species of Concern (SOC) as defined by the Code is shown in Addenda 5 below.

4.5 Mitigation zones

The Code stipulates standard mitigation zones for Level 1 surveys. These will be applied during the survey and are outlined below:

1) 1.5 km from the centre of the acoustic source for SOC with calf;
2) 1.0 km from the centre of the acoustic source for SOC without calf; and
3) 200 m from the centre of the acoustic source for all other marine mammals.

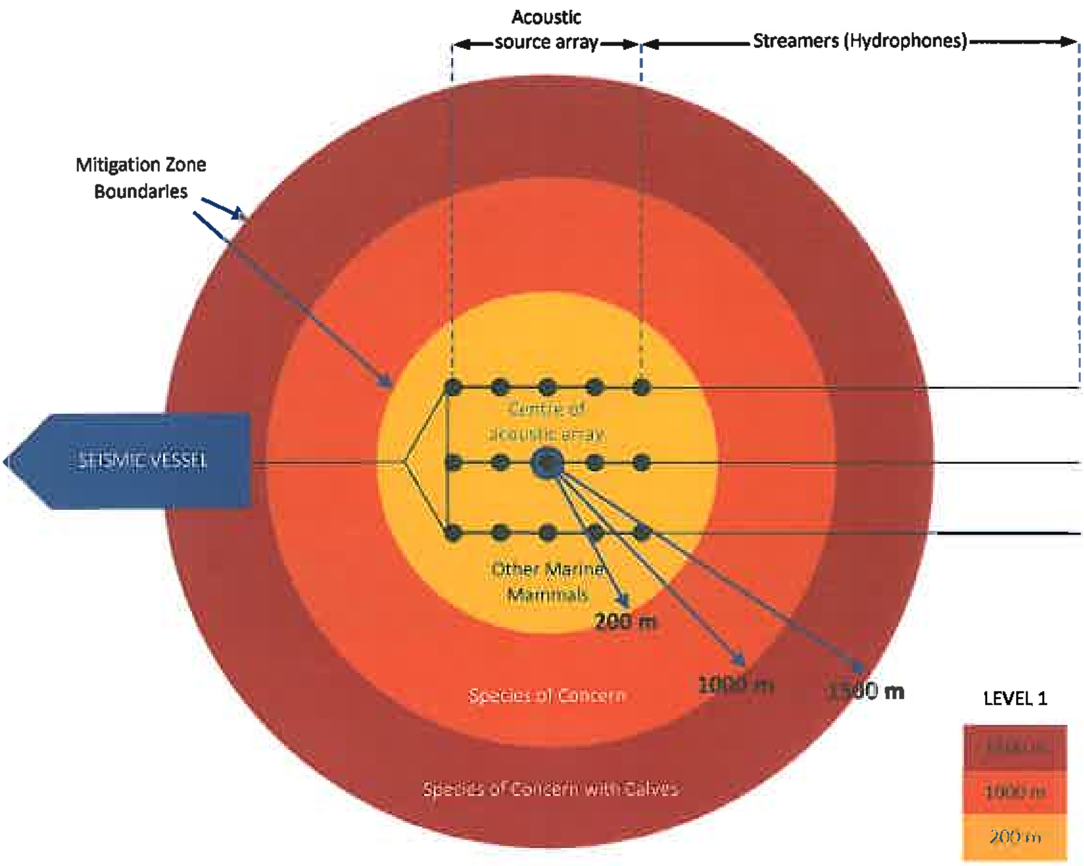

Figure 3: Mitigation Zone Boundaries for the survey as outlined in the Code.

4.5.1 PAM and calves

PAM cannot distinguish calves from adults, the Code therefore requires the proponent to apply the precautionary principle and the 1.5 km mitigation zone for any cetacean SOC detected by PAM.

PAMOs must be familiar with this requirement.

4.6 Mitigation actions

In the event that marine mammals are detected by the observer within the designated mitigation zones (**1.5 km, 1.0 km** and **200 m),** the observer will either delay the start of operations or shut down the source. These mitigation actions will apply to:

4.6.1 Species of Concern with calves

If during pre-start observations or when the acoustic source is active (including soft starts) the observer (MMO or PAMO) detects at least one cetacean SOC 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:

1) The observer confirms the group has moved to a point that is more than 1.5 km from the source; or
2) 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.

In regard to cetacean SOC with a calf: note that the requirements above apply to the entire group containing that calf. An explanatory note from DOC[6]: " *Yes, whole group has to be seen to move beyond zone, or not be seen for 30 mins*", and "*The intent of this provision is that since a group of marine mammals containing one calf has potential to contain more (and at distance it may be hard to follow movement of the cow/calf pair), the same precaution should apply to all the individuals*".

Due to the limited detection range of current PAM technology for ultra-high frequency cetaceans[7] (<300 m), any such bioacoustic detections will require an immediate shutdown of an active survey or will delay the start of operations, regardless of signal strength, or whether distance or bearing from the acoustic source has been determined. Shutdown of an activated acoustic source will not be required if visual observations by a qualified MMO confirm that the acoustic detection was of a species falling into the category of 'Other Marine Mammals'.

It is also recommended that observers monitor the area immediately beyond the 1.5 km mitigation zone. If SOC are approaching this zone, observers notify the seismic operator that a shutdown may be required.

4.6.2 Species of Concern without calves

If during pre-start observations or when the acoustic source is active (including soft starts) the observer (MMO or PAMO) detects a SOC (without calf) within 1.0 km of the source, start-up will be delayed, or the source will be shut down and not reactivated until:

1) The observer confirms the SOC has moved to a point that is more than 1.0 km from the source; or
2) Despite continuous observation, 30 minutes has elapsed since the last detection of the SOC within 1.0 km of the source, and the mitigation zone remains clear.

It is a requirement that due to the range limitations of PAM, all acoustic detections of cetaceans using ultra high frequency vocalisations (e.g. Māui or Hector's dolphins) trigger an immediate shutdown of an active survey or delay the start of operations unless a MMO confirms that vocalisations do not emanate from such a SOC. This is because the maximum effective detection range of ultra-high frequency vocalisations from the PAM equipment under these general operational conditions (i.e. background noise levels) is in the order of 300-400 m.

4.6.3 Other Marine Mammals

If, during pre-start observations prior to initiation of a Level 1 acoustic source soft start, a qualified observer detects a marine mammal 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 passed since the last detection of a New Zealand 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.

If all mammals detected within the relevant mitigation zones are observed moving beyond the respective areas, there will be no further delays to initiation of soft start.

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[6] Email to BPM from Mr Tara Ross-Watt, DOC Senior Adviser - International and Marine; 17 December 2012.
[7] For the purposes of the Code, ultra-high frequencies are defined as those between 30 and 180 kHz - e.g. Maui's or Hector's dolphins.

Note: The presence of "Other Marine Mammals" within 200 m of the source will not result in a shutdown if the source is active, it can only result in a delay to start-up of the source.

MMOs should pay particular attention to the reactions and behaviour of NZ fur seals in close proximity to the source, with particular attention paid to their behaviour when the acoustic source is fired. The aim is to build knowledge of the effects of seismic noise on the behaviour of this species.

4.6.4 Mitigation posters and summary

Refer to Addenda 1 of this MMMP for posters detailing mitigation action procedures.

5. Further Mitigation and Reporting Measures

In addition to the standard reporting outlined in Section 3, the following will be implemented during this survey and are over and above that identified in the Code. They have been agreed by DOC following discussions between Woodside and DOC.

1) **Additional marine mammal observations outside Operational Area**

   During transit to the Operational Area, a MMO will be on watch and recording marine mammal sightings. Any marine mammal sightings outside the Operational Area will be recorded in the standardised DOC Off Survey Reporting form.

2) **Necropsy of stranded marine mammals**

   If any marine mammals are stranded or washed ashore during or within two weeks after the survey and inshore of the Operational Area, a discussion between DOC and Woodside will occur to determine where the seismic vessel had been operating and whether a necropsy will be undertaken. DOC will be responsible for all aspects of the necropsy and coordination with pathologists at Massey University in order to determine the cause of death and whether it was a result of any pressure-related or auditory injuries, Woodside will consider covering the costs directly associated with Massey University undertaking a necropsy.

3) **Notification of any marine mammal carcass observed at sea**

   If a marine mammal carcass is observed at sea during the survey, the location and species (where possible) and any other useful information will be recorded and the lead MMO will notify and provide this information to DOC at the earliest opportunity.

6. Notifications to DOC

If a situation arises that requires a more direct line of communication from the observers to DOC, then the MMO Team Leader is to first inform the Party Chief of the issue and intended action. The following table summarises the situations when DOC (in effect, the Director-General) should be notified immediately. During this survey, the first point of contact within DOC is Ian Angus (
or iangus@doc.govt.nz). If a response is required urgently then telephone, but in all other circumstances use email. Should Ian Angus be unavailable, please phone 0800DOCHOT and state the information as outline in Section 3.2.

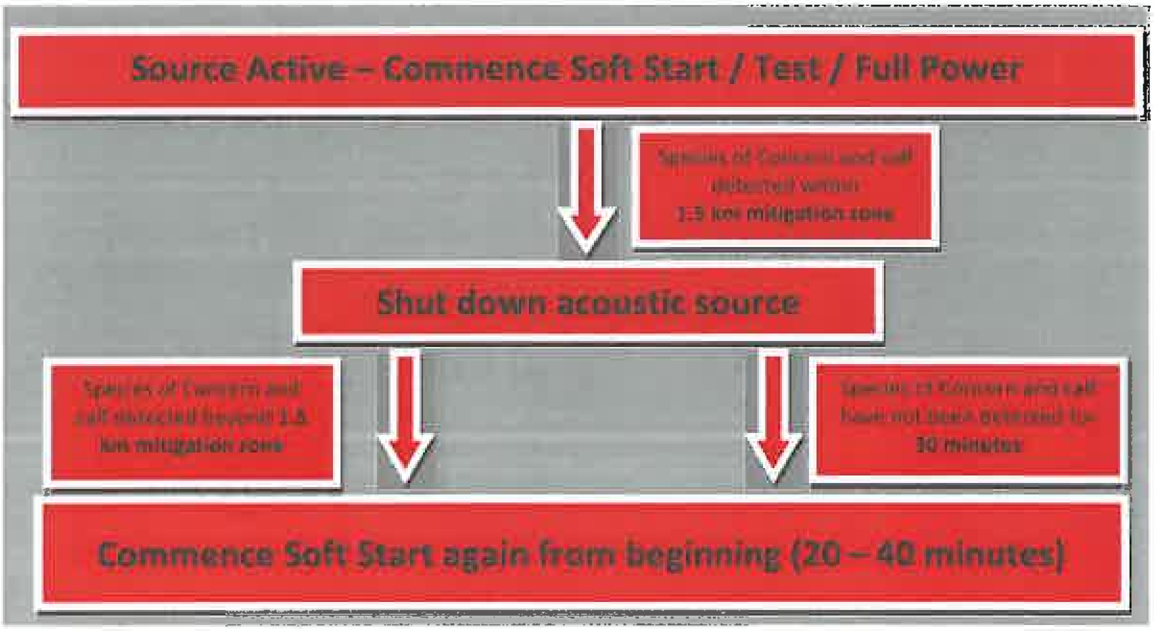
Table 1: Events that require DOC to be notified.

