Central Eyre Iron Project
Environmental Impact Statement

APPENDIX S

MARINE ENVIRONMENTAL NOISE ASSESSMENT

Sonus Pty Ltd
17 Ruthven Avenue
ADELAIDE SA 5000
Phone: +61 (0)8 8231 2100
Facsimile: +61 (0)8 8231 2122
Website: www.sonus.com.au
ABN: 67 882 843 130

Contact: Chris Turnbull
Mobile: +61 (0)417 845 720
E-mail: ct@sonus.com.au

Central Eyre Iron Project

Marine Environmental Noise Assessment

Prepared For

Jacobs
Level 5 33 King William Street, Adelaide SA 5000

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EXECUTIVE SUMMARY

The proposed Port is located west of Cape Hardy on the east coast of the Eyre Peninsula, South Australia, approximately 70 km north of Port Lincoln and 10 km south of Port Neill. The Port is proposed in response to the Iron Road Development requirement to export magnetite ore as part of the Central Eyre Iron Project.

The Marine Environmental Noise Assessment report was commissioned to determine the level of underwater noise during construction and operation of the proposed Port, and address the potential impacts on marine fauna.

There is no directly relevant South Australian legislation or guideline which provides objective criteria for the assessment of underwater noise associated with the proposed Port.

The primary assessment of noise impact to marine mammals has been based on the contemporary United States National Oceanic and Atmospheric Administration *Draft Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammals*. The U*nderwater Piling Noise Guidelines,* prepared by the Department of Planning, Transport and Infrastructure has also been considered. These Guidelines were developed to provide a framework for its staff and contractors to determine practicable mitigation measures that minimise impacts to marine mammals in the vicinity of piling activity within South Australia.

In addition, the assessment considers the noise impact to fish, turtles, cephalopods (cuttlefish) and penguins where objective noise criteria are available.

The underwater noise assessment indicates that separation between some noise sources and specific marine fauna will be required to achieve the noise criteria. Therefore, mitigation measures are recommended to protect marine fauna from significant impact. These measures include procedures to;

- observe specific marine fauna,
- shut-down construction when specific marine fauna are in close proximity, and
- minimise noise wherever practicable.

GLOSSARY

Ambient noise level	The noise level in the presence of all existing noise sources in the environment.
Auditory Weighting Functions	A frequency adjustment that reflects the frequencies of sound that particular species are most sensitive to.
Bathymetry	The depth of the seabed below the mean sea level.
Cetaceans	Marine mammals that include whales, dolphins and porpoises. They share many attributes including having a long tail with two flukes.
Compressional wave attenuation (α_p)	The reduction in noise as sound propagates through water and the seabed. The attenuation increases with frequency and is therefore provided as a decibel reduction per wavelength (dB/λ)
Compressional wavelength (λ_p)	The wavelength of a compressional wave.
Compressional wave speed (c_p)	The speed at which sound travels through water and the seabed. Provided as meters traveled per second (m/s).
Continuous noise	A sound that remains above the ambient noise level during the observation period.
Cumulative sound exposure level (SEL_{cum})	Total noise energy over the exposure period.
Decibel (dB)	Unit used to measure sound based on a logarithmic scale.
Equal Loudness (EQL) Weighting	A frequency adjustment applied to achieve an equal perceived level of noise based on the response of a bottlenose dolphin.
Frequency	The measurement of the number of times a sound wave cycles/oscillates per unit of time represented as Hz. Noise will typically be made up sound in different frequencies. However, there are noise sources that are predominantly high-frequency, such as a whistle, or low-frequencies, such as distant thunder.
Hertz (Hz)	Unit of frequency representing the number of cycles per second.
High-frequency Cetaceans	Typically porpoise species which have a hearing range between 200 Hz and 180 kHz.
Impulsive noise	A sound that is transient and consists of high peak noise levels. Impact pile driving is an example of an impulsive sound source.
Low-frequency Cetaceans	Typically baleen whale species (such as the Southern Right Whale) which have a hearing range between 7 Hz and 30 kHz.
M-Weighting	Generalised frequency adjustment applied to measured noise levels to replicate the frequency response of marine mammals. Typically represented as dB(M).
Mid-frequency Cetaceans	Typically dolphin species which have a hearing range between 150 Hz and 160 kHz.

Non impulsive noise	A sound that is prolonged, continuous or intermittent, which does not have high peak noise levels. Examples of non-impulsive sound sources include marine vessels, vibratory pile driving and drilling.
Peak level	Maximum noise level recorded during the measurement period expressed in dB re 1μPa. The peak level is commonly used as a descriptor for impulsive sources.
Permanent threshold shift (PTS)	A permanent and irreversible increase in the threshold of audibility, i.e. permanent hearing loss.
Phocid pinnipeds	Earless seals which have a hearing range between 75 Hz and 100 kHz
Otariid pinnipeds	Eared sea lions and fur seals which have a hearing range between 100 Hz and 40 kHz
Single strike sound exposure level (SEL_{ss})	The total energy for a single occurrence of an impulsive noise source referenced to a time of 1 second.
Sound exposure level (SEL)	The total energy of an event referenced to a period of 1 second.
Speed of sound	The speed at which sound travels through water and the seabed. Provided as meters traveled per second (m/s).
Temporary threshold shift (TTS)	A temporary and reversible increase in the threshold of audibility, i.e. temporary hearing loss.
Wavelength (λ)	The distance at which the sound wave shape repeats. The wavelength decreases with an increase in the frequency.

ABBREVIATIONS

CEIP	Central Eyre Iron Project
DPTI	Department of Planning, Transport and Infrastructure
EPA	Environment Protection Authority (South Australia)
EP Act	*Environment Protection Act 1993*
IRD	Iron Road Development
MOF	Module offloading facility
MSL	Mean sea level
PSU	Practical salinity units
PTS	Permanent threshold shift
TTS	Temporary threshold shift

TABLE OF CONTENTS

1 INTRODUCTION

Sonus has been engaged by Jacobs to conduct an environmental assessment of the underwater noise associated with a proposed Port, located west of Cape Hardy on the east coast of the Eyre Peninsula, South Australia, approximately 70 km north of Port Lincoln and 10 km south of Port Neill.

The Port is proposed in response to the Iron Road Development (IRD) requirement to export magnetite ore as part of the Central Eyre Iron Project (CEIP).

This environmental noise assessment considers underwater noise from the following:

- breakwater construction;
- impact piling;
- drilling;
- vessel activity, and;
- ship loading activity.

The assessment predicts the underwater noise from the proposed construction and operation activities and determines the potential impacts to marine fauna based on objective criteria established in relevant legislation, guidelines, research papers, and previous studies of a similar nature. Noise mitigation measures are recommended where the predicted noise exceeds the relevant criteria, to ensure the environmental noise impact on marine fauna is minimised.

2 PROJECT DESCRIPTION

The proposed Port is understood to comprise the following components, as shown in Figure 2.1 below:

- Tug Harbour formed by a rock breakwater to accommodate tug, pilot and service boats;
- Module offloading facility adjacent the tug harbour to accommodate heavy lift ships of a length up to 217m;
- Export wharf located at the end of the jetty with independent berthing and mooring dolphins for two bulk iron ore carriers of a length up to 315m. The export wharf will also include ship loaders, which transport the ore onto the ships, and;
- Access jetty between the causeway and export wharf that will have a fully covered conveyor to transport the ore to the export wharf.

Figure 2.1: Locality Plan of the Proposed Port

2.1 Method of Construction

2.1.1 Breakwater

The breakwater is proposed to be constructed from rock and material transported to site with large dump trucks. The rock and material will then be moved and spread with dozers and excavators.

2.1.2 Other areas

The jetty and wharf structures are proposed to be supported by piles that have been driven into and supported by the medium to high strength rock layers of the seabed using piling methods.

It is understood that the piling process will comprise:

- main piles driven to refusal into the seabed using impact piling methods;
- a socket drilled into the rock below each of the main piles;
- pin piles/anchors grouted in the socket (drilled in the rock) at one end, and in the base of the main pile at the other end.

The piles proposed for each area are detailed in the Table 2.1 below:

Table 2.1: Pile type and size for each area

Area	Main pile	Pin pile/Anchors
Module offloading facility (wharf)	800mm diameter tubular steel with a 20mm thick wall	700mm diameter tubular steel filled with concrete
Tug Jetty	700mm diameter tubular steel with a 20mm thick wall	508mm diameter tubular steel filled with concrete
Export Wharf	1200mm diameter tubular steel with a 25mm thick wall	200mm diameter steel bars
Wharf Dolphins (used to absorb the berthing energy of vessels)	1500mm diameter tubular steel with a 25mm thick wall	200mm diameter steel bars
Access jetty	1200mm diameter tubular steel with a 25mm thick wall	200mm diameter steel bars

2.1.3 Construction Noise Sources

The underwater noise sources associated with the construction of the Port will comprise:

- breakwater construction;
- impact piling;
- drilling; and
- vessels.

2.2 Operation

The underwater noise sources associated with the operation of the Port will comprise:

- conveyors which run the full length of the jetty to transport the ore to the export wharf (that is, the transfer of noise generated terrestrially to underwater);
- ship loaders which transport the ore onto the ships, (that is, the transfer of noise generated terrestrially to underwater) and;
- activity from the following vessels:
    - bulk iron ore carriers;
    - heavy lift ships;
    - tug boats;
    - pilot boats; and
    - service boats.

3 LEGISLATION AND GUIDELINES

There is no directly applicable South Australian legislation that provides objective criteria to assess underwater noise associated with the construction and operation of a port. Notwithstanding, the available documentation is summarised below.

3.1 Environment Protection and Biodiversity Conservation Act 1999

The *Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act) provides protection of the environment for matters of national environmental significance, which includes protecting listed migratory species and threatened species from significant impact such as from excessive underwater noise.

The EPBC Act does not provide criteria for the assessment of underwater noise. However, the EPBC Act Policy Statement 2.1 "Interaction between offshore seismic exploration and whales" (the EPBC Policy) provides an objective framework that minimises the biological consequences associated with seismic survey noise sources on whales. The EPBC Policy does not specifically apply to this assessment, however, it is noted that the approach of the EPBC Policy is to provide precautions to prevent temporary or permanent hearing threshold shift for whales.

3.2 National Parks and Wildlife Act 1972

The *National Parks and Wildlife Act 1972* states that a person must not interfere with a protected animal, or undertake or continue an act or activity that is, or is likely to be, detrimental to the welfare of a protected animal. It is noted that the species listed in the EPBC Act include the "protected animals" of the *National Parks and Wildlife Act 1972*.

3.3 Underwater Piling Noise Guidelines

The Department of Planning, Transport and Infrastructure (DPTI) has prepared *Underwater Piling Noise Guidelines* (DPTI, 2012) to provide a framework for its staff and contractors to determine practicable mitigation measure that minimise impacts to marine mammals in the vicinity of piling activity. Precaution zones are defined for both impulsive (impact piling) and continuous noise sources based on calculations of sound levels to prevent temporary or permanent hearing threshold shift to marine mammals.

4 POTENTIAL IMPACTS ON MARINE SPECIES

When considering the impact that noise has on the marine fauna, consideration is given to a range of factors such as the sensitivity of the species to noise, the distance between the noise source and fauna and the duration of exposure to the noise.

A range of studies have been conducted to determine the response of marine fauna to sound. The response or impacts associated with sound are broadly categorised as follows.

4.1 Audibility

The sound is at a level that can be perceived (this will depend on the ambient noise) by the marine fauna.

4.2 Behavioural Impact

Behavioural responses to noise can include changes in social interaction, feeding, movement, separation distance between mother and infant, and temporary or permanent habitat abandonment.

4.3 Auditory Threshold Shift

Exposure to intense noise levels for a sufficient duration can result in a noise induced threshold shift (hearing loss) of an animal's auditory system.

The magnitude of the threshold shift will typically decrease over time when the noise has stopped. Where the threshold shift decreases to zero (the hearing returns to the pre-exposure value), it is considered to be a temporary threshold shift (TTS) and does not represent physical injury or permanent hearing loss.