Situation	Timing of notification	Comments
The PAM system becomes non-operational	Immediate	This refers to when both primary and backup systems are non-operational
Any instances of non-compliance with the Code	Immediate	This is a standard requirement under the Code and includes instances where the operational capacity notified in the MMIA is exceeded – refer Section 4.3.2 of this MMMP
MMOs consider that there are higher numbers of marine mammals encountered than what was summarised in the MMIA, including large numbers of migratory whales	Immediate	MMO Team Leader should report to DOC immediately if there appears to be a higher number of marine mammals encountered than summarised in the MMIA. This includes large numbers of whales on northward migration
Sighting of Māui dolphin	Immediate	DOC is notified as soon as possible. If the sighting was reliable, DOC staff may mobilise a boat to try and gather a biopsy sample.
If PAM is being repaired, and operations continue without active PAM for maximum of 2 hours 20 mins per event	As soon as practicable	DOC is notified via email as soon as practicable with the time and location in which operations began without an active PAM system (Code 4.1.2)

Addenda 1: Standard Mitigation Procedures – Good Sighting Conditions (poster format)

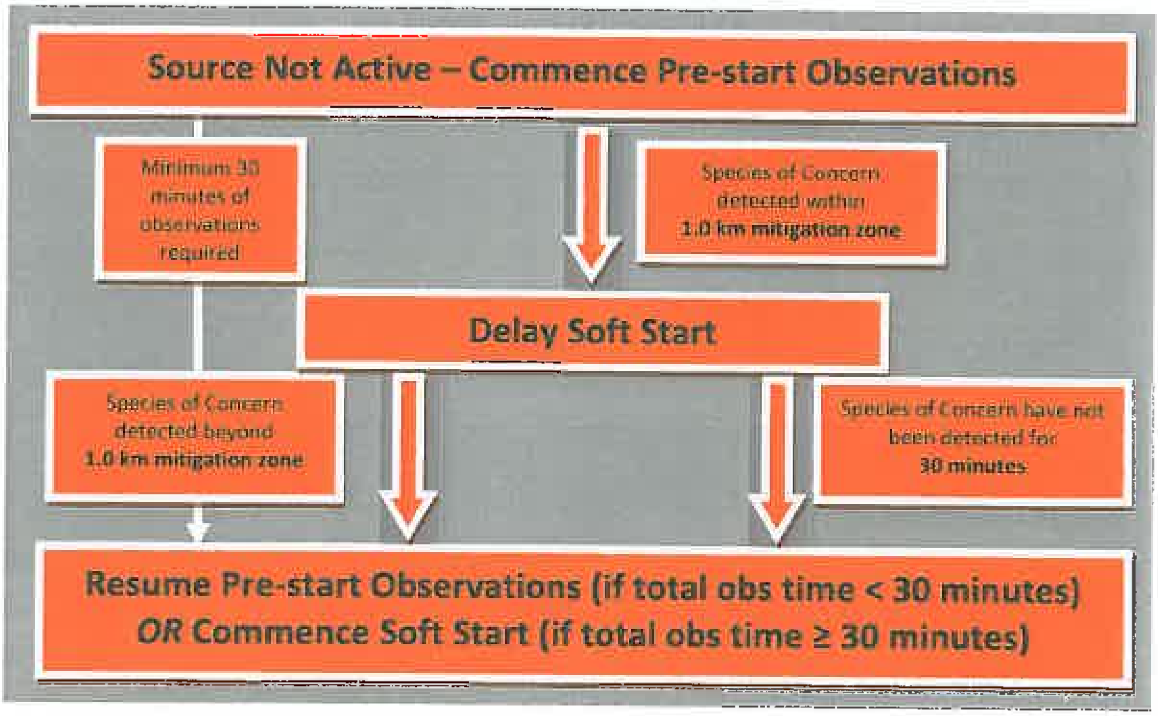
The following posters depict mitigation procedures. It is recommended they be posted in the instrument room, the PAM station and on the bridge. Operational flowcharts are also found in Appendix 4 of the Code.

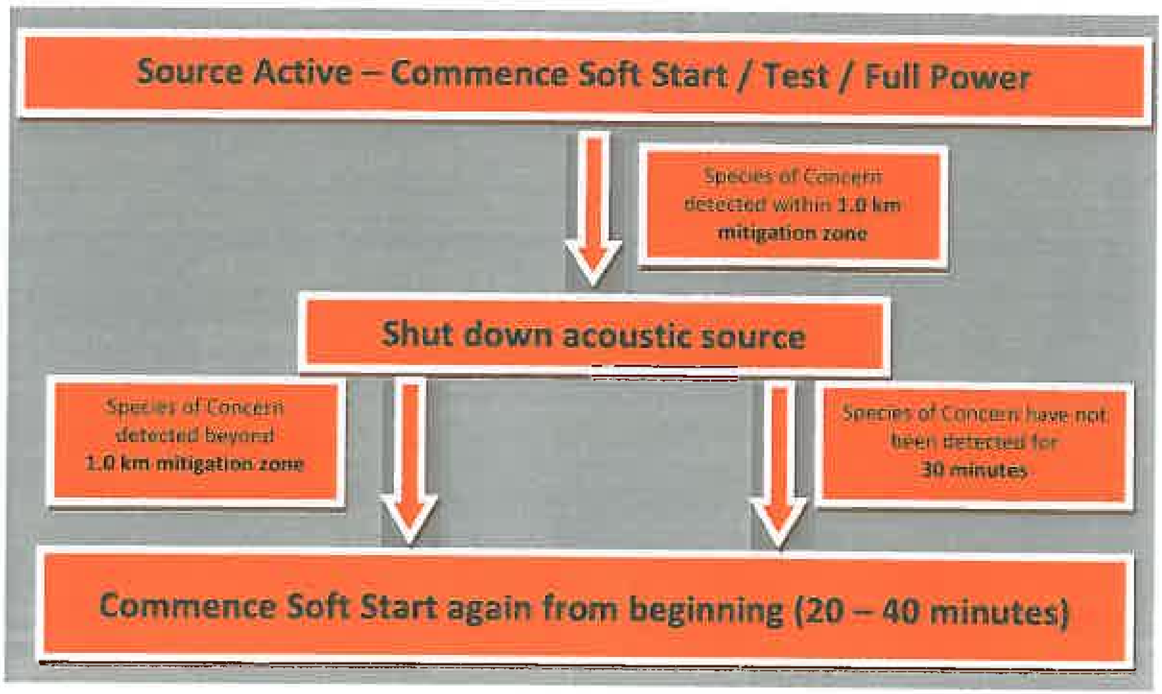
Species of Concern with Calves within 1.5 km of Acoustic Source



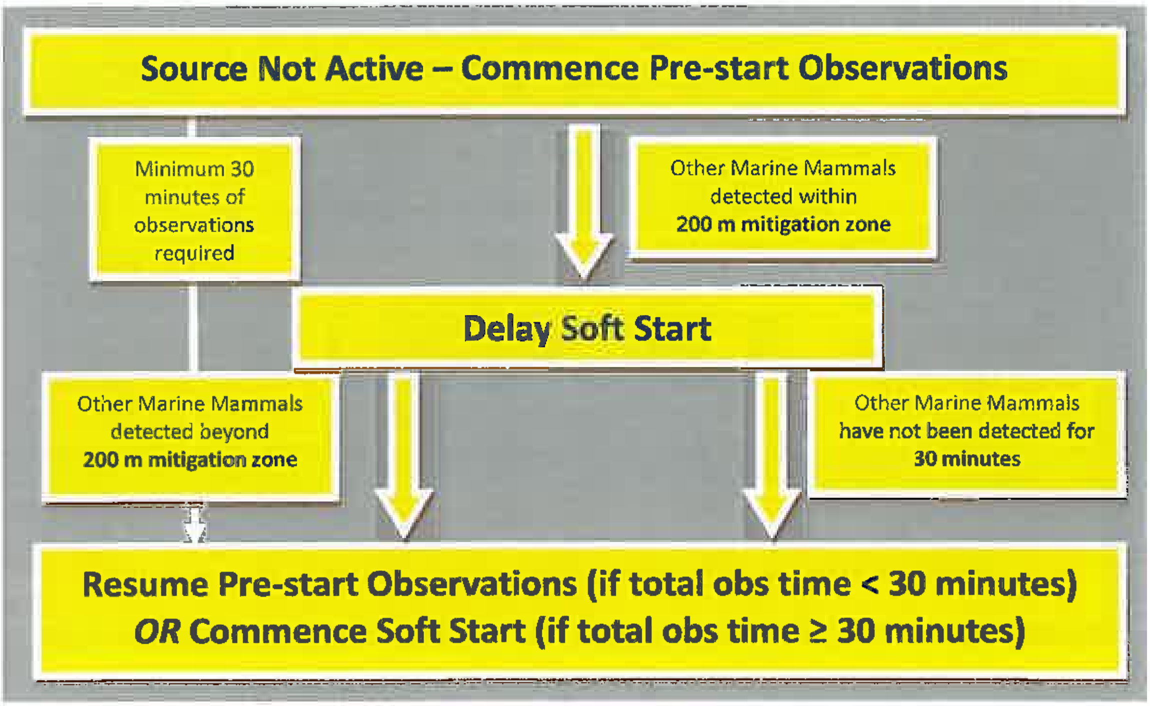
STANDARD MITIGATION ZONES

Species of Concern (no Calves) within 1.0 km of Acoustic Source

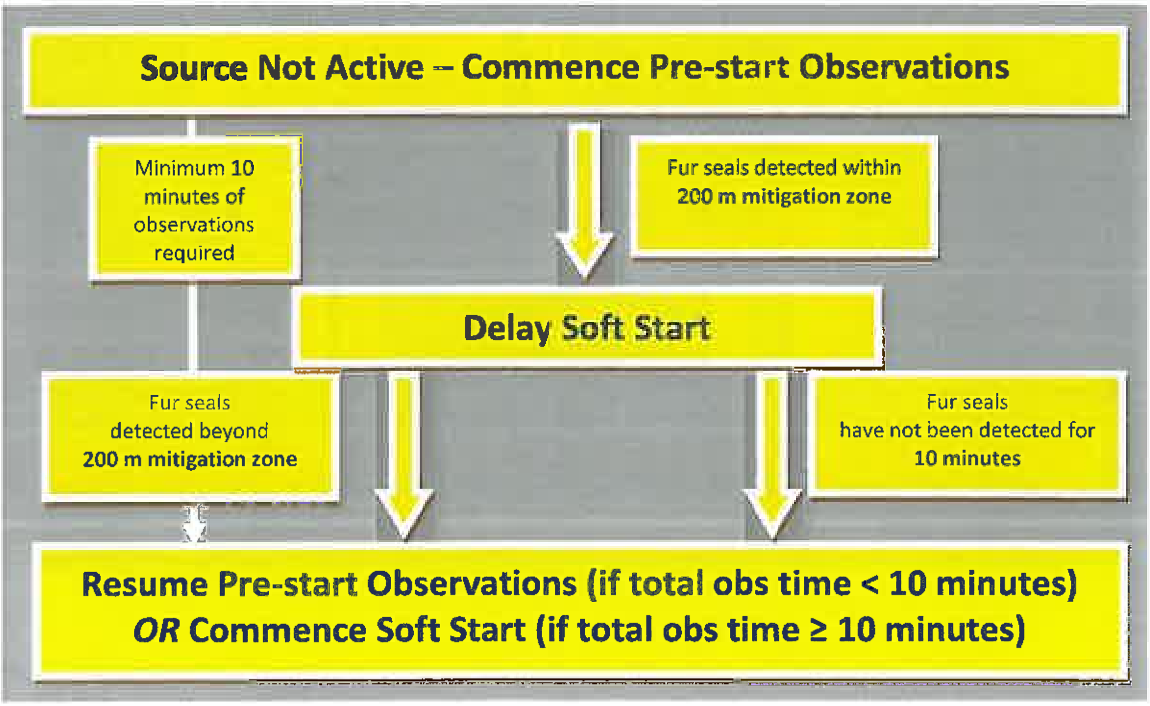




Other Marine Mammals within 200 m of Acoustic Source (excluding fur seals)



Fur seals within 200 m of Acoustic Source



Addenda 2: Recommended Communication Protocols (poster format)

Note: Seismic control room to immediately notify observers (MMO and PAMO) of any changes in the status of acoustic source.