Where the threshold shift does not decrease to zero (the hearing does not return to the pre-exposure value), it is called a permanent threshold shift (PTS). This represents an injury to the auditory system and hearing loss.

4.4 Trauma or Fatality

Exposure to extremely high noise levels can cause physical trauma. Fauna most likely to be at risk of trauma or fatality are small fauna with gas filled organs such as swim bladders in fish.

4.5 Summary of Potential Impacts on Marine Fauna

The impacts of noise on marine fauna will vary depending on a range of factors, including the type of animal, characteristics of the noise source, seabed composition, bathymetry and sound speed profile in the water. Notwithstanding the above, Figure 4.1 provides an indicative summary of the potential physiological impact zones (indicated by the shaded areas) relative to the noise source, which is located in the centre.

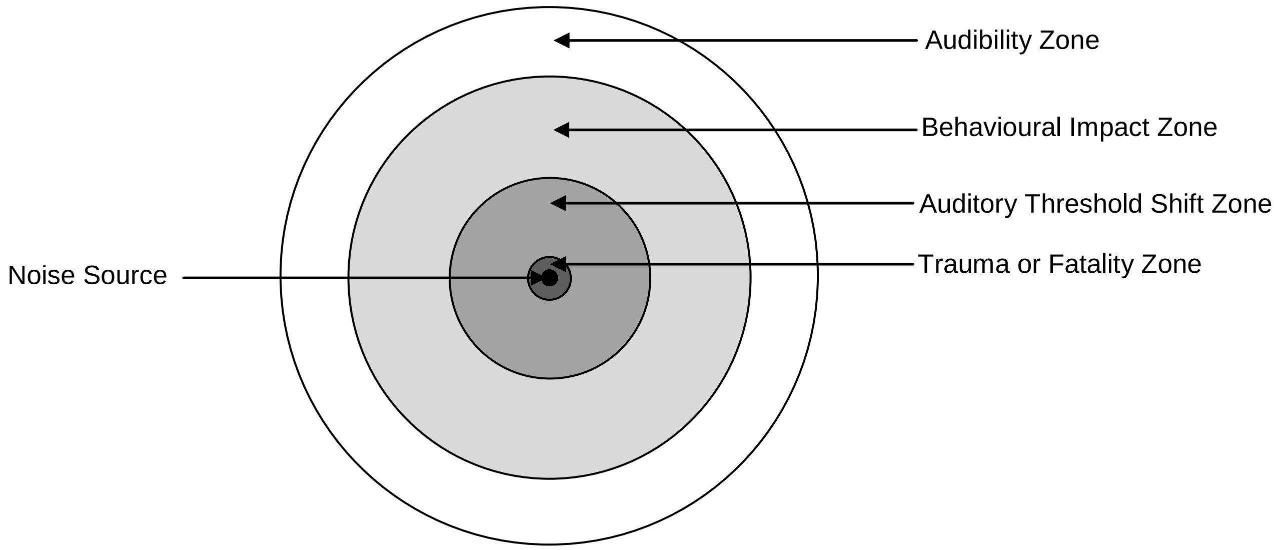

Figure 4.1: Potential physiological impact zones

5 UNDERWATER NOISE DESCRIPTORS

The noise descriptors used in this report, and for underwater acoustics in general, include the following:

- *Sound exposure level* (SEL), is the total energy of an event referenced to a period of 1 second. The SEL therefore accounts for both the noise level and duration of the event. A SEL can be used to represent a range of different types of noise sources and is expressed in dB with a reference pressure of 1 μPa^2•s. Variations of the SEL include:
    - the *single strike sound exposure level* (SEL_{ss}), which is the total energy of a single occurrence of an impulsive noise source, and;
    - the *cumulative sound exposure level* (SEL_{cum}), which is the total energy of the entire period of exposure.
- *Peak level*, which is the maximum instantaneous noise level for an event. A peak level is typically used to represent impulsive noise sources and is expressed in dB with a reference pressure of 1 μPa.

6 ASSESSMENT CRITERIA

The noise assessment criteria have been determined based on a range of studies, which assess the effects for Cetaceans (whales, dolphins and porpoises), Pinnipeds (eared sea lions and fur seals), fish (with and without swim bladders), turtles, Cephalopods (cuttlefish) and penguins.

6.1 Marine Mammals

A number of peer reviewed studies have assessed the impact of noise on marine mammals. These studies are typically based on a limited number of individuals within a species. Therefore, there are limitations regarding the recommendations of these studies. However, to provide the most contemporary information, reference is made to the recommendations for marine mammals of the United States National Oceanic and Atmospheric Administration (NOAA), *Draft Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammals* (NOAA, 2013).

Noise that is considered to be an auditory injury equates to the onset of PTS (NOAA, 2013). The level of noise at the onset of PTS changes for different species and types of noise as provided in Table 6.1 below, with the threshold level being reached if either the peak level or SEL_{cum}, is exceeded (NOAA, 2013).

Table 6.1: Marine mammal noise criteria

Species	Hearing Range	PTS onset from underwater noise (Received Level)	
		Impulsive Noise	***Non-impulsive Noise (includes continuous noise)***
Low-frequency Cetaceans (Baleen whales)	between 7 Hz and 30 kHz	*Peak level*: 230 dB_{peak} SEL_{cum}: 187 dB	*Peak level*: 230 dB_{peak} SEL_{cum}: 198 dB
Mid-frequency Cetaceans (Dolphins)	between 150 Hz and 160 kHz	*Peak level*: 230 dB_{peak} SEL_{cum}: 187 dB	*Peak level*: 230 dB_{peak} SEL_{cum}: 198 dB
High-frequency Cetaceans (Porpoise)	between 200 Hz to 180 kHz	*Peak level*: 201 dB_{peak} SEL_{cum}: 161 dB	*Peak level*: 201 dB_{peak} SEL_{cum}: 180 dB
Phocid Pinnipeds (Earless Seals)	between 75 Hz and 100 kHz	*Peak level*: 235 dB_{peak} SEL_{cum}: 192 dB	*Peak level*: 235 dB_{peak} SEL_{cum}: 197 dB
Otariid Pinnipeds (Eared sea lions and Fur seals)	between 100 Hz and 40 kHz	*Peak level*: 235 dB_{peak} SEL_{cum}: 215 dB	*Peak level*: 235 dB_{peak} SEL_{cum}: 220 dB

The SEL_{cum} accounts for both source level and duration of exposure. In order to use the SEL_{cum}, an exposure time must be assumed. Generally, fauna will be continuously moving and avoid an area of high noise level. To account for typical marine fauna movement and avoidance, the safe exposure level will be achieved where fauna do not get closer than the point where the SEL_{cum} is equivalent to one hour of exposure (NOAA, 2013).

In addition, the ability to hear sounds varies for each species of mammal. The above SEL_{cum} values are therefore based on an "auditory weighting function" which reflects the frequencies that the species are most sensitive to. The auditory weighting functions used are provided in Appendix A and are based on the most conservative combination of the M-Weighting and the Equal Loudness Weightings (NOAA, 2013). It is noted that the peak levels are un-weighted.

6.1.1 DPTI 2012

Given that DPTI 2012 would be used where the DPTI is assessing the noise associated with piling in South Australian waters, a comparison has been made between NOAA 2013 and DPTI 2012.

In order to make the comparison, the descriptors used in NOAA 2013 need to be converted to the descriptors used by DPTI 2012. Therefore, the comparison in the following table details the impact piling criteria for single strike sound exposure level (SEL_{ss}). These have been based on the assumption that 1800 piling impacts may occur in any hour.

Table 6.2: SEL_{ss} comparison

Species	SEL_{ss} criteria (dB)	
	NOAA 2013	DPTI 2012
Low-frequency Cetaceans (Baleen whales)	154	150
Mid-frequency Cetaceans (Dolphins)	154	150
High-frequency Cetaceans (Porpoise)	128	150
Phocid Pinnipeds (Earless Seals)	159	150
Otariid Pinnipeds (Eared sea lions and fur seals)	182	

The above table indicates that:

- the NOAA 2013 criteria for low-frequency and mid-frequency Cetaceans are marginally higher (less onerous) than the DPTI 2012 criteria;
- the NOAA 2013 criteria for high-frequency Cetaceans are more onerous than DPTI 2012 criteria, and;
- the NOAA 2013 criteria for Phocid Pinnipeds and Otariid Pinnipeds are higher (less onerous) than the DPTI 2012 criteria.

The differences in the criteria are due to the NOAA 2013 providing a more finite approach which is specific to the underwater hearing for different families of Cetaceans and Pinnipeds, rather than general criteria for each species.

Notwithstanding the difference in the criteria, the recommended mitigation measures (detailed in Chapter 9) provide shutdown zones that are conservatively determined based on the more onerous DPTI 2012 criteria for Cetaceans and Pinnipeds.

6.2 Fish

There is limited information known about the effects of noise on fish. The studies that have been conducted to date only consider a tiny fraction of the species in existence and in environments which typically do not represent wild fish in their natural habitats (Popper & Hastings 2009).

Fish are able to detect sounds, with the majority of species classified as "hearing generalists" that have a narrow hearing bandwidth. A small number of fish species are classified as "hearing specialists" and have a greater hearing bandwidth and sensitivity due to a coupling between gas filled organs (such as the swim bladder) and inner ear (Hastings & Popper 2005). The hearing range for the different types of fish is provided below:

Table 6.3: Fish hearing range

Fish hearing category	Hearing Range
Hearing generalist	Between 50 Hz and 500-1500 Hz
Hearing specialist	Between 50 Hz and 3-100 kHz

In addition, the sensitivity to noise also depends on the mass of the fish. It has been found that tissue damage from noise will increase as the mass of the fish decreases (Carlson, Hastings and Popper 2007).

As the effect of noise on a fish is dependent on the size and biology of individual fish species, the following criteria determined by Stadler and Woodbury (2009) provides conservative criteria for fish, which are 2 grams or larger.

Table 6.4: Fish noise criteria

Species	***Impulsive Noise***
Fish	*Peak level*: 206 dB_{peak} SEL_{cum}: 187 dB

It is noted that the above peak and sound exposure levels values are un-weighted.

The SEL_{cum} accounts for both source level and duration of exposure. In order to use the SEL_{cum}, an exposure time must be assumed. Generally, fish will be continuously moving and avoid an area of high noise levels. However, to account for exposure, Stadler and Woodbury (2009) recommend that the safe exposure level will be achieved where fauna do not get closer than the point where the SEL_{cum} is equivalent to a full day of exposure.

6.3 Turtles

There is limited information known about the effects of underwater noise on turtles. Independent Studies by Ridgway and Bartol (cited in Bartol 2008) confirm that turtles can hear and that the hearing range of turtles is approximately between 200Hz and 1000Hz.

There are no recommended noise criteria for turtles. However based on behavioural response studies by:

- O'Hara & Wilcox (cited in Bartol 2008) turtles were deterred by noise and would not typically get closer than 30m from a noise source of 220dB at 1m.
- Moein (cited in Bartol 2008) found that turtles were initially deterred by noise ranging from 175 to 179dB at 1m. However, after exposure they habituated to the noise.

Based on the hearing range of turtles and the lack of specific objective criteria, the low-frequency Cetaceans noise criteria have been applied.

6.4 Penguins

There is very limited information known about the effects of underwater noise on penguins. Studies indicate that the hearing range of penguins is best between 2000Hz and 5000Hz in air and is likely to reduce to frequencies below 4000Hz in water (Dooling & Therrien, 2012). Based on the hearing range, and the lack of specific objective criteria, the low-frequency Cetaceans noise criteria have also been applied to penguins.

6.5 Cephalopods

There is very limited information known about the effects of underwater noise on Cephalopods (cuttlefish). Studies indicate that Cephalopods can perceive low-frequencies. It is not known if Cephalopods can "hear" or if they are sensitive to particle velocity (Mooney et al, 2012). Notwithstanding, it has been shown that they can perceive sounds with frequencies of up to 1.5kHz, but as they do not have any gas filled bladders there is no possibility for sound amplification and therefore have a hearing capacity comparable to fish without swim bladders (Hu et al, 2009). Based on the above, the noise criteria for fish have been conservatively applied to Cephalopods.

6.6 Summary of objective criteria

Based on the above and the understanding that the relevant species in the vicinity of the proposed Port include low-frequency Cetaceans, mid-frequency Cetaceans, Otariid Pinnipeds and fish, the available underwater noise criteria for these species are provided in the Table 6.3 below.

Table 6.3: Summary of relevant limits

Species	**Criteria**	
	Impulsive Noise	***Non-impulsive Noise (includes continuous noise)***
Low-frequency Cetaceans (Baleen whales), Penguins and Turtles	*Peak level*: 230 dB_{peak} SEL_{cum}: 187 dB	*Peak level*: 230 dB_{peak} SEL_{cum}: 198 dB
Mid-frequency Cetaceans (Dolphins)	*Peak level*: 230 dB_{peak} SEL_{cum}: 187 dB	*Peak level*: 230 dB_{peak} SEL_{cum}: 198 dB
Otariid Pinnipeds (Eared sea lions and fur seals)	*Peak level*: 235 dB_{peak} SEL_{cum}: 215 dB	*Peak level*: 235 dB_{peak} SEL_{cum}: 220 dB
Fish and Cephalopods (Cuttlefish)	*Peak level*: 206 dB_{peak} SEL_{cum}: 187 dB	

7 NOISE PREDICTION MODEL

7.1 Noise Propagation Model - RAMGeo

Noise predictions were conducted using the RAMGeo acoustic model in the AcTUP acoustic "toolbox". The RAMGeo acoustic model considers the bathymetry, profile of speed of sound in water and interaction with the different materials in the seabed.

Underwater acoustic noise models calculate the transmission loss as a function of distance and frequency for a single direction. The overall noise at a distance is then calculated by subtracting the transmission loss from each of the noise sources.

Noise zones (for the purposes of determining noise reduction control measures) have been generated by calculating the noise in a range of directions around the noise source. Typically, predictions in eight directions provide enough information to generate an accurate indication of zones around the noise sources.

7.2 Noise Propagation Model Parameters

7.2.1 Bathymetry

The bathymetry in the vicinity of the proposed Port Marine facilities has been determined by a survey carried out by Hydro Survey Australia for the environmental approval of the proposed Port Marine facilities. For areas beyond the survey area, approximations of the bathymetry have been made.

7.2.2 Speed of sound in water

The speed of sound in the water is related to the pressure, salinity and temperature of the water. As these properties are relatively consistent in shallow water (depths down to 200m) (Jensen et al, 2011), a constant speed of sound of 1528m/s has been assumed for this assessment based on the mean temperature of 21.5°C and salinity of 37PSU measured near the proposed site using a Acoustic Doppler Current Profiler (Grant, Greer & Frazerhurst, 2012).

7.2.3 Geotechnical information

Geotechnical information has been collected by the project team in the vicinity of the proposed jetty. The seabed layers and the average depth of each layer are detailed in Table 7.1 below:

Table 7.1: Seabed layers

Layer	Description	Average Depth of Soil/Rock layer (m)
1	Water	variable
2	Superficial sediment consists of firm clay or medium dense sand	9.4
3	Medium to high strength rock	6.3
4	Very high to extremely high strength rock	>200

When assessing noise propagation in shallow-water where the speed of sound is nearly constant over depth, the propagation is almost exclusively dependent on the integration with the seabed (i.e. the thickness and properties of the seabed layers, down to the underlying rock).

As the geotechnical information is limited at this stage of the development, a sensitivity analysis has been conducted to determine the transmission loss as a function of distance for different seabed assumptions. The following seabed properties considered for each layer are shown in Table 7.2.

Table 7.2: Seabed Materials used in Sensitivity Analysis

Layer	Material	Compressional wave speed, c_p, (m/s)	Density, ρ, (kg/m^3)	Compressional wave attenuation, α_p, (dB/λ_p)
1	Water	1528	1026	0
2	Firm Clay	1528	1539	0.2
	Medium dense sand	1681	1949	0.8
3	Medium strength rock	1986	2155	0.4
	High strength rock	2445	2257	0.2
4	Very high strength rock	3056	2462	0.1
	Extremely high strength rock	5348	2770	0.1

The sensitivity analysis considers different scenarios to determine the difference in noise levels predicted for different seabed materials. The seabed materials used in each of the eight scenarios are detailed in Table 7.3 below.

Table 7.3: Sensitivity Analysis Scenarios

Layer	Material	Scenario							
		1	2	3	4	5	6	7	8
1	Water	✓	✓	✓	✓	✓	✓	✓	✓
2	Firm Clay	✓		✓	✓		✓		
	Medium dense sand		✓			✓		✓	✓
3	Medium strength rock	✓	✓		✓			✓	
	High strength rock			✓		✓	✓		✓
4	Very high strength rock	✓	✓	✓		✓			
	Extremely high strength rock				✓		✓	✓	✓

The transmission loss as a function of distance has been calculated for each of the above scenarios and is shown in Figure 7.1 below based on the noise from impact piling. It is noted that the values are un-weighted and other variables such as bathymetry are constant for the eight scenarios.

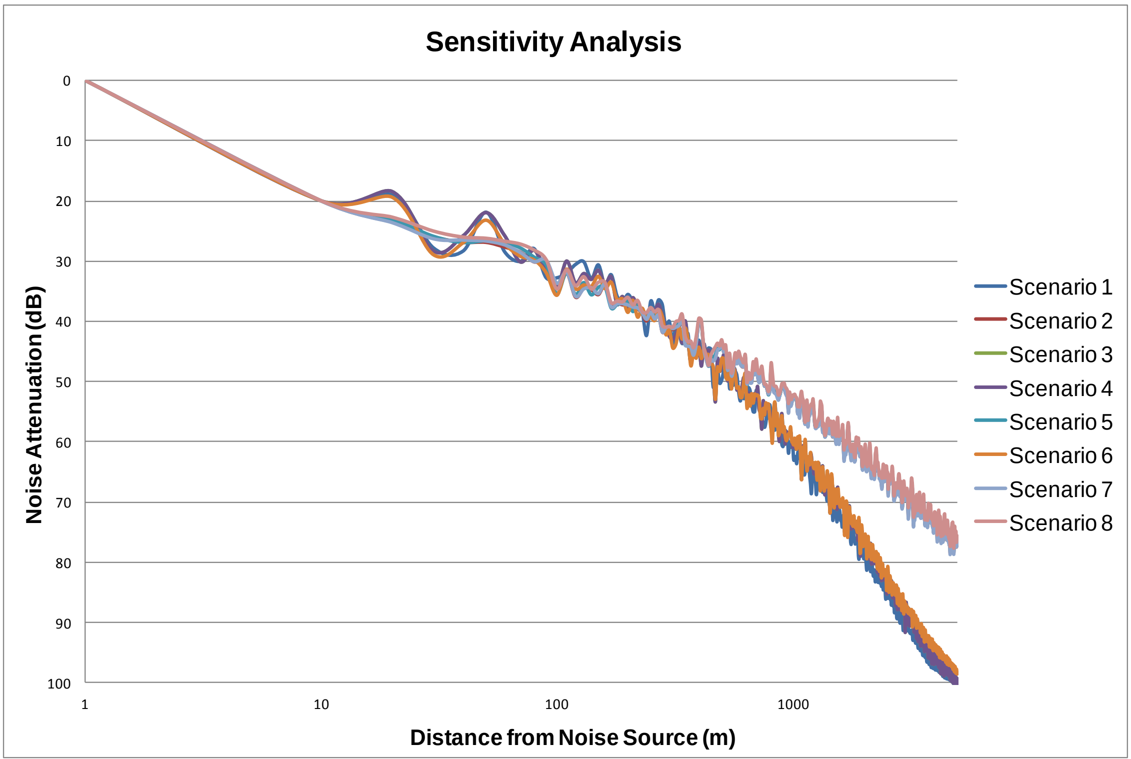

Figure 7.1: Sensitivity Analysis

The results of the sensitivity analysis indicate that the difference in predicted underwater noise level occurs at distances greater than 500m. Based on comparisons between predicted noise levels, Scenario 8 is considered to typically provide the lowest level of sound attenuation and therefore has been used to represent a conservative representation of the reduction of noise in shallow water.

7.2.4 Summary of Underwater Noise Propagation Model Parameters

The material properties used for the underwater noise modelling of the proposed Port are based on the conservative Scenario 8 above and are summarised in Table 7.4 below.

Table 7.4: Material properties

Layer	Depth of layer (m)	Properties
Water	Variable	c_p = 1528 m/s ρ = 1026 kg/m^3
Medium dense sand	9.4	c_p = 1681 m/s ρ = 1949 kg/m^3 α_p = 0.8 dB/λ_p
Medium strength rock	6.3	c_p = 2445 m/s ρ = 2257 kg/m^3 α_p = 0.2 dB/λ_p
Very high strength rock	∞	c_p = 5348 m/s ρ = 2770 kg/m^3 α_p = 0.1 dB/λ_p

7.3 Sound Levels

7.3.1 Construction Noise

The underwater noise associated with construction activity will vary significantly depending on the type of equipment, how the equipment is operated, and the composition of the sea bed. The typical range of noise created from impact piling is detailed in the table below:

Table 7.4: Noise range from piling

Noise source	Noise levels for different Noise Descriptors	
	Peak (dB re 1 µPa)	**SEL (dB)**
Impact Piling	190-250 at 1m	170-225 at 1m

Based on the size of the proposed piles, a noise level has been assumed and is provided in the tables below.

Table 7.5: Noise at 1m from impact piling

Noise Source	SEL_{ss} in each Octave Band Centre Frequency (dB)												Total (dB)	Peak Level (dB)
	8Hz	16Hz	31.5Hz	63Hz	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz	8kHz	16kHz		
Impact piling	186	180	150	164	177	186	181	186	180	176	164	168	191	230

Table 7.6: Noise at 1m from drilling

Noise Source	SEL in each Octave Band Centre Frequency (dB)												Total (dB)
	8Hz	16Hz	31.5Hz	63Hz	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz	8kHz	16kHz	
Drilling	165	169	157	160	156	158	155	154	157	153	139	142	171

The following assumptions have been made for the assessment of piling and drilling:

- 1800 piling impacts may occur in any hour;
- 3600 piling impacts may occur in a day;
- Drilling may occur for 30 minutes in any hour and one hour per day;
- The total combined amount of vessel activity in the vicinity of the port may be up to 4 hours of operation a day.

It is noted that the predicted noise levels are based on exposure over a period of up to one day. Therefore, the noise predictions are not dependent on the total construction period or the total number of piles throughout the overall construction period.

In addition, the underwater noise from the rock dumping associated with breakwater construction is considered to be at a relatively low level and does not have characteristics that would result in physiological damage. Given the low levels of underwater noise associated with rock dumping there is limited literature on the measured noise levels. Based on the above, noise predictions have not been made in assessing the noise from rock dumping, rather the measures have been recommended to minimise any localised impacts to marine fauna.

7.3.2 Operational Noise

The underwater noise associated with operational activity will vary significantly depending on the type of vessels used and how they are operated. The range of noise from boats is detailed in the table below:

Table 7.7: Noise range of boats

Noise source	SEL (dB)
Boats	110-195

Based on the size of the proposed bulk carrier, the level of underwater noise has been estimated and is provided in the table below. This level is considered to be at the upper end of the range and has been conservatively used for the assessment of all vessels in the harbour and wharf.

Table 7.8: Noise from boats at 1m

Noise Source	SEL in each Octave Band Centre Frequency (dB)												Total (dB)
	8Hz	16Hz	31.5Hz	63Hz	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz	8kHz	16kHz	
Bulk Carrier	164	179	184	188	186	184	181	179	178	176	170	165	193

In addition, there will be some operational noise from the ore conveyor, ship loaders and equipment located on the jetty and wharf. As these noise sources do not have any direct connection to the water there will be limited noise propagation into the water from these sources. It is possible that some structure borne vibration energy could travel through the jetty/wharf and couple back into the water column. However, the structure borne propagation would only comprise low levels of very low frequency sound that would be quickly attenuated to levels below the ambient underwater noise level. Therefore this noise would be unlikely to impact marine fauna.