Normal Operations - No Marine Mammal Sighting/Detection

45 minutes before commencement of soft start, Seismic notify observers to begin pre-start observations

↓

Prior to soft start, seismic call observers for ALL CLEAR

↓

Seismic notify observers time of soft start

↓

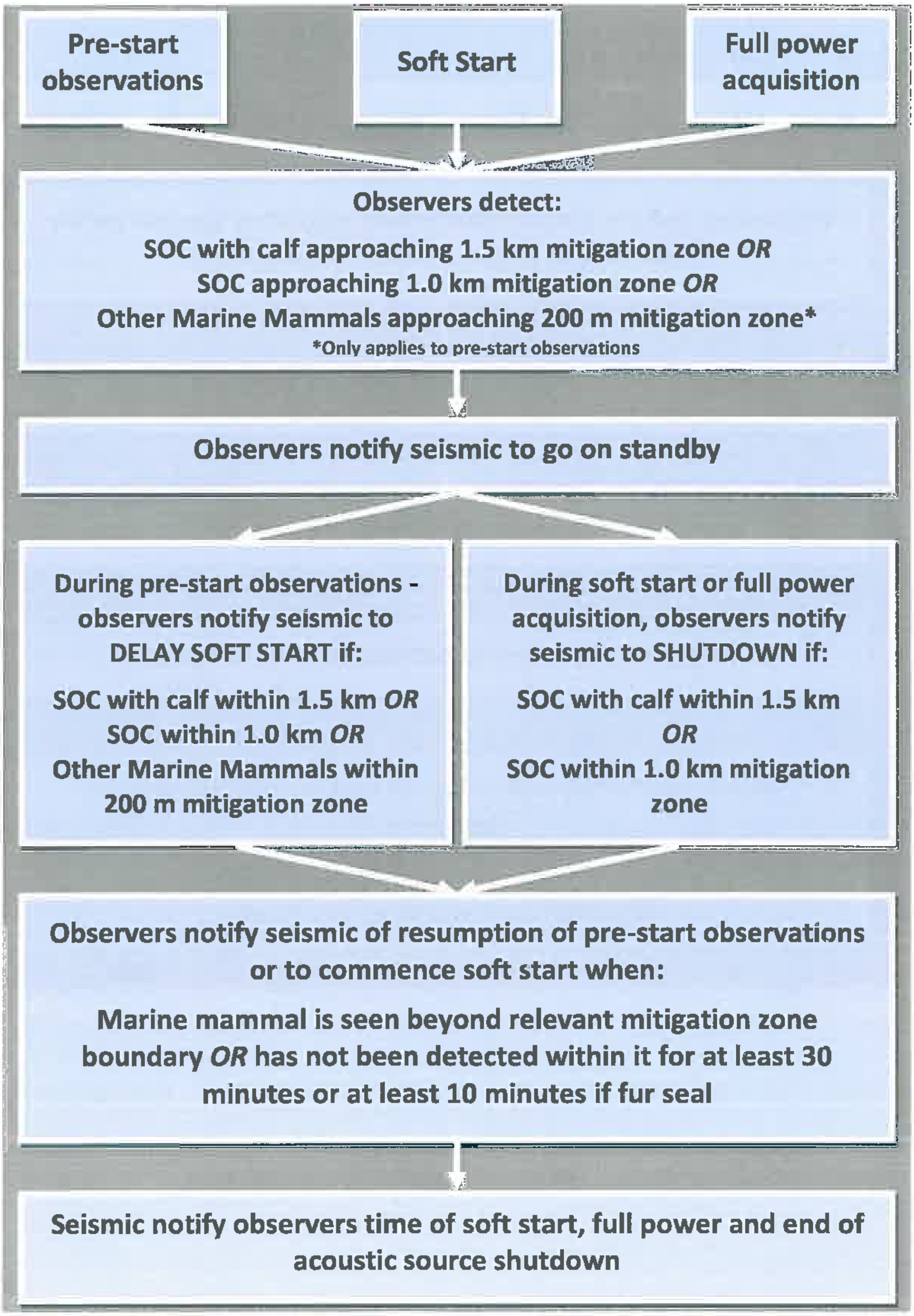
Seismic call observers to confirm time of full power

↓

Seismic notify observers time of end of acoustic source shutdown

Seismic must notify observers immediately if operational capacity is exceeded at any stage

Delayed Soft Start or Shutdown – Marine Mammal Sighting/Detection



Addenda 3: Operational Area coordinates

These coordinates have been loaded into VADAR for real time monitoring of vessel location and marine mammal detections relative to the Operational Area.

Operational Area (WGS84)	
Longitude (decimal degrees West)	**Latitude (decimal degrees South)**
172.347179	-38.1985828
172.7034	-38.0685227
173.0402955	-38.6366935
172.6683848	-38.7727507
172.8411128	-39.0625322
172.6314804	-39.1385689
172.1883289	-38.3924451
172.1853843	-38.387384
172.409973	-38.3061383
172.347179	-38.1985828

Addenda 4: Checklist for MMOs and PAMOs before acoustic source is put into water

MMOs and PAMOs to complete this checklist prior to the acoustic source being put into the water. MMO on watch to complete checklist during daylight hours, PAMO on watch to complete during hours of darkness.

There will be at least one MMO (during daylight hours) and one PAMO on watch <u>at all times while the acoustic source is in the water in the Operational Area</u>.

	Task	**Confirmed by? (MMO &/or PAMO)**
1	Establish communications protocol with seismic control room and between MMO and/or PAMO on watch and ensure these are functioning	
2	Ensure MMOs, PAMOs and seismic control room are aware that the acoustic source must not enter the water within the Operational Area without MMO (daylight hours) and PAMO (24 hours) on watch	
3	Is seismic control room aware that they need to inform MMO and/or PAMO at what time they intend to place seismic source into the water?	
4	MMO (daylight hours) informs PAMO that they are on watch prior to acoustic source being placed in water and endorses go ahead for acoustic source to be placed in water PAMO has acknowledged this?	
5	PAMO (24 hours) informs MMO that they are on watch prior to acoustic source being placed in water and endorses go ahead for acoustic source to be placed in water MMO has acknowledged this?	
6	MMO (during daylight hours) informs seismic control room that MMO and PAMO are on watch and that acoustic source can be placed in water. Seismic control room acknowledged this? If during hours of darkness, PAMO undertakes this task	
7	Seismic control room informs MMO and/or PAMO when the acoustic source enters the water	

Addenda 5: Species of Concern as defined in the Code

Common name	Latin name
Andrew's beaked whale	*Mesoplodon bowdoini*
Antarctic minke whale	*Balaenoptera bonarensis*
Arnoux's beaked whale	*Berardius arnuxii*
Blainville's beaked whale	*Mesoplodon densirostris*
Blue whale	*Balaenoptera musculus*
Bottlenose dolphin	*Tursiops truncatus*
Bryde's whale	*Balaenoptera edeni*
Cuvier's beaked whale	*Ziphius cavirostris*
Dwarf Minke whale	*Balaenoptera acutorostrata subsp.*
Dwarf sperm whale	*Kogia simus*
False killer whale	*Pseudorca crassidens*
Fin whale	*Balaenoptera physalus*
Ginkgo-toothed whale	*Mesoplodon ginkgodens*
Gray's beaked whale	*Mesoplodon grayi*
Hector's beaked whale	*Mesoplodon hectori*
Hector's dolphin	*Cephalorhynchus hectori*
Humpback whale	*Megaptera novaeangliae*
Killer whale	*Orcinus orca*
Long-finned pilot whale	*Globicephala melas*
Māui's dolphin	*Cephalorhynchus hectori maui*
Melon-headed whale	*Peponocephala electra*
New Zealand sea lion	*Phocarctos hookeri*
Pygmy/Peruvian beaked whale	*Mesoplodon peruvianus*
Pygmy blue whale	*Balaenoptera musculus brevicauda*
Pygmy killer whale	*Feresa attenuata*
Pygmy right whale	*Caperea marginata*
Pygmy sperm whale	*Kogia breviceps*
Sei whale	*Balaenoptera borealis*
Shepherd's beaked whale	*Tasmacetus shepherdi*

Short-finned pilot whale	*Globicephala macrorhynchus*
Southern Bottlenose whale	*Hyperoodon planifrons*
Southern right whale	*Eubalaena australis*
Southern right whale dolphin	*Lissodelphis peronii*
Sperm whale	*Physeter macrocephalus*
Strap-toothed whale	*Mesoplodon layardii*
True's beaked whale	*Mesoplodon mirus*

APPENDIX 5

Sound Transmission Loss Modelling

Curtin University

Centre for Marine Science and Technology

Received underwater sound level modelling for the Vulcan 3D seismic survey

Prepared for:

Environmental Offshore Services Ltd

Prepared by: Marta Galindo-Romero and Alec Duncan

PROJECT CMST 1323
REPORT 2014-41

3rd September 2014

Summary

This report describes acoustic propagation modelling that was carried out to predict received sound exposure levels from the Vulcan 3D seismic survey in New Zealand permit area PEP 55793 (North Taranaki Basin).

Both short range and long range modelling were carried out. The modelling method used to produce the short range results accurately deals with both the horizontal and vertical directionality of the seismic source. The method used for computing the long range results only considers the horizontal directionality of the array but accounts for water column and seabed variations in depth and range.

The modelled seismic source was a 3460 cubic-inch airgun array at a depth of 7m.

The short range modelling predicted that the maximum sound exposure levels would be below the Code of Conduct thresholds of 186 dB re 1 μPa^2.s at 200 m and 171 dB re 1 μPa^2.s at 1 and 1.5 km.

The long range modelling results were highly directional due to the combined effects of seismic source directionality and bathymetry. Levels showed moderate attenuation inshore of the source, in the North-East direction, faster attenuation inshore in the South-East direction, and slow attenuation offshore. Maximum levels at the outer boundary of the West Coast North Island Marine Mammal Sanctuary due to a source in 152m water depth, on the eastern side of the survey boundary, were predicted to be 133 dB re 1 μPa^2.s.

Contents

List of Figures

1 Introduction

This report describes acoustic propagation modelling which was carried out to predict the underwater sound levels that are likely to be produced by the Vulcan 3D seismic survey which will be carried out in New Zealand permit area PEP 55793. The aims of the modelling were to establish whether the survey will meet the sound exposure level requirements of the New Zealand Department of Conservation 2013 Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations, and to predict the maximum sound exposure levels in the West Coast North Island Marine Mammal Sanctuary. The Code requires modelling to determine whether received sound exposure levels will exceed 186 dB re 1 μPa^2.s at a range of 200m from the source, or 171 dB re 1 μPa^2.s at ranges of 1km and 1.5km.

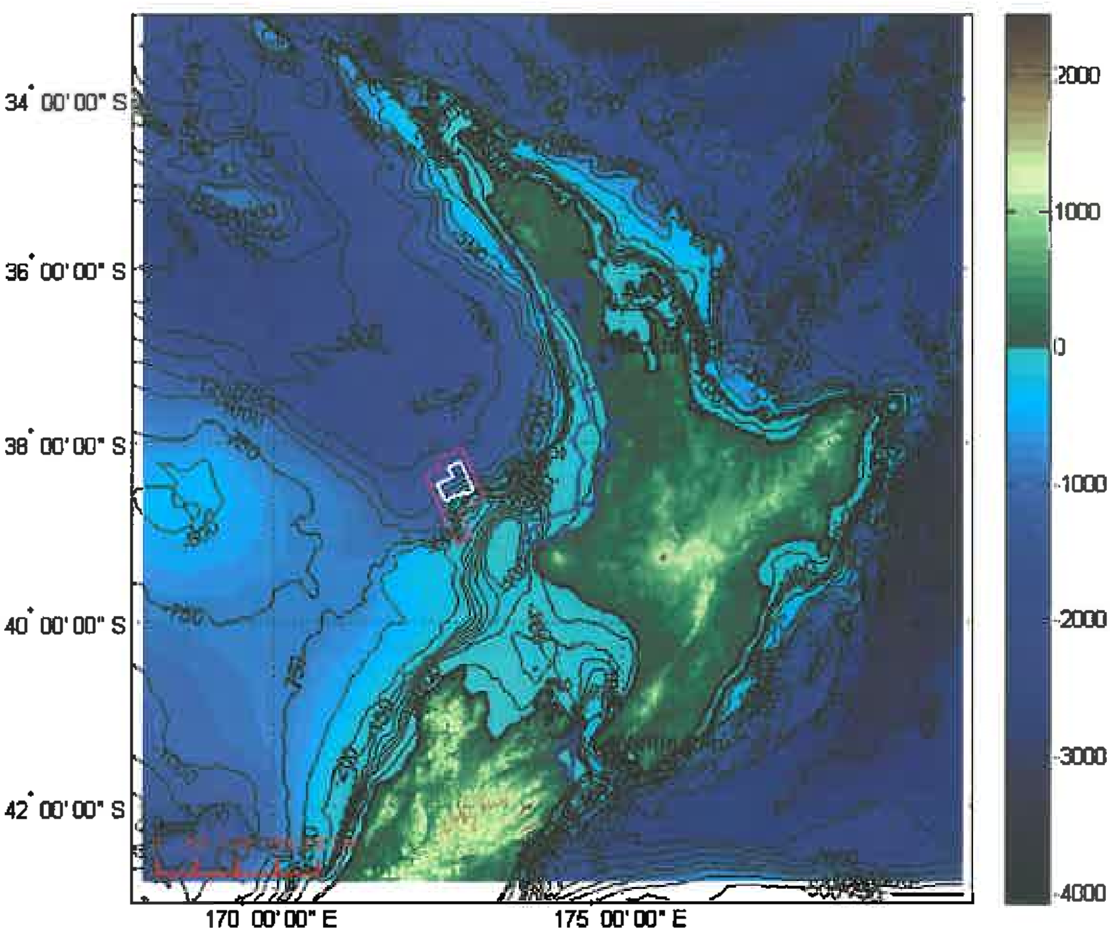


Figure 1. Map of the New Zealand North Island showing the survey area. The magenta polygon shows the bounds of the operational area for the survey vessel, and the white polygon shows the bounds of the actual survey. The blue bounding polygon is the Marine Mammal Sanctuary area.