7.4 Noise Source Locations

Noise predictions have been made for the activities shown at the discrete locations detailed in the Figure 7.2 below.

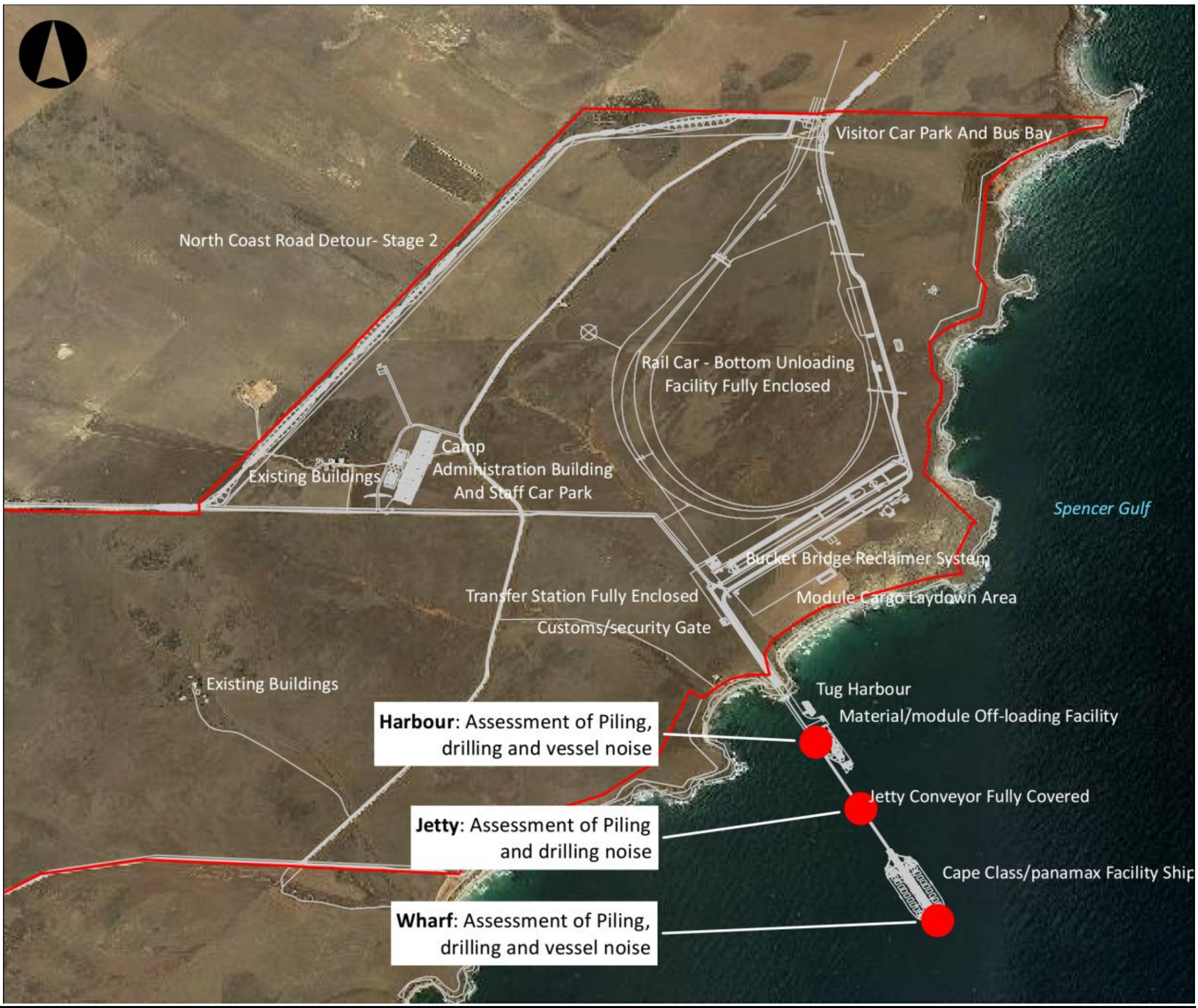

Figure 7.2: Noise Source Locations

8 RESULTS

The underwater noise has been predicted, using the inputs and assumptions provided above, for a range of distances in eight directions from each noise source and at each source location.

The noise predictions for the worst case (i.e. highest noise level) direction at each of the three source locations and the relevant criteria (as summarised in table 6.3) are provided in graphs for impact piling (Appendix B), drilling (Appendix C) and vessels (Appendix D).

It is noted that:

- The impact piling sound exposure graphs for low-frequency Cetaceans, mid-frequency Cetaceans and Otariid Pinnipeds detail:
  - the SEL_{cum} noise predictions and criteria for comparison with NOAA 2013, and;
  - the SEL_{ss} noise predictions and criteria for comparison with DPTI 2012;
- Although the calculations account for the sound exposure from each individual activity, the cumulative effects of multiple noise sources will not change the outcome of the assessment. This is because piling dominates the overall noise levels and adding noise from other sources makes no significant difference, and;
- The SEL predictions for each species are provided as separate graphs in the appendices as the noise source weighting and criteria vary between species.

8.1 Summary of Results

The separation distances can be determined from the graphs in Appendices B, C and D based on the point on the graph where the predicted noise levels intersect with relevant criteria. The distances are summarised in the table below.

Table 8.1: Separation distance required to achieve criteria

Noise Source	**Separation distance required to achieve the criteria (m)**										
	Low-frequency Cetaceans			**Mid-frequency Cetaceans**			**Otariid Pinnipeds**			**Fish**	
	***SEL_{cum}* (NOAA 2013)**	***SEL_{ss}* (DPTI 2012)**	***Peak level***	***SEL_{cum}* (NOAA 2013)**	***SEL_{ss}* (DPTI 2012)**	***Peak level***	***SEL_{cum}* (NOAA 2013)**	***SEL_{ss}* (DPTI 2012)**	***Peak level***	***SEL_{cum}***	***Peak level***
Impact Piling	240	470	0	<10	30	0	<10	470	0	450	30
Drilling	0	-	-	0	-	-	0	-	-	10	-
Vessels	10	-	-	0	-	-	0	-	-	80	-

9 RECOMMENDED MITIGATION MEASURES

The underwater noise predictions indicate that separation between some noise sources and specific marine fauna will be required to achieve the noise criteria. Therefore, mitigation measures (such as soft starts when impact piling) are recommended to minimise any impact to marine fauna by minimising noise and reducing the likelihood of fauna being exposed to levels above the relevant criteria.

The following mitigation measures are proposed:

- The movement of marine mammals, turtles and penguins should be observed within 1.5km from the piling activity (the observation zone) and where these fauna come within 500m (the shutdown zone), piling should be shut-down as soon as practicable (noting that the peak level is acceptable but measures need to be taken to avoid cumulative impacts). A shutdown zone of 300m will achieve the NOAA 2013 noise criteria. Notwithstanding, a 500m shutdown zone is recommended to also ensure compliance with the DPTI 2012 noise criteria for Cetaceans and Pinnipeds.
- Standard management and mitigation procedures should be implemented. The management and mitigation procedures should include:
  - Avoid conducting piling activities during sensitive times such as when marine mammals are likely to be breeding, calving, or feeding;
  - Use low noise piling methods, such as vibro-driving, instead of impact piling methods where practicable;
  - Ensure that a suitably qualified person is available during piling activities to conduct the following standard operational procedures:
    - *Pre-start procedure* – The presence of marine mammals, turtles and penguins should be visually monitored by a suitably trained crew member for at least 30 minutes before the commencement of the soft start procedure.
    - *Soft start procedure* – If marine mammals, turtles or penguins have not been sighted within, or are unlikely to enter, the shut down zone during the pre-start procedure, the soft start procedure may commence in which the piling impact energy is gradually increased over a 10 minute time period. Visual monitoring should continue during the soft start procedure. Where visibility is poor or when it is dark, the soft start procedure should be postponed until visual inspections of the safety zones can be made.

- *Normal operation procedure -* If marine mammals, turtles or penguins have not been sighted within or are unlikely to enter the shut down or observation zone during the soft start procedure, piling may be increased to full impact energy. Visual monitoring should continue during normal operation. The soft start procedure should be repeated where piling is stopped for more than 30 minutes.
- *Stand-by operations procedure - If a marine mammal, turtle or a penguin is sighted within the observation zone during the soft start or normal operation procedures, the operator of the piling rig should be placed on stand-by to shut-down the piling rig. Visual monitoring should continue during stand-by operation.*
- *Shut-down procedure – If a marine mammal, turtle or a penguin is sighted within or about to enter the shut-down zone, the piling activity should be stopped. Visual monitoring should continue and where these marine fauna are observed to move out of the shut-down zone, or it has not been seen for 30 minutes, the piling activities should recommence using the soft start procedure.*

Examples of the observation and shut-down zones for impact piling are provided in the appendices for each of the noise prediction locations as follows:

- the harbour is shown as Appendix E;
- the jetty is shown as Appendix F, and;
- the wharf is shown as Appendix G.

The contractor conducting the piling activities should record sightings of marine mammals, penguins and turtles as well as all actions taken to minimise impacts. The record should include the location, date, start and completion time, details on the trained crew members conducting the visual observations, times when there is poor visibility, and the time and distance of any sightings.

It is noted that the above measures are consistent with the recommendations of DPTI 2012.

In addition, the construction of the breakwater should begin onshore and advance into the sea. This will allow fauna to leave the area and reduce the impact to marine fauna.

10 CONCLUSION

An underwater noise assessment has been made of the construction and operation of the proposed Port. The assessment considers the noise from:

- breakwater construction;
- impact piling;
- drilling;
- vessel activity, and;
- ship loading activity.

The assessment of the construction and operational noise from the proposed Port predicts the underwater noise and determines the potential impacts to marine fauna based on objective criteria established in relevant legislation, guidelines, research papers, and previous studies of a similar nature.

The underwater noise assessment indicates that separation between some noise sources and specific marine fauna will be required to achieve the noise criteria. Therefore, mitigation measures are recommended to protect marine fauna from significant impact. These measures include procedures to:

- observe specific marine fauna;
- shut-down construction when specific marine fauna are in close proximity, and;
- minimise noise wherever practicable.

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APPENDIX A: AUDITORY WEIGHTINGS ADJUSTMENT

Frequency	Species				
	Low-frequency Cetaceans that (Baleen whales)	Mid-frequency Cetaceans (Dolphins)	High-frequency Cetaceans (Porpoise)	Phocid Pinnipeds (Earless Seals)	Otariid Pinnipeds (Eared sea lions and fur seals)
1	-50.5	-103.5	-111.4	-75.0	-80.0
1.25	-46.7	-99.7	-107.6	-71.1	-76.1
1.6	-42.6	-95.4	-103.3	-66.8	-71.8
2	-38.9	-91.5	-99.4	-63.0	-68.0
2.5	-35.4	-87.6	-95.5	-59.1	-64.1
3.15	-32.0	-83.6	-91.5	-55.1	-60.1
4	-28.7	-79.5	-87.4	-50.9	-55.9
5	-25.9	-75.6	-83.5	-47.1	-52.1
6.3	-23.5	-71.6	-79.5	-43.1	-48.1
8	-21.4	-67.4	-75.3	-39.0	-43.9
10	-20.0	-63.6	-71.5	-35.2	-40.1
12.5	-18.9	-59.7	-67.6	-31.4	-36.3
16	-18.0	-55.5	-63.3	-27.2	-32.1
20	-17.5	-51.7	-59.5	-23.6	-28.3
25	-17.2	-47.9	-55.7	-20.0	-24.6
31.5	-16.2	-44.0	-51.7	-16.5	-20.9
40	-12.8	-40.1	-47.7	-13.1	-17.2
50	-9.9	-36.5	-44.0	-10.2	-14.0
63	-7.4	-33.0	-40.3	-7.7	-10.9
80	-5.2	-29.6	-36.6	-5.5	-8.2
100	-3.6	-26.7	-33.4	-3.9	-6.0
125	-2.4	-24.2	-30.4	-2.7	-4.3
160	-1.4	-22.0	-27.6	-1.7	-2.9
200	-0.9	-20.4	-25.4	-1.1	-1.9
250	-0.5	-19.2	-23.7	-0.7	-1.3
315	-0.2	-18.3	-22.3	-0.5	-0.8
400	-0.1	-17.6	-21.3	-0.3	-0.5
500	0.0	-17.2	-20.7	-0.2	-0.3
630	0.0	-17.0	-20.2	-0.1	-0.2
800	-0.1	-16.8	-19.9	-0.1	-0.1
1000	-0.3	-16.7	-19.7	0.0	-0.1
1250	-0.5	-16.6	-19.6	0.0	-0.1
1600	-1.0	-16.6	-19.5	0.0	0.0
2000	-1.7	-16.6	-19.5	0.0	0.0
2500	-2.6	-16.5	-19.5	0.0	0.0
3150	-3.9	-15.7	-18.7	0.0	-0.1
4000	-5.7	-12.3	-15.0	0.0	-0.1
5000	-7.9	-9.4	-11.9	0.0	-0.1
6300	-10.5	-6.7	-8.9	0.0	-0.2
8000	-13.7	-4.5	-6.3	-0.1	-0.3
10000	-16.9	-2.8	-4.2	-0.1	-0.5
12500	-17.9	-1.6	-2.7	-0.1	-0.8
16000	-18.7	-0.7	-1.4	-0.2	-1.3
20000	-19.7	-0.2	-0.6	-0.3	-1.9
25000	-21.1	0.0	-0.2	-0.5	-2.9
31500	-23.0	0.0	-0.1	-0.8	-4.2
40000	-25.4	-0.3	-0.2	-1.3	-6.0