The survey area is displayed in Figure 1 with a white polygon, which is inside a magenta polygon representing the operational area. The boundaries of the North Island Marine Mammal Sanctuary are also plotted. This survey covers a small geographic footprint in the North Taranaki Basin, but the offshore environment transitions from the continental shelf through the continental slope to benthic regions, and the active geologic regime around New Zealand introduces some major geographic and geological features into the environment. As such, the offshore region close to the Vulcan seismic survey and the surrounding area is geographically and geologically complex. The bathymetry data shown in Figure 1 was obtained from the NIWA elevation and bathymetry grid (CANZ 2008).

This report is organised as follows: Section 2 describes the methods used to carry out the modelling, and the results are presented in Section 3. Major conclusions are summarised in Section 4.

2 Methods

2.1.1 Source modelling

The seismic source proposed for this survey is the 3460 cubic-inch array shown in Figure 2. The source depth is 7 m.

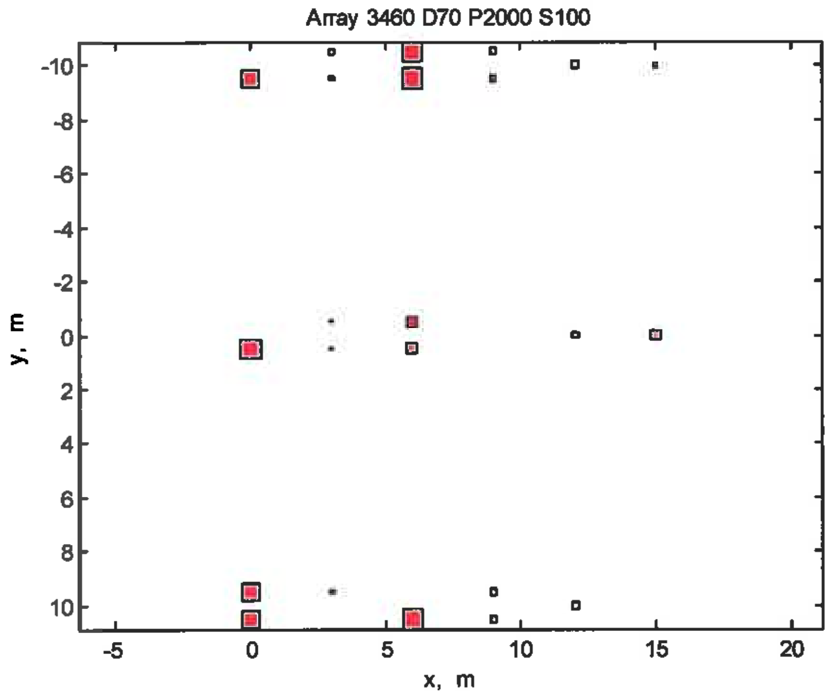


Figure 2. Plan view of the 3460 cubic-inch array. Array elements are shown much larger than actual size but are scaled proportional to the cube root of their volume.

2.1.2 Modelling and calibration methods

Acoustic signals required for this work were synthesised using CMST's numerical model for airgun arrays. The procedure implemented for each individual source element is based on the bubble oscillation model described in Johnson (1994) with the following modifications:

- An additional damping factor has been added to obtain a rate of decay for the bubble oscillation consistent with measured data;
- The zero rise time for the initial pressure pulse predicted by the Johnson model has been replaced by a finite rise time chosen to give the best match between the high frequency roll-off of modelled and measured signal spectra;
- For the coupled-element model used in this work, the ambient pressure has been modified to include the acoustic pressure from the other guns in the array and from the surface ghosts of all the guns. Including this coupling gives a better match between the modelled signal and example waveforms provided by seismic contractors, but only has a minor influence on the spectrum of this signal and hence on the modelled received levels.

The model is subjected to two types of calibration:

- The first is historical and was part of the development of the model. It involved the tuning of basic adjustable model parameters (damping factor and rise time) to obtain the best match between modelled and experimentally measured signals, the latter obtained during sea trials with CMST's 20 in^3 air gun. These parameters have also been checked against several waveforms from larger guns obtained from the literature.
- The second form of calibration is carried out each time a new array-geometry is modelled, the results of which are presented below. Here, the modelled gun signals' amplitudes are scaled to match the signal energy for a far-field waveform for the entire array computed for the direction (including ghost) to that of a sample waveform provided by the Client's seismic contractor. When performing this comparison the modelled waveform is subjected to filtering similar to that used by the seismic contractor in generating their sample, or additional filtering is applied to both data sets to emphasise a section of the bandwidth of the supplied data which CMST regards as being most reliable.

Beam patterns for the calibrated array were built up one azimuth at a time as follows:

- The distances from each gun to a point in the far-field along the required azimuth were calculated. (The far-field is the region sufficiently far from the array that the array can be considered a point source);
- The corresponding time delays were calculated by dividing by the sound speed;
- Computed signals for each gun were delayed by the appropriate time, and then these delayed signals were summed over the guns;
- The energy spectral density of the resulting time domain waveform was then calculated via a Fourier transform;
- During this procedure care was taken to ensure that the resulting spectrum was scaled correctly so that the results were in source energy spectral density units: dB re 1 $\mu Pa^2 s/Hz$ @ 1m.

2.1.3 Source modelling results

Figure 3 show comparisons between the example waveforms and spectra for the vertically downward direction provided by the client and those produced by the CMST airgun model after calibration. There are differences in detail but the general agreement is good.

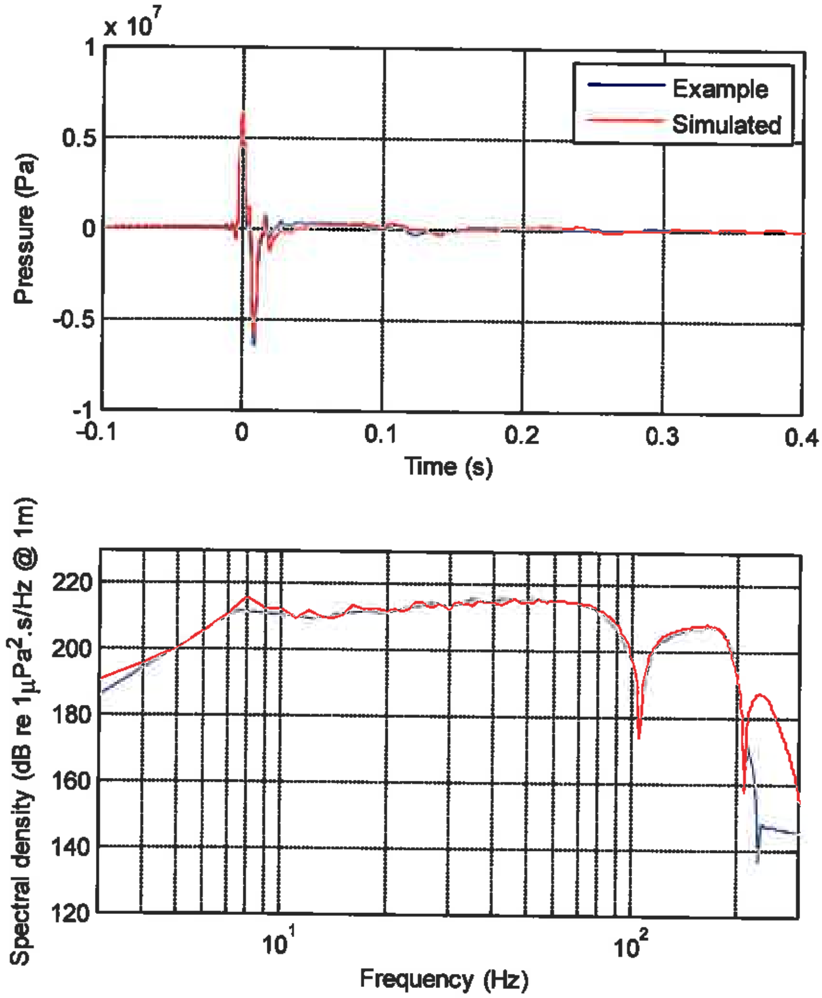


Figure 3. Comparison between the waveforms (top) and spectra (bottom) for the 3460 cubic-inch Bolt Array. The example signal for the vertically downward direction provided by the client (blue) and the signal produced by CMST's airgun array model (red).

In this case the provided example waveforms were for an array depth of 7 m, the same as the expected operational depth.

Vertical and horizontal cross-sections through the frequency dependent beam pattern of the array are shown in Figure 4. These beam patterns demonstrate the strong angle and frequency dependence of the radiation from the seismic source. The horizontal beam pattern shows that in the horizontal plane a large amount of the high frequency energy is radiated in the cross-line direction and a significant amount of energy is also radiated in the in-line direction. These beam patterns are characteristic of a seismic source with wide spacing between elements or in this case wide spacing between sub-arrays.