APPENDIX B: IMPACT PILING NOISE

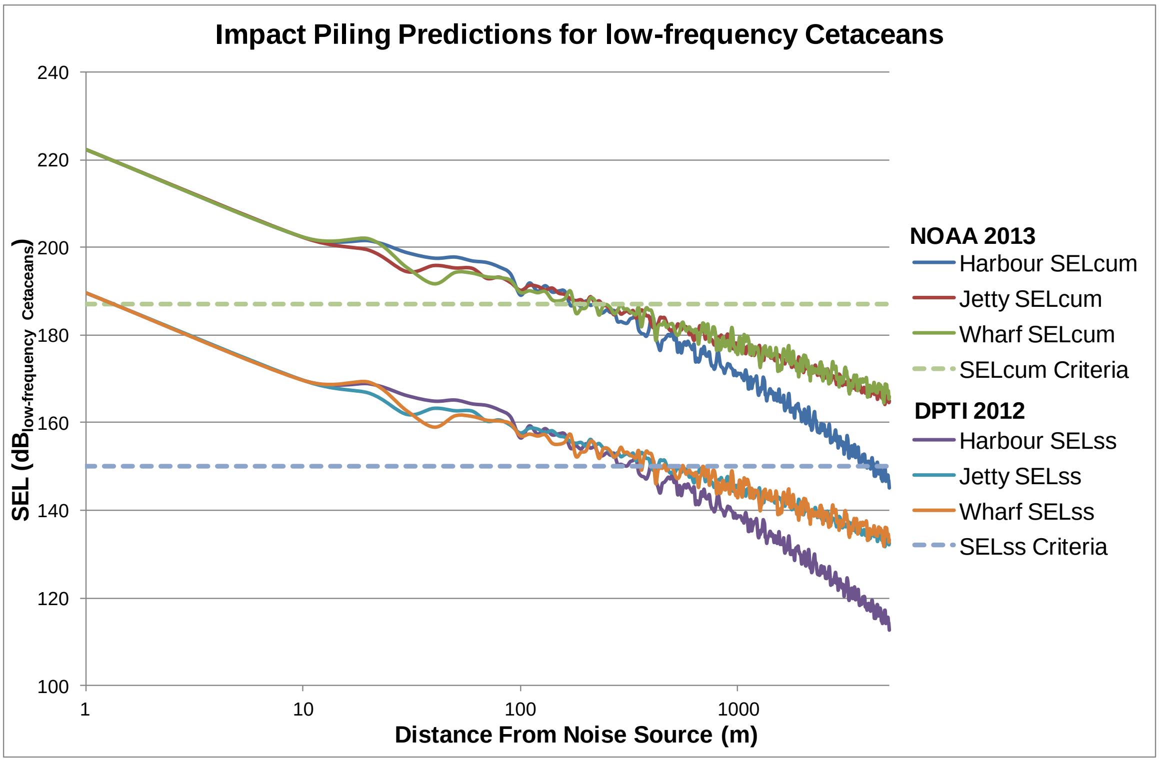


Figure B.1: Impact Piling Noise Predictions for low-frequency Cetaceans

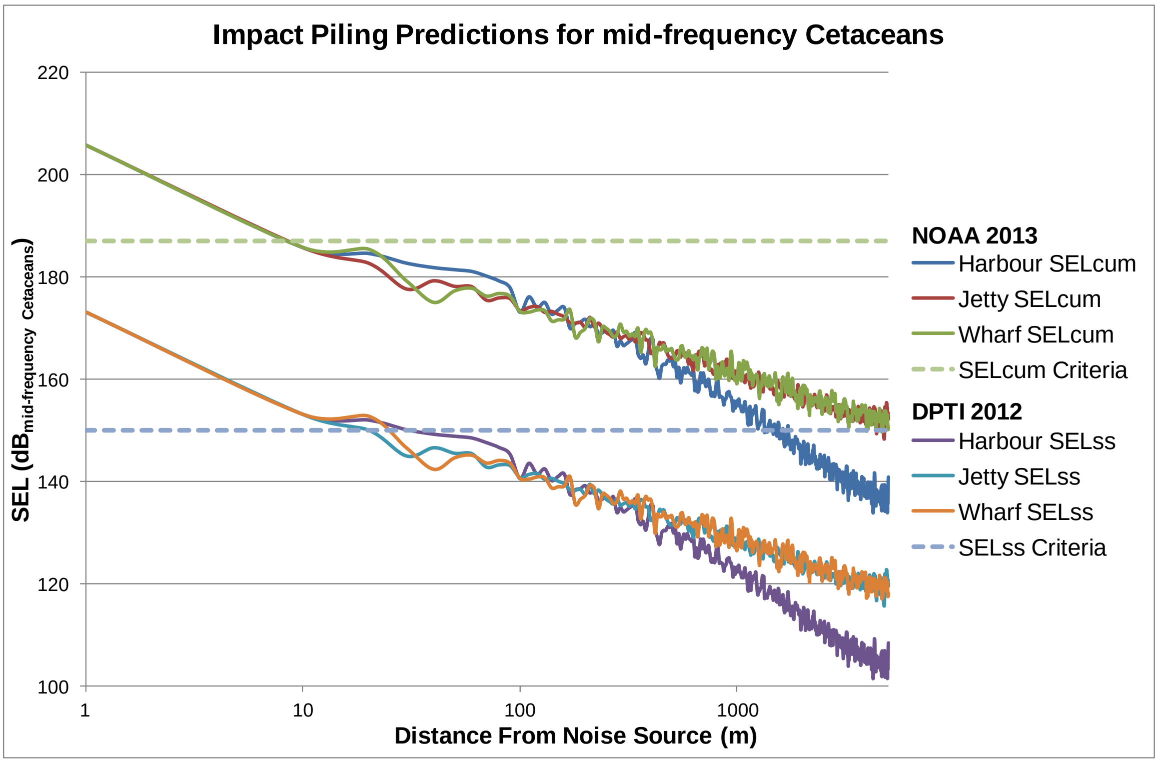


Figure B.2: Impact Piling Noise Predictions for mid-frequency Cetaceans

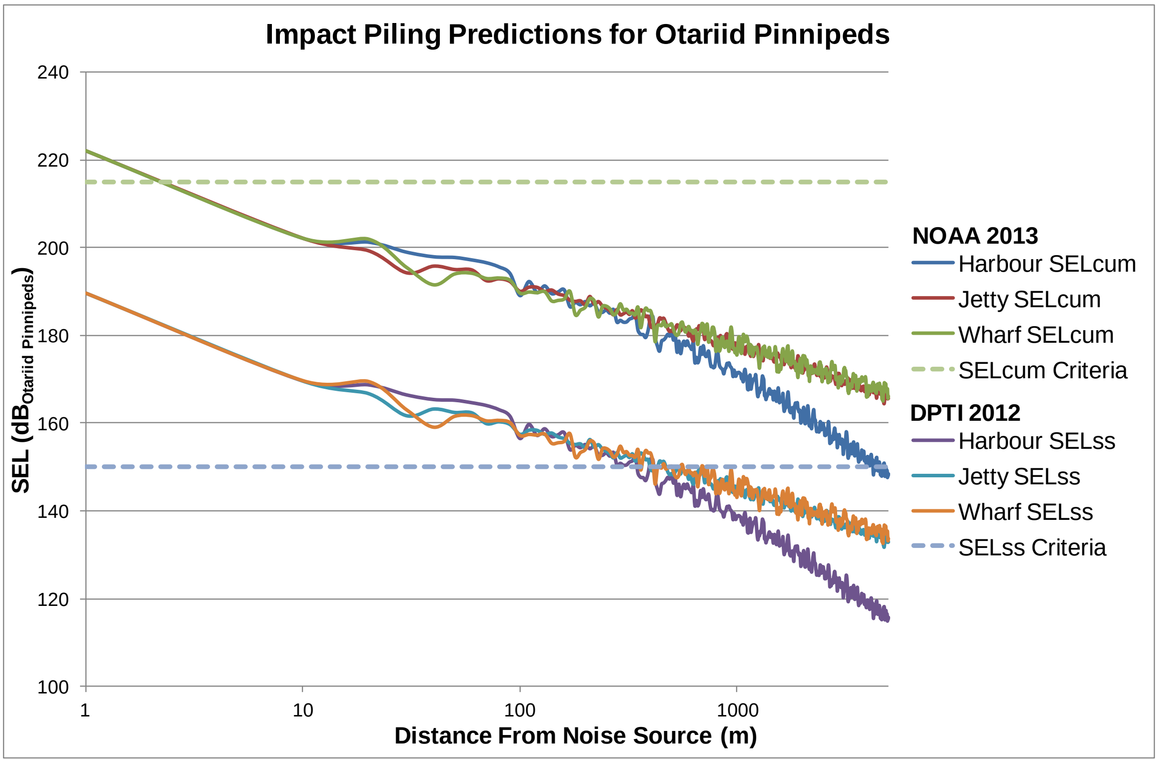


Figure B.3: Impact Piling Noise Predictions for Otariid Pinnipeds

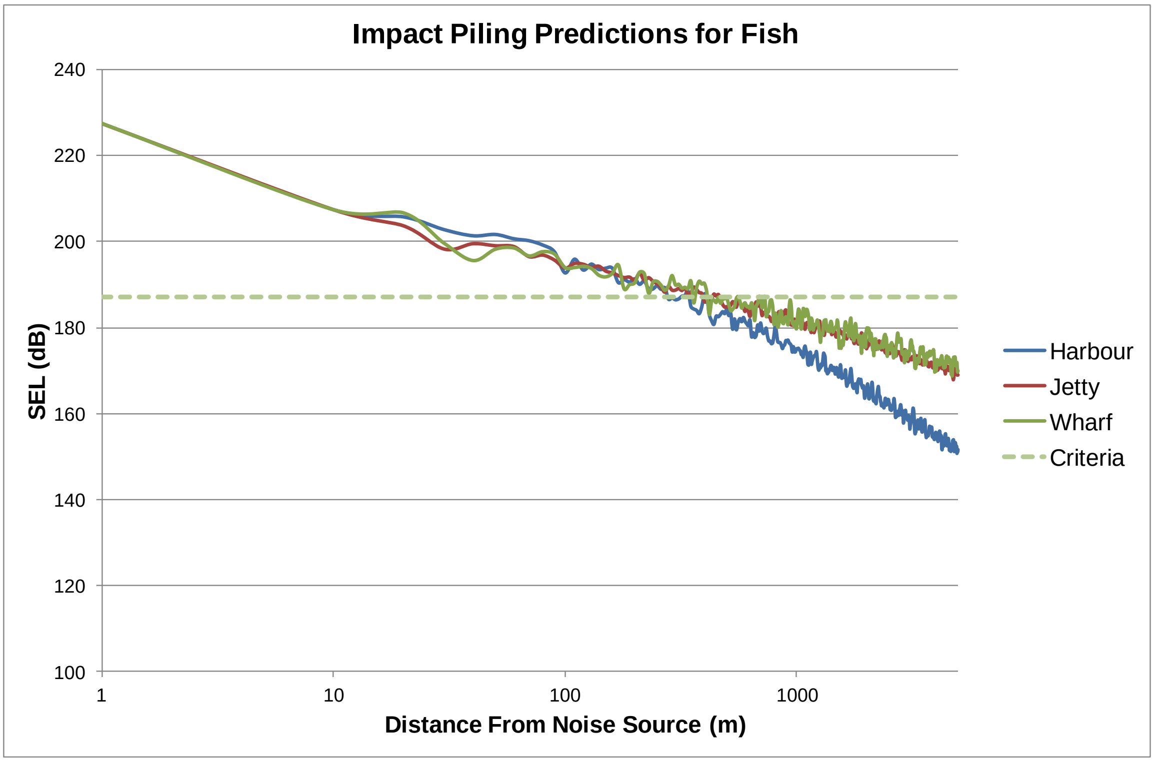