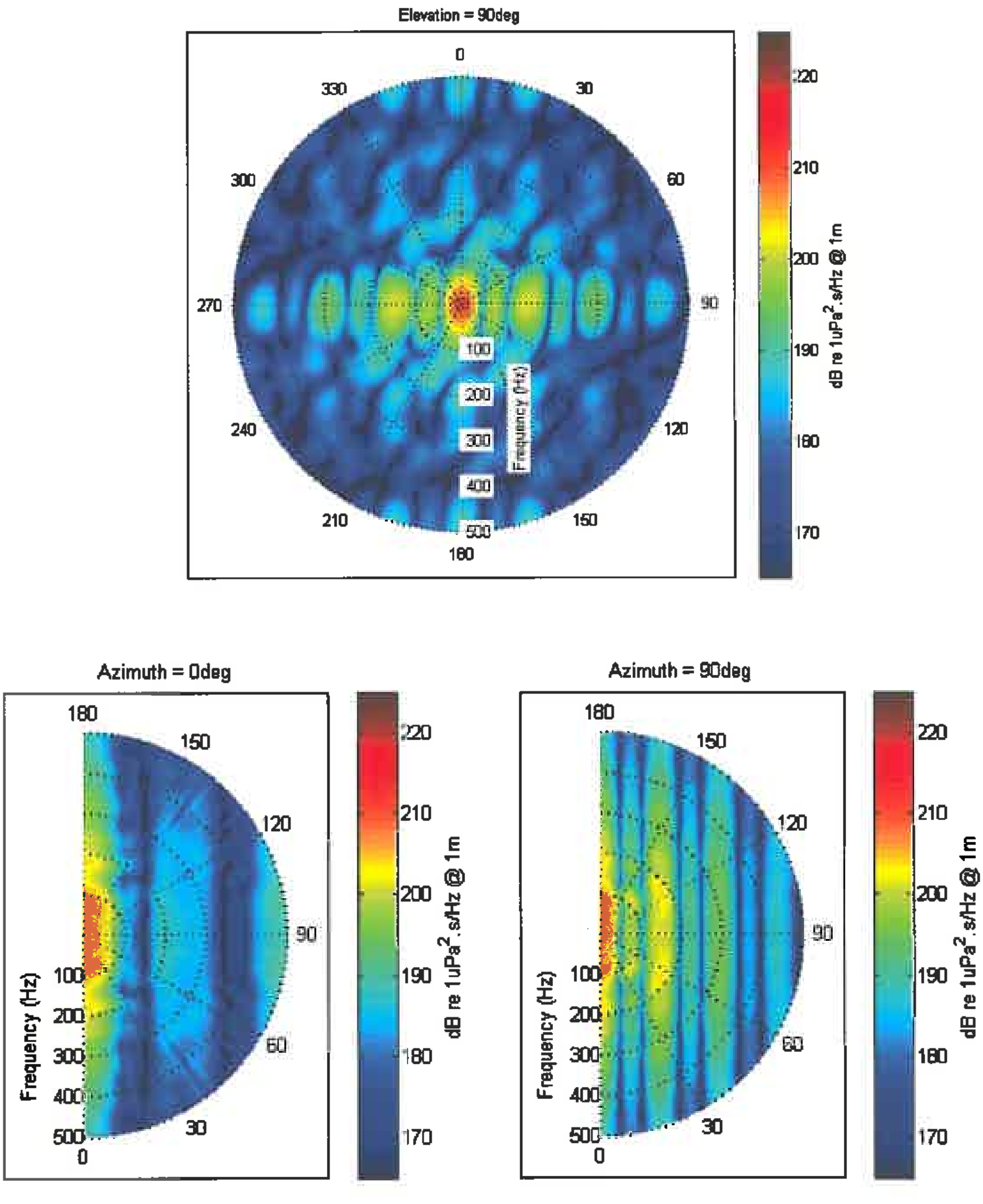


Figure 4. Array far-field beam patterns as a function of orientation and frequency. The top plot is for the horizontal plane with 0 degrees azimuth corresponding to the in-line direction. The bottom two plots are for the vertical plane for the in-line direction (left) and cross-line direction (right). Zero elevation angle corresponds to vertically downwards.

2.1.4 Propagation modelling

2.1.4.1 Water-column properties

The appropriate Spring (October to December) sound speed profiles from the World Ocean Atlas (Locarnini et al., 2006) (Antonov, Locarnini, Boyer, Mishonov, & Garcia, 2006) was chosen for this modelling work in order to capture the worst-case conditions that could be encountered at the beginning of the survey. Full water depth sound speed profiles for three of the geoacoustic regions defined for this survey (see next section) are shown in Figure 5.

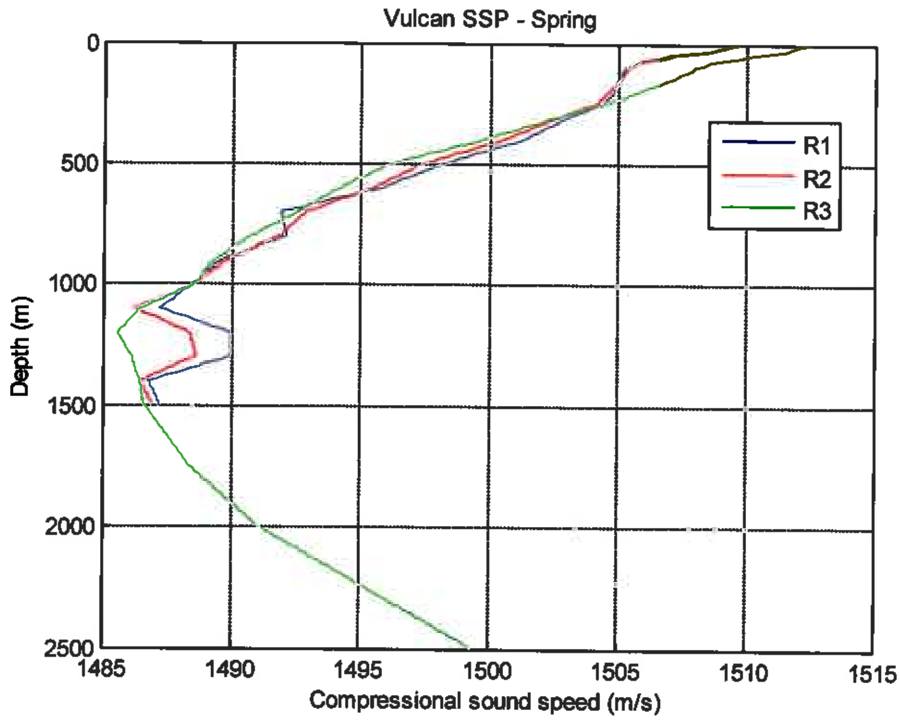


Figure 5. Sound velocity profiles obtained from NOAA World Ocean Atlas.

2.1.4.2 Regional geoacoustic models & bathymetry

Since the survey spans an area of complex bathymetry, four geoacoustic regions representing different bottom types were used. These regions are shown in Figure 6.. The regions were chosen to represent the probable bottom sediment compositions and sub-bottom layering. The bottom models for each region were based on information from published literature on New Zealand regional seabed geology and the acoustic properties of marine sediments. For the R1, R2, and R3 regions, elastic propagation parameters were ignored. When limited information is known about sediments and the average sediment composition consists of sand, silt, and clay, neglecting elastic effects is a reasonable approximation (Jensen, Kuperman, Porter, & Schmidt, 2011). For the R4 region, an equivalent fluid bottom was used rather than an elastic bottom. For long range propagation this is a reasonable approximation. The resulting seabed properties for each geoacoustic region are tabulated below in Table 1.

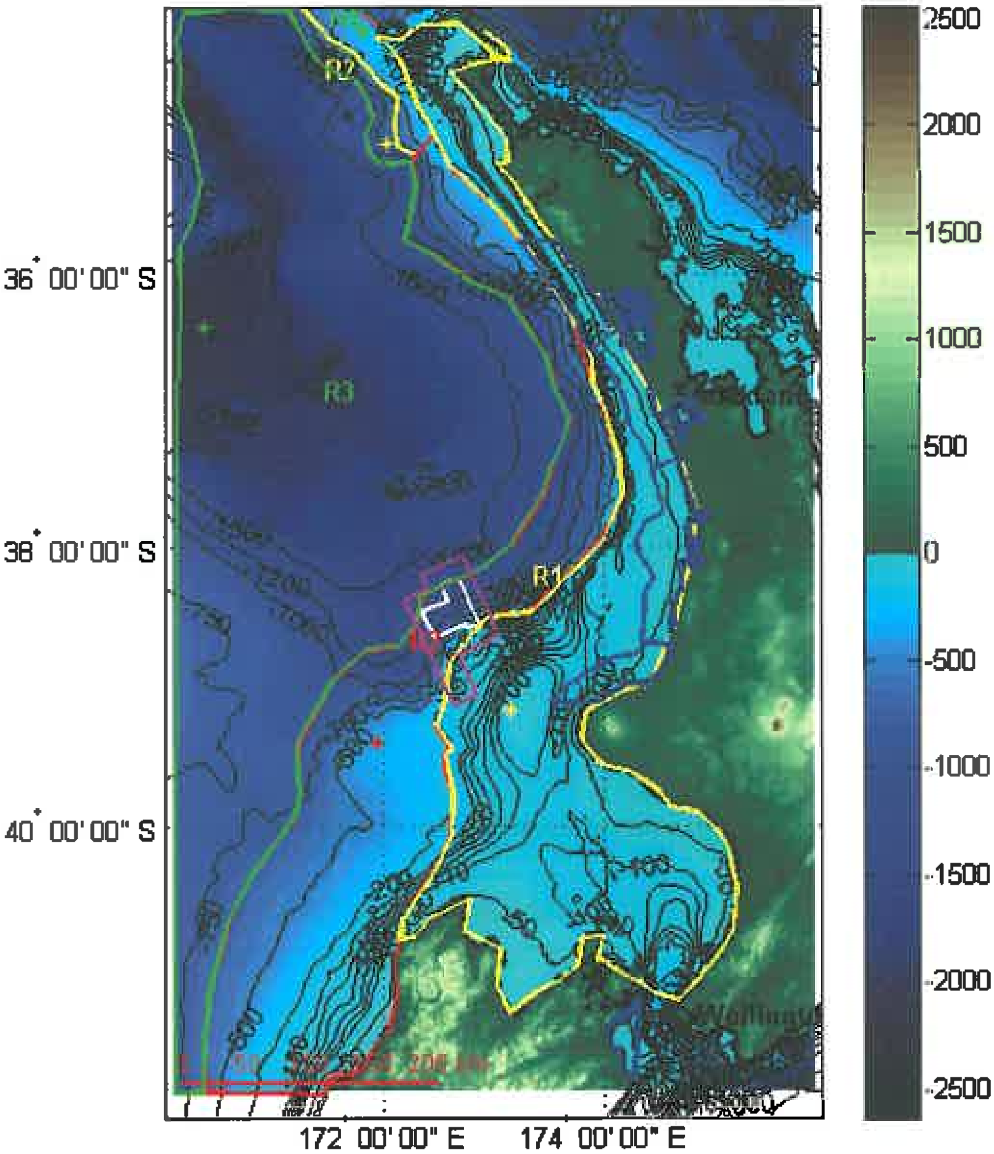


Figure 6. Geoacoustic regions for the Vulcan survey region. The magenta polygon shows the bounds of the operational area, and the white polygon shows the bounds of the actual survey. The blue bounding polygon is the Marine Mammal Sanctuary area.

Table 1: Geoacoustic Properties for the regions in defined in Figure 8

Layer Sediment Description	Thickness (m)	ρ (kg.m^{-3})	c_p (m.s^{-1})	α_p (dB/λ)
R1: Taranaki - Northland Continental Shelf				
Fine Sand Layer	150	1856 2030	1700 1844	0.8
Fine Sand Half Space	N/A	2030	1844	0.8
R2: Taranaki - Northland Continental Slope				
Silt – Clay Layer	150	1488 1662	1549 1733	0.1
Silt – Clay Half Space	N/A	1662	1733	0.1
R3: Southern New Caledonia Basin - Reinga Basin - Challenger Plateau				
Pelagic Plain Mud - Ooze	400	1421 1886	1520 2011	0.1
Mud - Ooze Half Space	N/A	1886	2011	0.1

R4: Vening Meinez Facture Zone - Reinga Ridge			c_p (m.s^{-1})	c_s (m.s^{-1})	α_p (dB/λ)	α_s (dB/λ)
Carbonate Sediment Half Space	N/A	1900	2100	550	0.1	0.2
Equivalent Fluid Half Space	N/A	1900	2290	0.0	7.6	0.0

Symbol key for Table 1:
ρ = density, c_p = compressional wave speed, c_s = shear wave speed, α_p = compressional wave attenuation, α_s = shear wave attenuation, λ = wavelength

The Vulcan survey area spans the southwest Pacific back arc complex associated with previous rifting-subduction events as part of the later stages of the opening of the Tasman sea (Bache et al., 2012) . The offshore region is composed of linked sedimentary basins, ridge systems intersected by the New Zealand land mass (C. I. Uruski, 2010). The onshore area is composed of a shelf-slope system with varied amounts of terrestrial sediments

(Carter, 1975; Griffiths & Glasby, 1985). There are also local patches of carbonate sediments that become more common in the Northern area of the survey.