Figure B.4: Impact Piling Noise Predictions for Fish

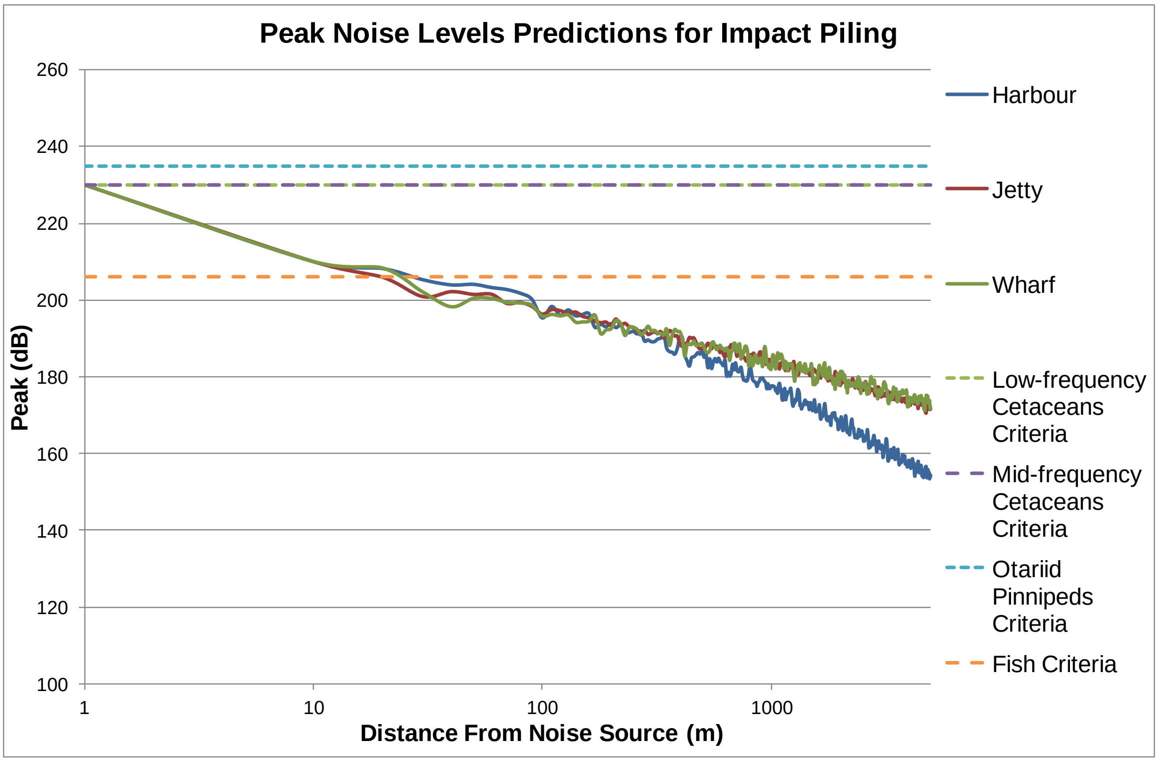


Figure B.5: Peak Noise Levels Predictions for Impact Piling

APPENDIX C: DRILLING NOISE

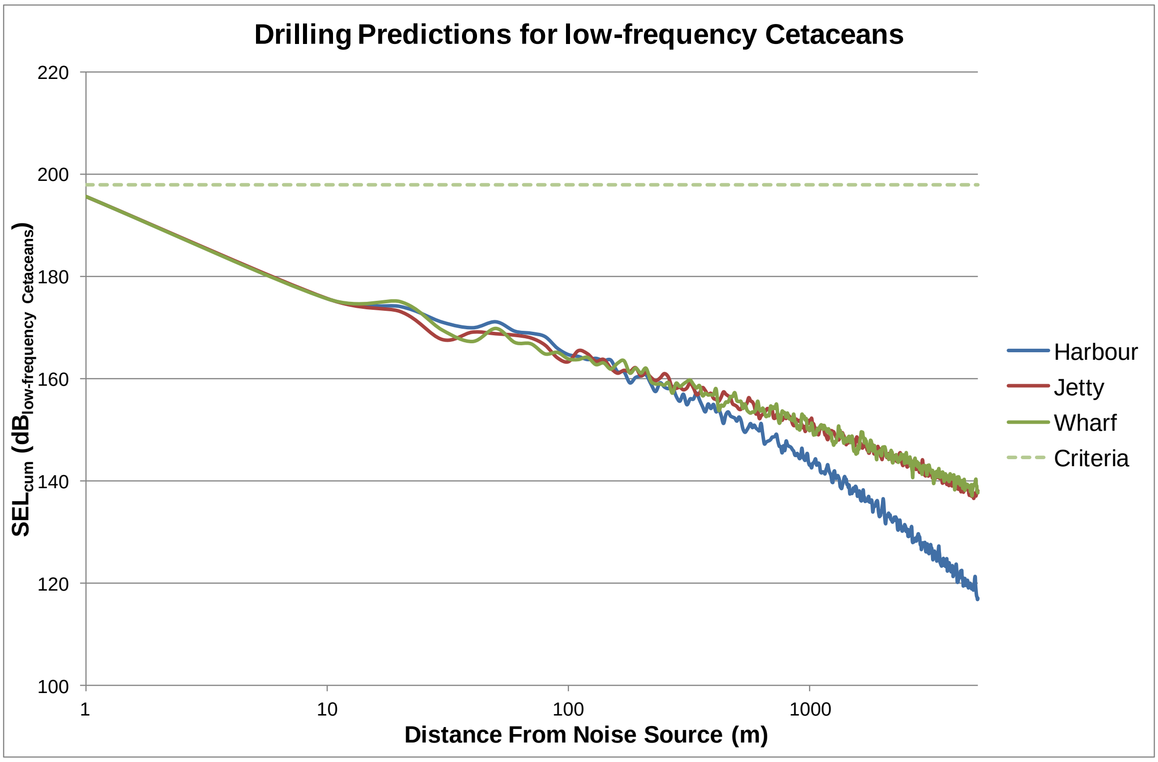


Figure C.1: Drilling Noise Predictions for low-frequency Cetaceans

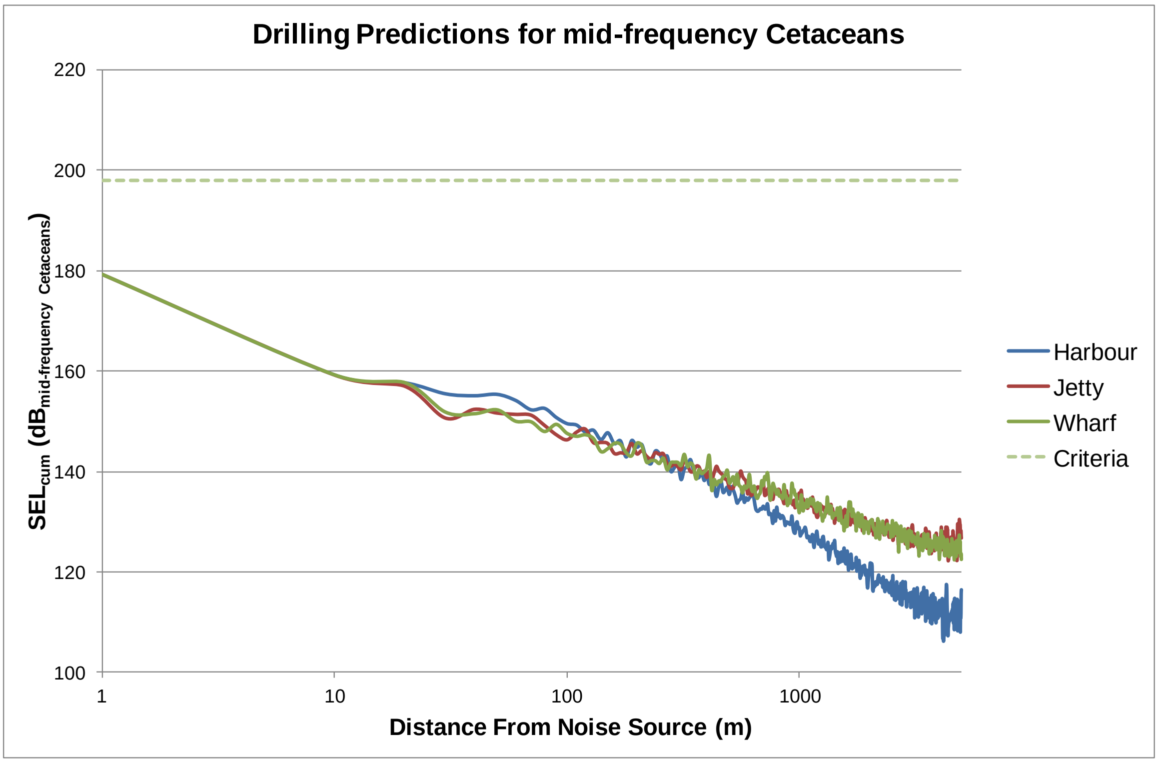


Figure C.2: Drilling Noise Predictions for mid-frequency Cetaceans

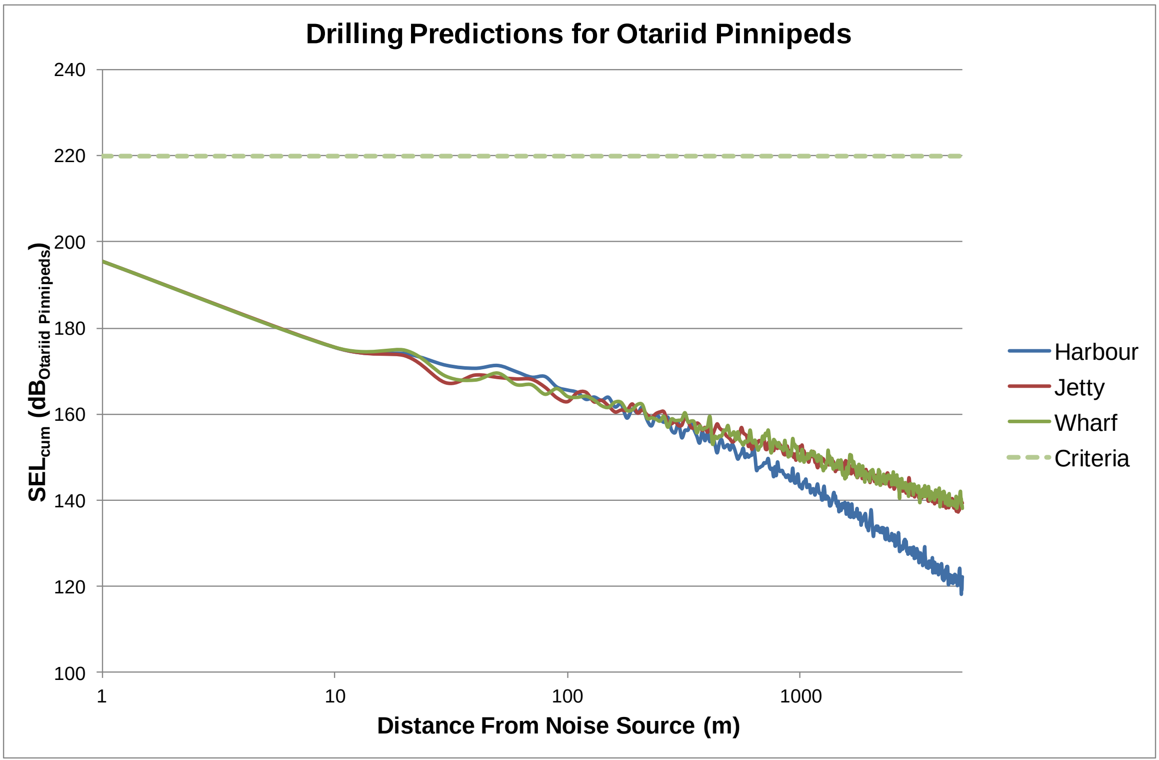


Figure C.3: Drilling Noise Predictions for Otariid Pinnipeds

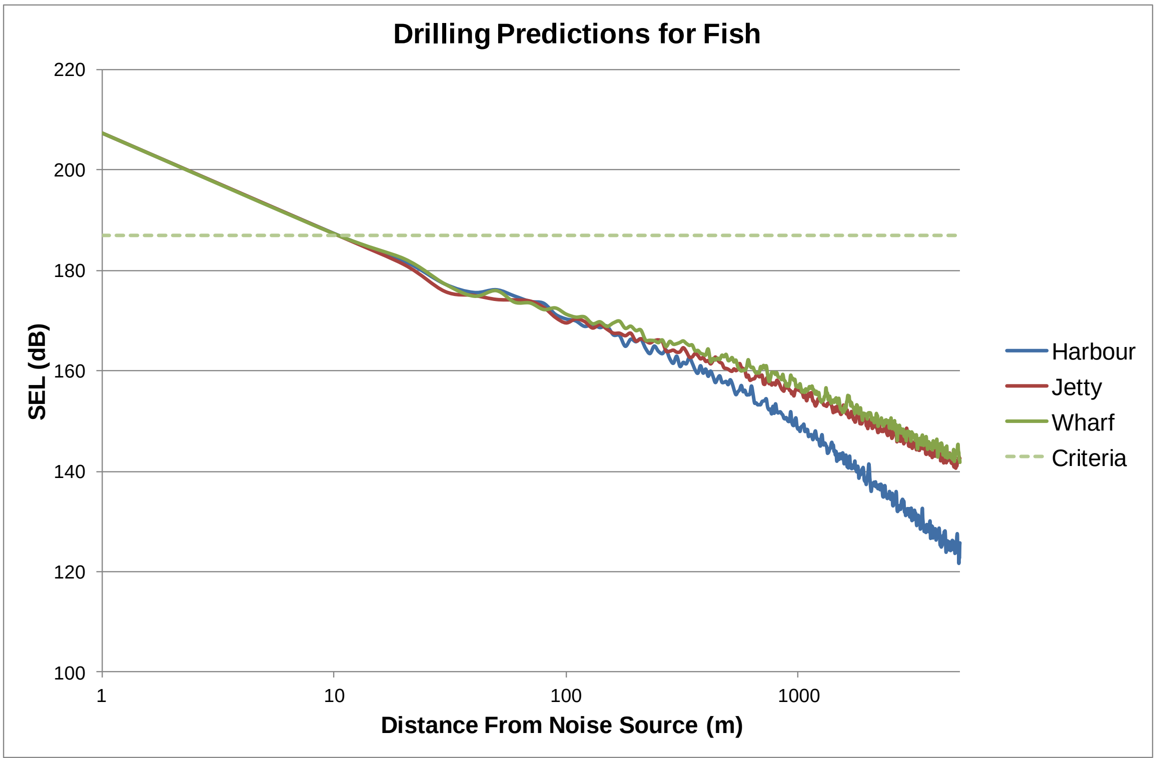


Figure C.4: Drilling Noise Predictions for Fish

APPENDIX D: VESSEL NOISE

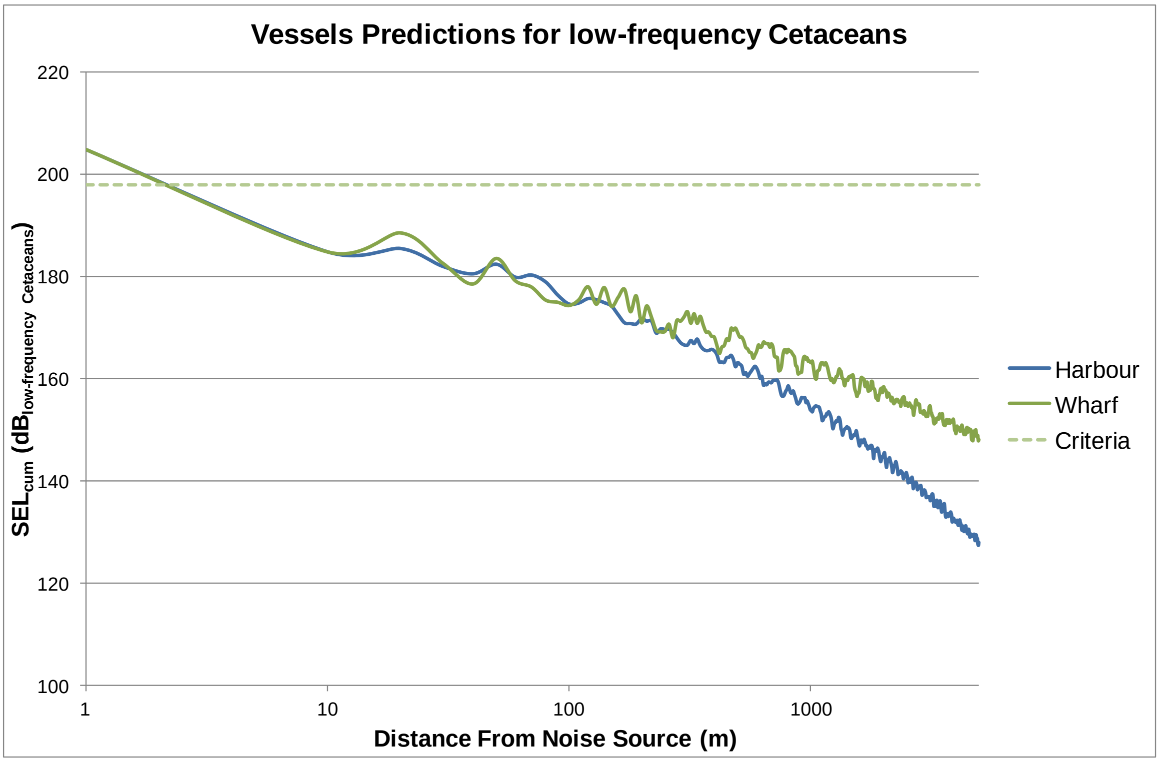


Figure D.1: Vessel Noise Predictions for low-frequency Cetaceans

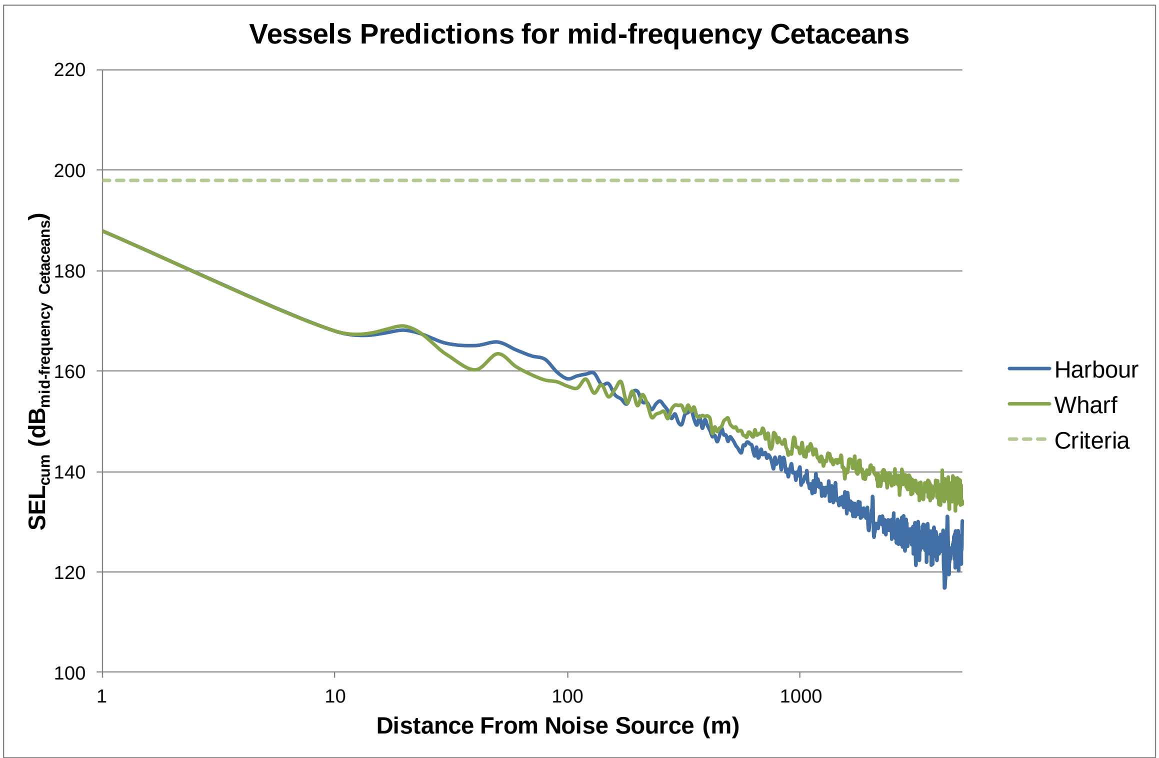


Figure C.2: Vessel Noise Predictions for mid-frequency Cetaceans