The bottom sediments of the continental shelf and continental slope within the Northland-Waikato-Taranaki regions consist of detrital terrigenous sediment (Carter, 1975, 1980). On this section of the continental shelf, the sediment types can range from coarse siliceous sand near shore, and fine sand at the shelf break (Carter, 1980). The detrital sediments are further transported down the continental slope. Silts and clays that grade to mud are predominantly deposited on the continental slope. In general, sediments become finer away from the continental shelf to the lower areas of the pelagic areas of the Southern New Caledonia Basin (Collot et al., 2008), Reinga Basin (Bache, Stagpoole, & Sutherland; Bache et al., 2012; Herzer et al., 1997), and Challenger Plateau (Andrews & Eade, 1973). As such the R1, R2, and R3 regions represent this fining trend from the near shore to offshore areas.

The sediment thickness of continental shelf and slope of the South Taranaki basin has been estimated at an average thickness of 150 m by Nodder (1995). This thickness was assumed to continue northward. Seismic surveys discussed in C. Uruski and Wood (1991) indicate that sediments packages within the Southern New Caledonia Basin are 400-500 m thick. The regions R1 and R2 were modelled with a 150 m thick sediment layer and R3 with a 400 m thick layer.

The northernmost extent close to Northland is absent of any major river system (Griffiths & Glasby, 1985), and current and relic carbonate sediments dominate on the seafloor (Carter, 1975). These sediments are composed of carbonate grains; clasts range from gravel to sand sizes (Summerhayes, 1969a, 1969b). The R4 region represents this bottom type and spans the Vening Meinez Facture Zone and Reinga Ridge off the Northland Cape.

With the likely bottom sediment types defined for the offshore area, the geoacoustic parameters for the regions R1 – R3 were taken from Hamilton (1980). For layers of unconsolidated sediments compaction and resulting porosity reduction can change the sound propagation parameters within a layer (Jensen et al., 2011). Therefore, a gradient between the top and the bottom of the sediment layer for the regions R1, R2, and R3 was used. Both the compressional wave speed (Hamilton, 1979) and density (Hamilton, 1976) were increased linearly with depth within these layers.

There is insufficient literature defining the geoacoustic properties of unconsolidated carbonate sediment (Hamilton, 1980). In light of this we assume the sediments in R4 are analogues or similar to the seabed geology present around coastal Australia. The geoacoustic parameters of semi-cemented calcarenite/sand as defined by Duncan, Gavrilov, McCauley, Parnum, and Collis (2013) were used for R4. A fluid bottom replaced the elastic parameters of limestone and calcarenite bottoms of R4. The properties of the fluid half space were chosen by calculating a fluid reflection coefficient and matching it as closely as possible to the solid bottom reflection coefficient. The reflection coefficient fit is shown in Figure 7. Fluid bottoms are required to facilitate the use of RAMGeo as a sound propagation code for long range modelling.

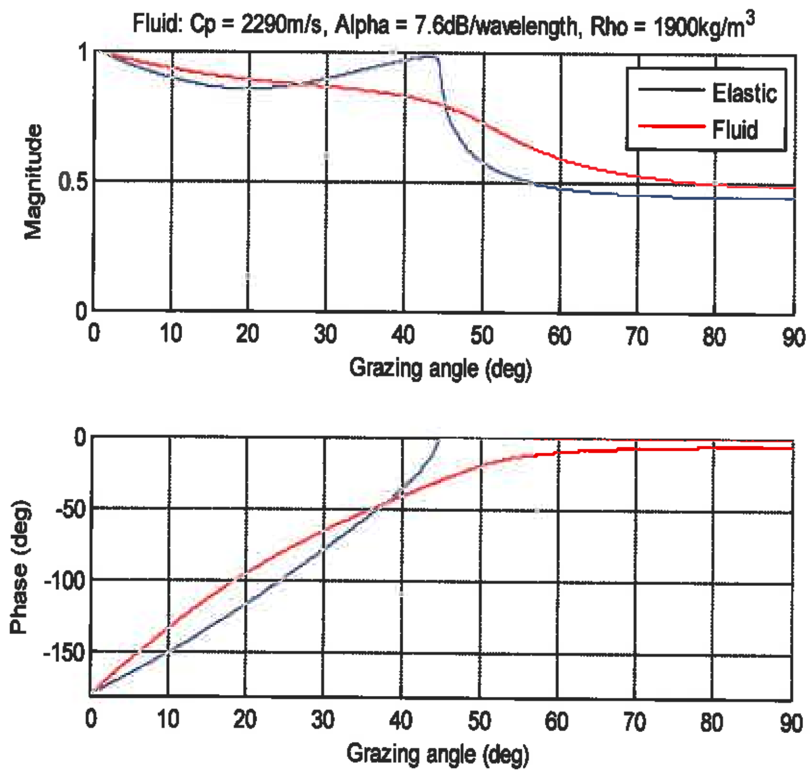


Figure 7. Equivalent fluid bottom for R4.

2.1.4.3 Short Range Modelling

2.1.4.3.1 Choice of propagation modelling codes

The short ranges involved in this component of the modelling made it possible to use the range independent propagation modelling code SCOOTER (Michael B. Porter, 2007) for this work. SCOOTER is a wavenumber integration code, which is stable, reliable, and can deal with arbitrarily complicated fluid and/or solid seabed layering. It cannot, however, deal with changes of water depth with range, and is therefore considered a range independent model, but that is unimportant in this particular application.

2.1.4.3.2 Source Locations

One source location, S1 was used for the modelling of sound propagation at short ranges for the Vulcan survey (Figure 8).

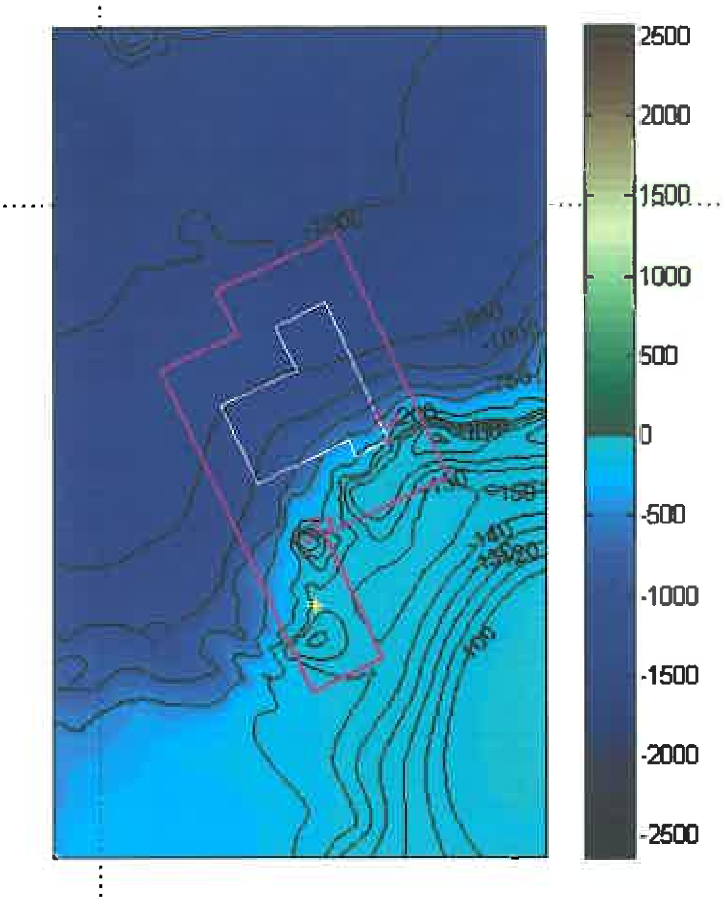


Figure 8. The magenta dots labelled S1 and S2 are the source locations chosen for short and long range modelling. The magenta polygon shows the bounds of the operational area, and the white polygon shows the bounds of the actual survey. The yellow dot is the location of the future well tie.

The location chosen was the shallowest area near the future well tie (represented as a yellow dot in Figure 8), and was chosen for modelling as a source in this location will produce the highest sound levels due to the contribution of seabed reflections.

2.1.4.4 Long Range Modelling

2.1.4.4.1 Choice of propagation modelling codes

For longer ranges the effects of varying water depth are important and it was necessary to use a range dependent model. In this case the parabolic equation code RAMGeo (Collins, 1993) was used. This code is well tested and reliable but can only deal with fluid seabeds.

2.1.4.4.2 Long Range Source Location

A single source location was chosen to model long range sound propagation. This source location is labelled S2 and is shown in Figure 8 and below in Figure 9. This location was chosen as being likely to produce the highest sound levels inshore of the survey area and within the marine mammal sanctuary area.

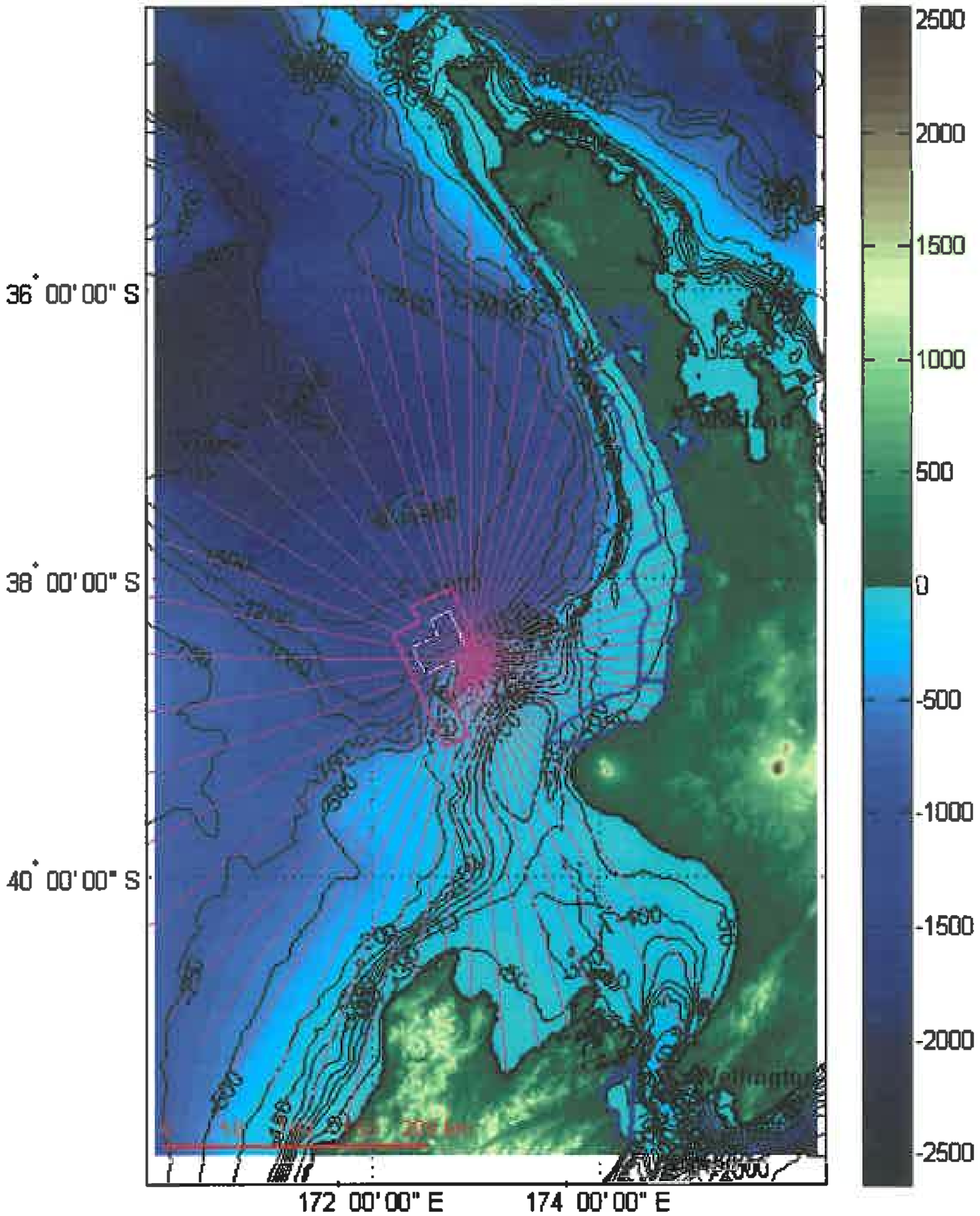


Figure 9. Geoacoustic regions, marine sanctuary area, and source location (S2) used for long-range modelling for the Vulcan survey. The magenta polygon shows the bounds of the operational area where the survey takes place, and the white polygon shows the bounds of the actual survey. The blue bounding polygon is the Marine Mammal Sanctuary area.