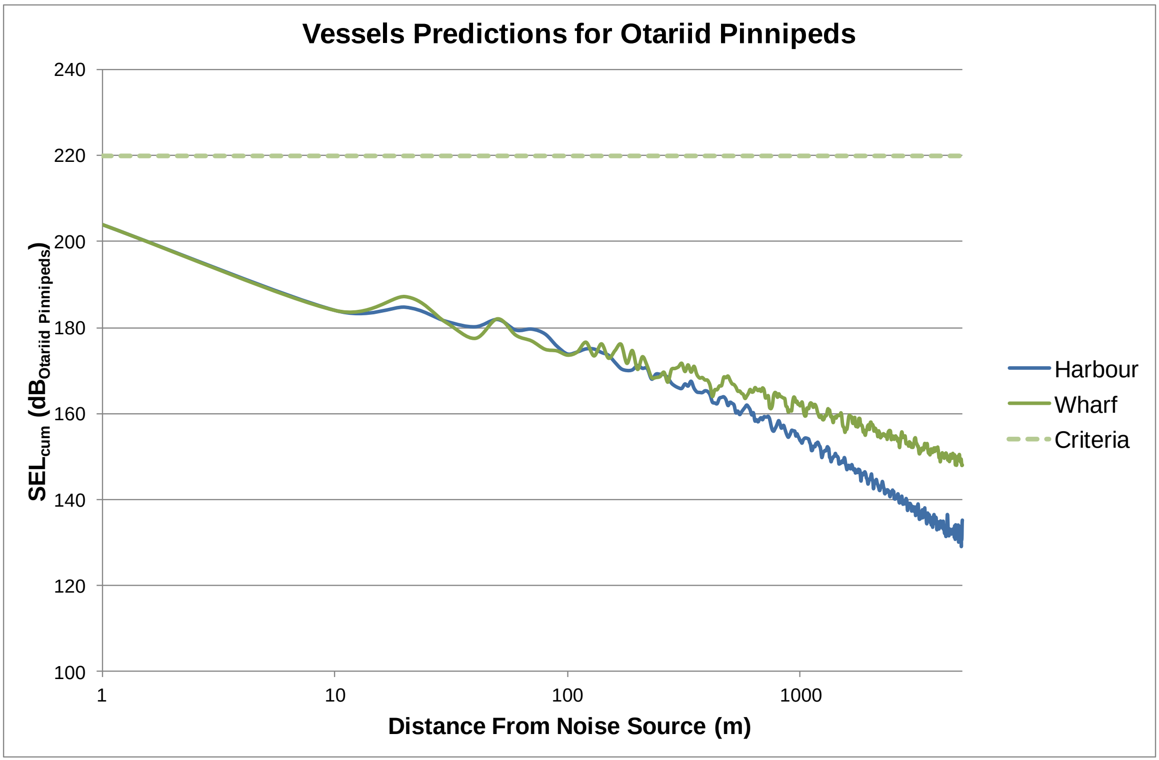


Figure D.3: Vessel Noise Predictions for Otariid Pinnipeds

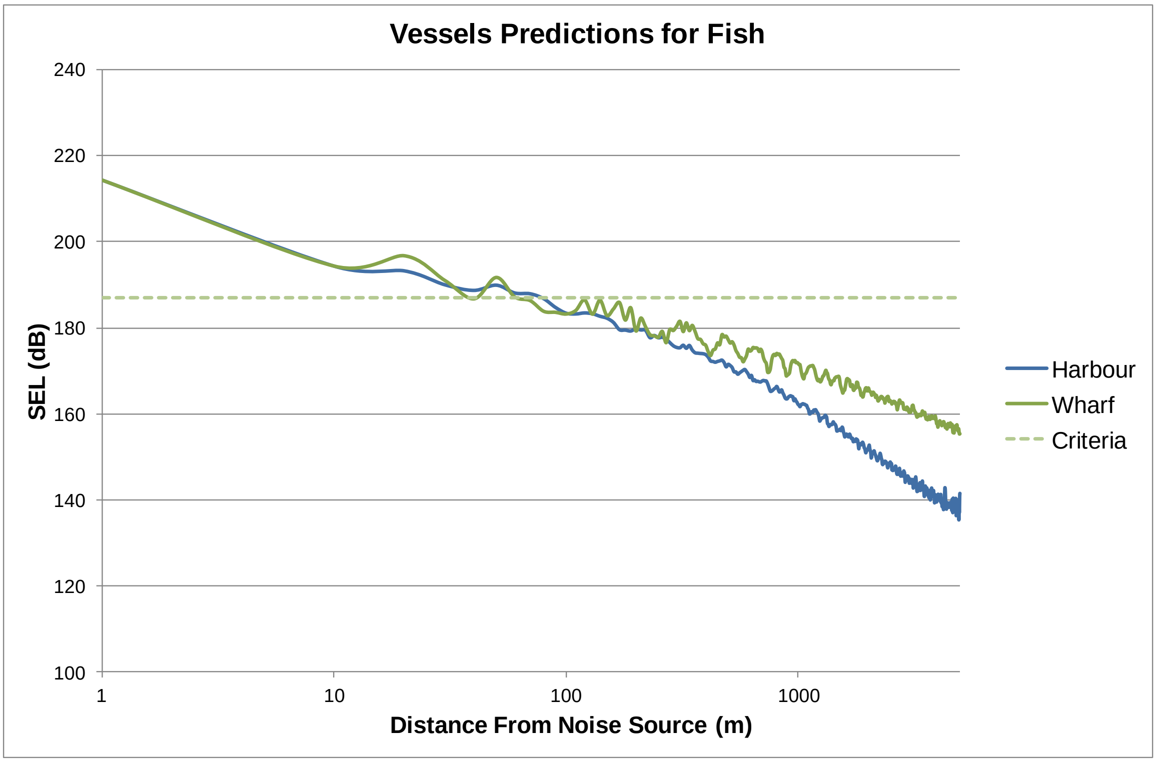
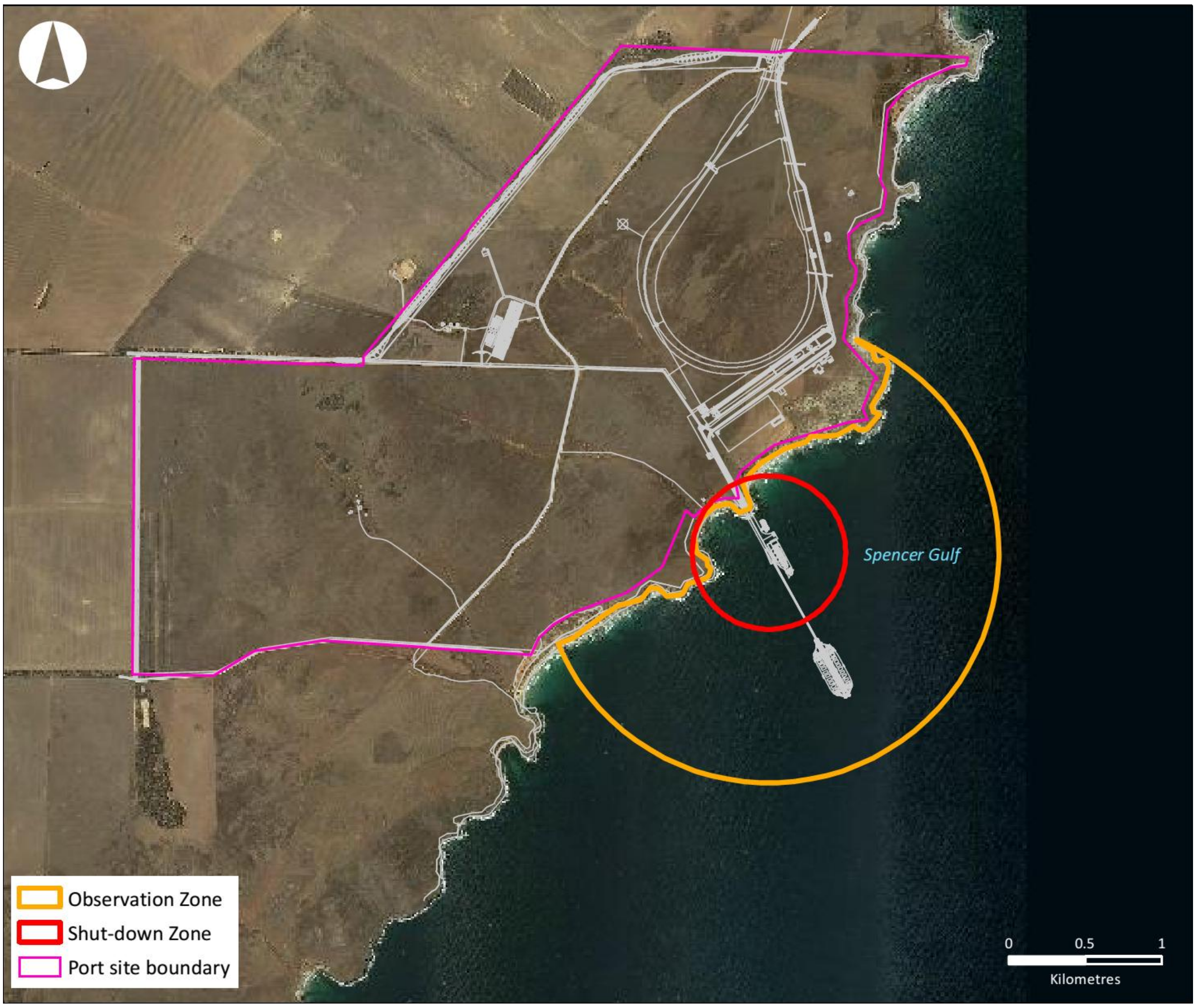
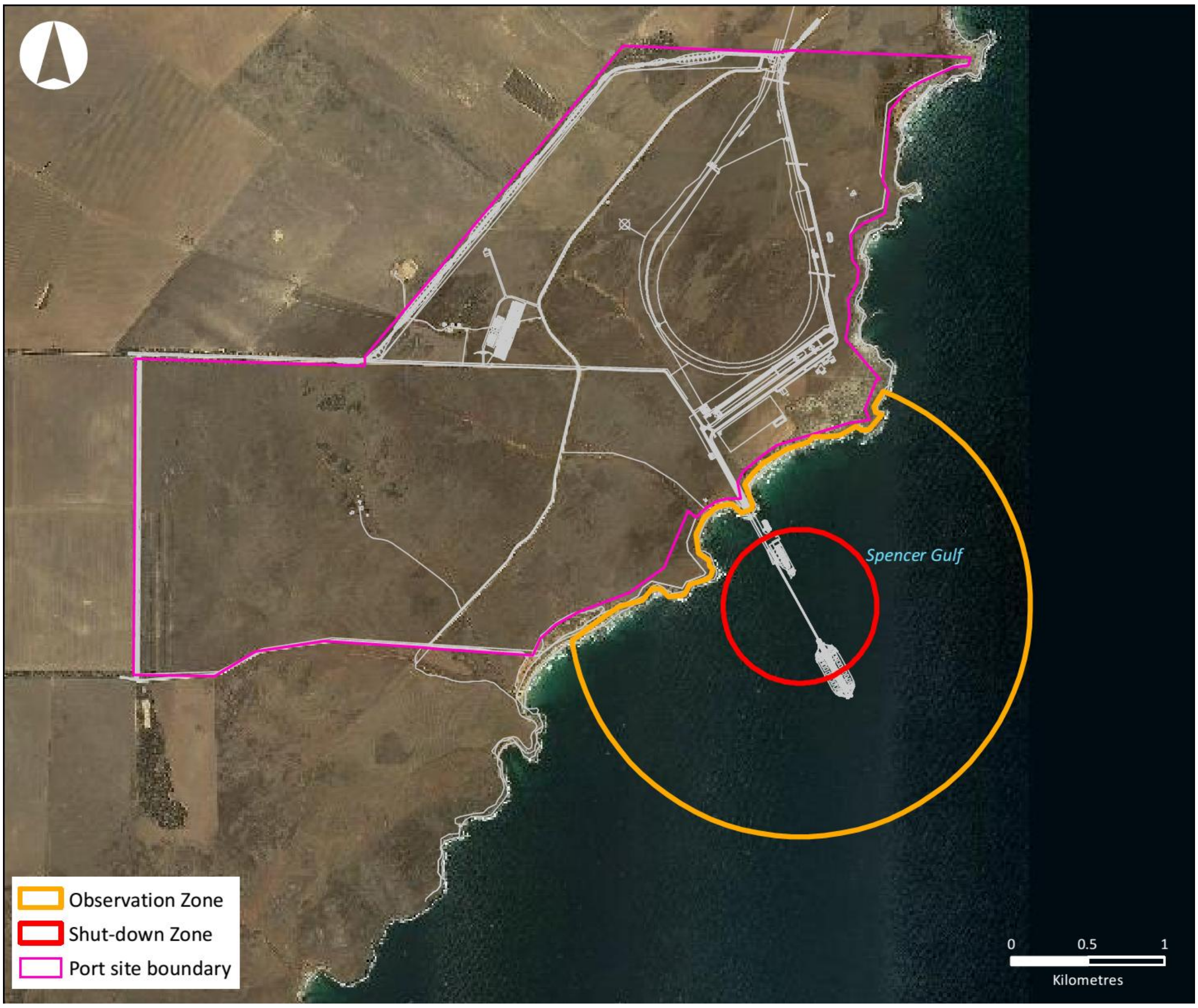


Figure D.4: Vessel Noise Predictions for Fish

APPENDIX E: OBSERVATION AND SHUT-DOWN ZONES – HARBOUR



APPENDIX F: OBSERVATION AND SHUT-DOWN ZONES – JETTY



APPENDIX G: OBSERVATION AND SHUT-DOWN ZONES – WHARF