2.1.5 Sound exposure level (SEL) calculations

2.1.5.1 Short Range Modelling

At short ranges it is important to include both the horizontal and vertical directionalities of the seismic source, which requires summing the signals from the individual airguns at each receiver location. This process is accurate but very computationally demanding, and it is not feasible to apply it at ranges of more than a few kilometres.

Calculation of received sound exposure levels was carried out using the following procedure:

1. For each source location:
    a. SCOOTER was run at 1 Hz frequency steps from 2 Hz to 1000 Hz for a source depth corresponding to the depth of the seismic source (7m). The output of SCOOTER at each frequency and receiver location is the ratio of the received pressure to the transmitted pressure. The ratio is a complex number and represents both the amplitude and phase of the received pressure.
2. For each receiver location:
    a. The range from the receiver to each airgun in the array was calculated, and used to interpolate the results produced by the propagation modelling code, in order to produce a transfer function (complex amplitude vs. frequency) corresponding to that receiver - airgun combination.
    b. These transfer functions were inverse Fourier transformed to produce the corresponding impulse response, which was then convolved with the signal from the appropriate airgun to give a received signal due to that gun.
    c. The received signals from all guns in the array were summed to produce a received pressure signal.

The sound exposure level (SEL) at the receiver was calculated by squaring and integrating the pressure signal.

2.1.5.2 Long Range Modelling

For longer ranges the short-range modelling procedure described above was too computationally intensive to be feasible and instead SELs were calculated as a function of range, depth and azimuth from each source location as follows:

- Transmission loss was modelled at different azimuth increments out to 350 km maximum range using RAMGeo (fluid Parabolic Equation model) for a set of discrete (bin-centre) frequencies at one-third octave intervals from 8 Hz to 1000 Hz. Between 0 and 146° an increment of 2° was used. Then it was gradually increased from 5° to 10° and reduced again to 5°. The bathymetry along the track was interpolated from the CANZ (2008) dataset, and the local acoustic environment was as described previously.
- Frequency-dependent source level was obtained by integrating the horizontal plane source spectrum for the appropriate (relative) azimuth over each frequency band. (Band edges were chosen as the geometric means of adjacent frequencies.) Relative azimuths were calculated based on a survey line direction of 335°T.
- Source level and transmission loss were then combined to compute the received level as a function of range, depth and frequency. This calculation was carried out at the same azimuth increments. Corresponding transmission loss data were extracted from the closest available transect (in azimuth) used in the propagation modelling.
- Integrated squared acoustic pressure was calculated for each 1/3rd-octave spectral bin. These values were summed and converted to decibels to yield SEL.

3 Results

3.1.1 Short Range Modelling Results

Maximum received sound exposure levels at any depth are plotted as a function of range and azimuth from the source at S1 in Figure 10. The directionality of received levels in the horizontal plane is due to the directionality of the seismic source, which produces its highest levels in the cross-line and in-line directions.

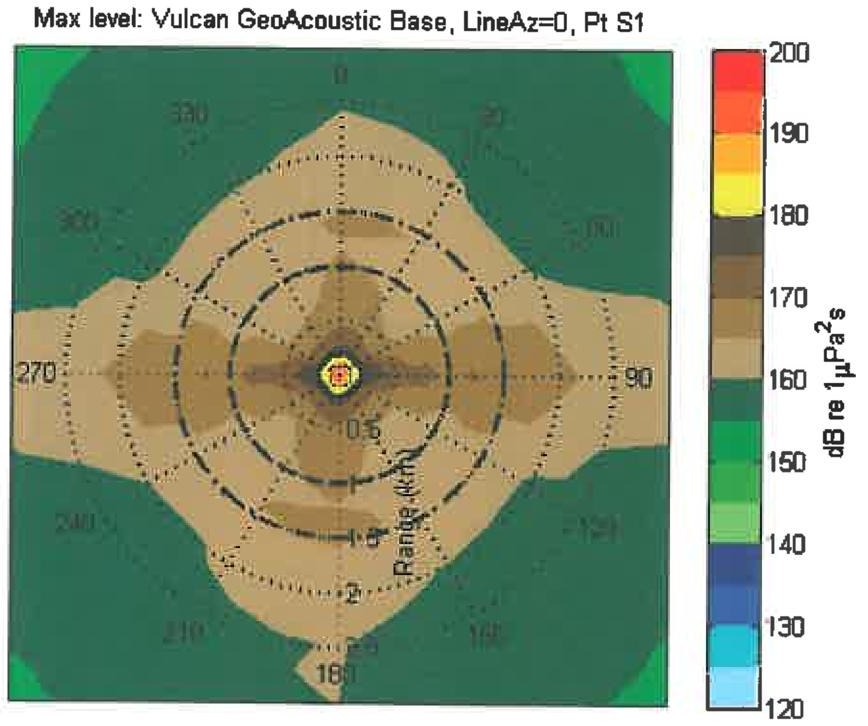


Figure 10. Predicted maximum received SEL at any depth produced as a function of azimuth and range from the source (spring sound speed profile). An azimuth of 0° (up) corresponds to the in-line direction. The thick black circle corresponds to mitigation ranges of 200m (solid), 1km (dash), and 1.5km (dash-dot).

Figure 11 shows a point plot that displays the sound exposure levels produced by the array at S1 as a function of range. The maximum predicted sound exposure level at the specified mitigation ranges for a seismic survey vessel operating within the permit areas PEP 55793 (Vulcan) are listed in Table 2.

Figure 12 shows the percentage of shots not exceeding two thresholds as a function of range. The thresholds are limits imposed by the New Zealand Department of

Conservation 2013 Code of Conduct, 171 dB re 1 μPa^2.s and 186 dB re 1 μPa^2.s. It can be seen that 100 % of the shots lie below the threshold of 186 dB re 1 μPa^2.s at distances equal or greater than 200 m. From 700 m from the source all of them lie below 171 dB re 1 μPa^2.s.

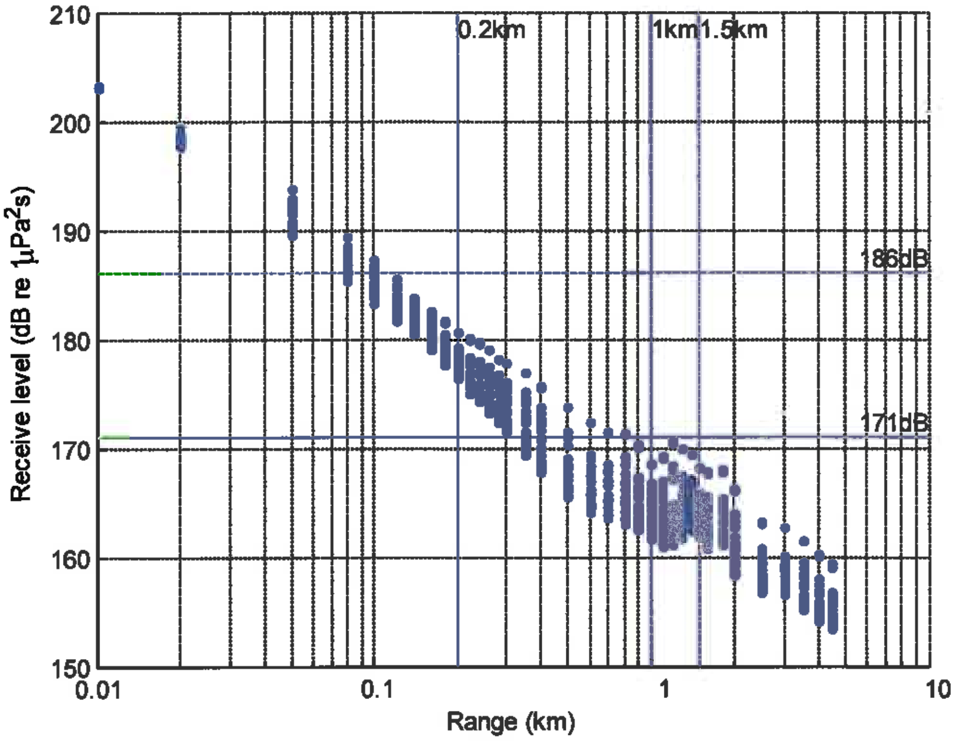


Figure 11. Scatter plot of maximum SEL at the source location S1. Points are maximum predicted received levels at any depth as a function of range, plotted for all azimuths. Vertical magenta lines show mitigation ranges of 200m (solid), 1km (broken), and 1.5km (dash-dot). Horizontal green lines show mitigation thresholds of 171 dB re 1 μPa2.s (solid) and 186 dB re 1 μPa2.s (broken).

Table 2. Maximum sound exposure levels as a function of range from source location S1 in PEP 55793 (Vulcan)

Range	Maximum Sound Exposure Level (dB re 1 μPa^2.s)
200m	180.7
1.0 km	168.5
1.5 km	168.2

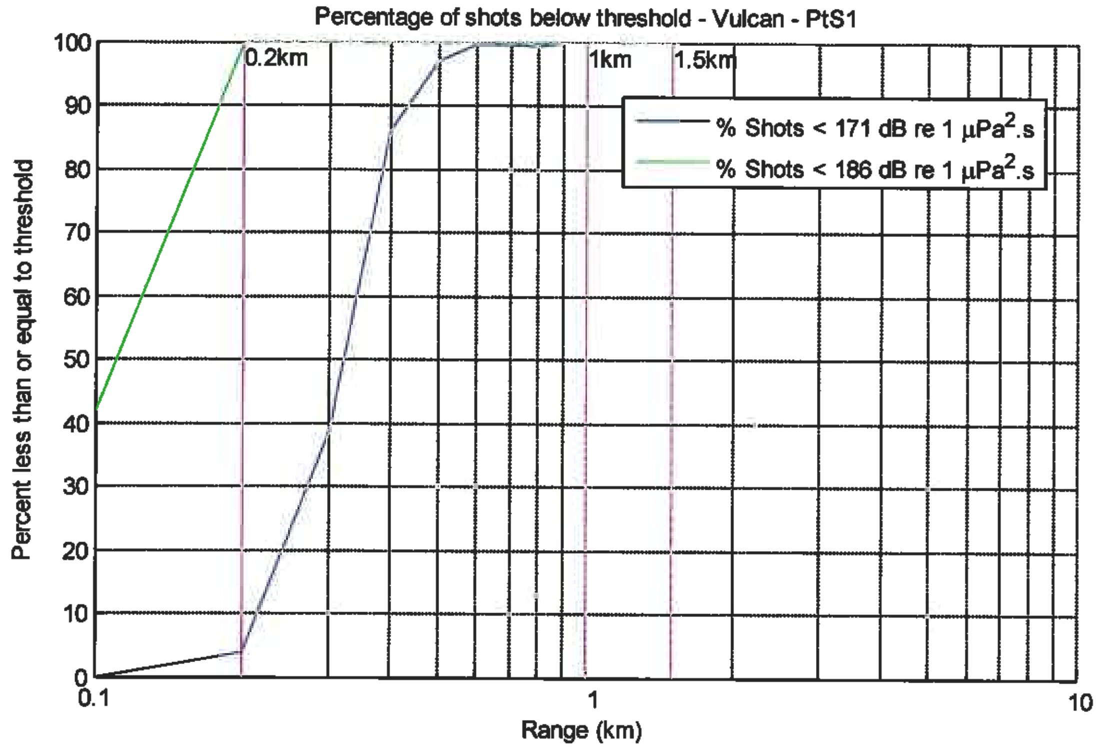


Figure 12. Percentage of shots not exceeding two thresholds as a function of range.

3.1.2 Long Range Modelling Results

Figure 13 shows the geographical distribution of received sound exposure levels out to a maximum range of 350 km from source location S2, which is in 152m of water. Note that in order to illustrate the lower sound levels that occur at longer ranges a different colour scale has been used for these plots than for the short range results given in the previous section. Maximum levels at the outer marine mammal sanctuary boundary for a source at S2 are predicted to be 133 dB re 1 μPa2.s.

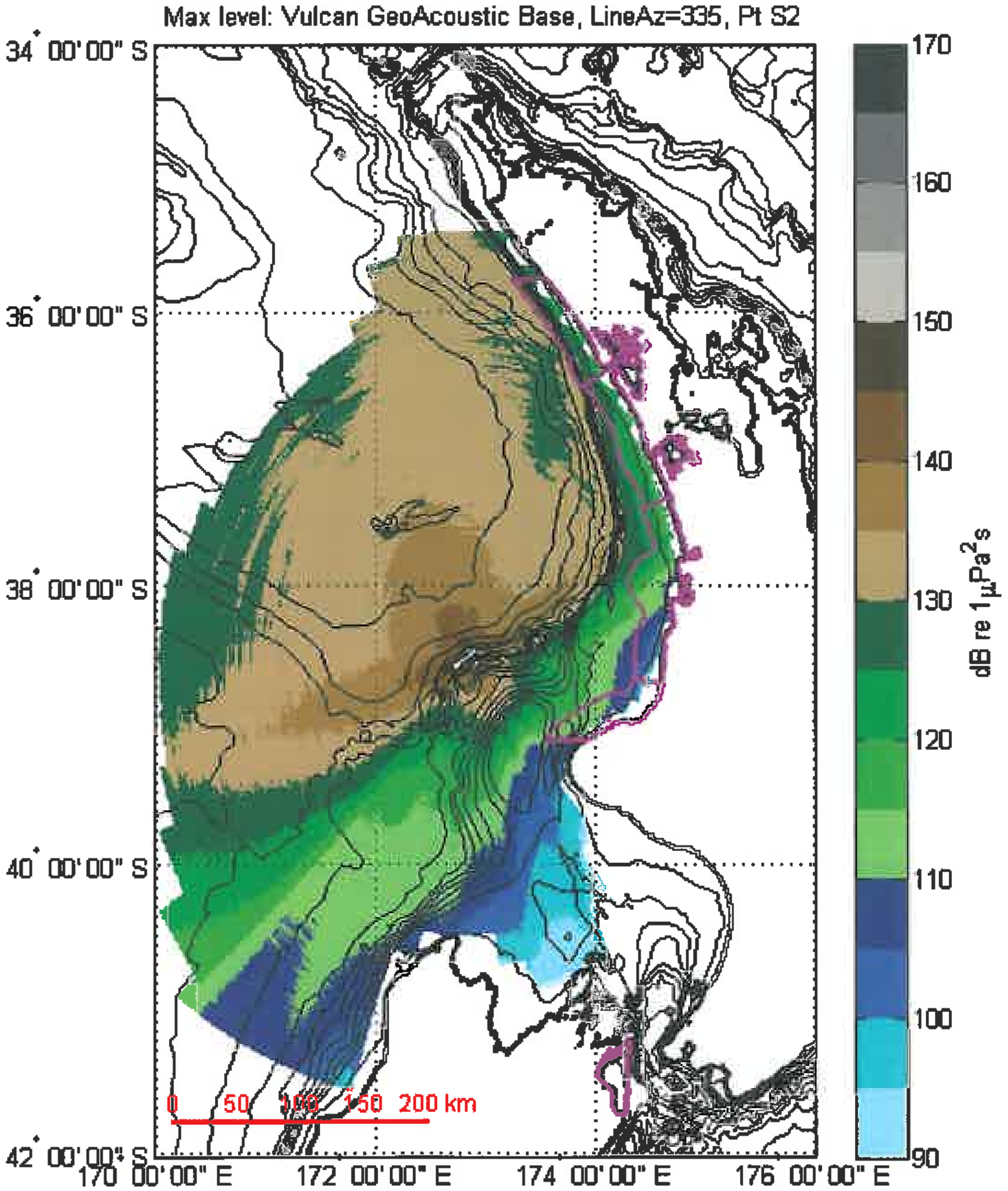


Figure 13. Geographical distribution of modelled sound exposure level for a source at S2 to a maximum range of 350km - spring sound speed profile. (Maximum level at any depth.) Survey line azimuth is 335°T. The boundary of the West Coast North Island Marine Mammal Sanctuary is plotted in magenta.

The strong and complicated directionality apparent in these plots is due to a combination of the directionality of the array, which produces maxima in the in-line and cross-line directions and the effects of bathymetry. The effect of variable bathymetry causes rapid attenuation upslope from the source and enhances propagation downslope. Upslope from the source, rays steepen on each subsequent seabed reflection, increasing the attenuation rate. Conversely in the downslope direction rays are flattened on each subsequent seabed reflection, which reduces the number of seabed interactions and therefore the attenuation rate.

These effects are illustrated in Figure 14 and Figure 15, which show vertical cross-sections through the sound field produced by a source at S2 in the in-line and cross-line directions respectively. The highest levels are transmitted vertically downward into the seabed, however acoustic energy is also trapped in the ocean interior. Offshore from the source the downwardly refracting sound speed profile results in the higher sound levels being found in the lower half of the water column.

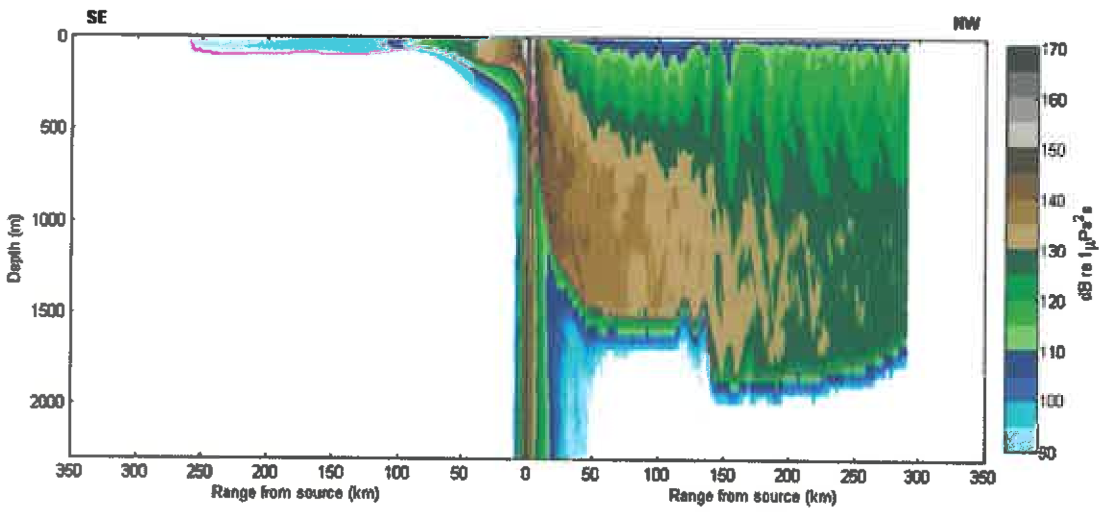


Figure 14. Vertical cross-section through the sound field in the in-line direction (160°T - 340°T), centred on S2, the magenta line outlines seabed.

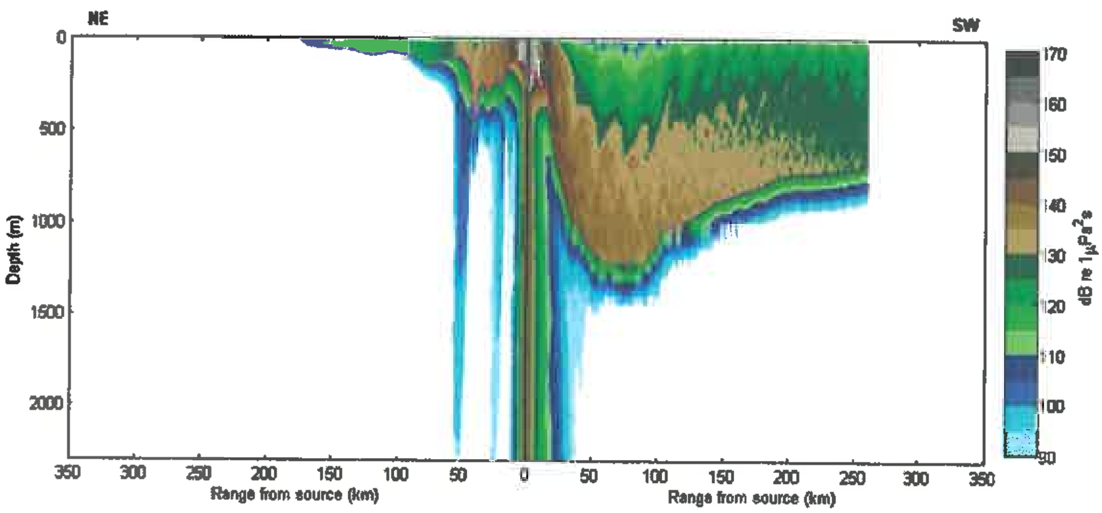


Figure 15. Vertical cross-section through the sound field in the cross-line direction (70°T - 250°T), centred on S2, the magenta line outlines seabed.

4 Conclusions

The modelling method used to produce the short range results is very computationally intensive but accurately deals with both the horizontal and vertical directionality of the seismic source and with variations in water depth. The majority of the sound energy is transmitted downward and is absorbed by the seabed, but some energy is trapped and propagates within the ocean interior.

The short range modelling predicted that the maximum sound exposure levels from the 3460 cubic-inch Bolt Array would be below the threshold of 186 dB re 1 μPa^2.s at 200 m and below 171 dB re 1 μPa^2.s at 1 and 1.5 km.

The long range modelling results were significantly directional due to the combined effects of seismic source directionality and bathymetry. Levels showed moderate attenuation inshore of the source, in the North-East direction, faster attenuation inshore in the South-East direction, and slow attenuation offshore. Maximum levels at the outer boundary of the West Coast North Island Marine Mammal Sanctuary due to a source in 152m water depth, on the eastern side of the survey boundary, were predicted to be 133 dB re 1 μPa^2.s.

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APPENDIX 6

Vulcan 3D MSS Environmental Risk Assessment Summary

Planned Activities	Consequence	Likelihood	Consequence x Likelihood	Risk Ranking
Interference with the fishing community and marine traffic	3	3	9	Medium
Interference with marine archaeology, cultural heritage or submarine infrastructure.	4	4	16	Low
Changes in seabird behaviour.	4	4	16	Low
Introduction of marine pests or invasive species	3	4	12	Low
Interaction with marine mammals	3	4	12	Low
Changes in abundance or behaviour of fish	3	3	9	Medium
Avoidance and startle responses in marine mammals and other marine megafauna	3	3	9	Medium
Disruption to feeding activities	3	3	9	Medium
Disruption of reproductive behaviour in marine mammals	3	3	9	Medium
Interference with acoustic communication signals.	3	3	9	Medium
Physiological effects on marine mammals	3	3	9	Medium
Physiological effects on seabirds	4	4	16	Low
Physiological effects on fish	3	4	12	Low
Physiological effects on larvae	3	4	12	Low
Physiological effects on benthos	3	4	12	Low
Physiological effects on deepwater corals	4	4	16	Low
Physiological effects on cephalopods	3	4	12	Low
Generation of sewage and greywater	4	3	12	Low
Generation of galley waste and garbage	4	3	12	Low
Generation of oily waters	4	4	16	Low
Atmospheric emissions	4	4	16	Low
Cumulative effects from seismic surveys	4	4	16	Low
Unplanned Activities				
Streamer break or loss	4	4	16	Low
Fuel or oil spills	4	4	16	Low
Vessel collision or sinking	4	3	12	Low
Average Values	3.5	3.6	13	
Overall Significance Risk Ranking of Vulcan 3D MSS Programme			13	Low