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Adelaide Desalination Project
Technical Studies & Investigations

Technical Report– Underwater Noise & Vibration

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Contents

1. Introduction

In December 2007, the Government of South Australia announced that it was proposing to construct seawater Desalination Plant at Port Stanvac, located approximately 30km south of the Adelaide Central Business District.

The Adelaide Desalination Project includes the following elements:

- A desalination plant based on reverse osmosis technology, with an initial capacity of 50 GL of drinking water per annum with the potential for the capacity to be expanded to 100 GL of drinking water per annum; and
- Intake and outfall pipelines and structures to draw raw seawater into the facility and return approved seawater discharge to Gulf St Vincent.

The desalination plant was granted 'Major Development' status by the Minister for Urban Development and Planning on 17 April 2008, triggering a comprehensive and coordinated State-run assessment of this project. The State also announced that a Design, Build, Operate and Maintain (DBOM) method would be adopted to procure the desalination plant and associated marine (intake/outfall) works.

1.1 Background

On average, 60% of Adelaide's potable water supply is met from the Mount Lofty Ranges catchment and 40% from the River Murray. In a drought year, however, as much as 90% of Adelaide's water is supplied from the River Murray.

As such, the security of Adelaide's metropolitan water supply is largely affected by climatic variability and by Adelaide's limited water storage capacity (approximately one years' demand).

With the impact of severe droughts and anticipated climate change likely to lead to reduced flows and greater variability of flows to local reservoirs, the security of Adelaide's water supply has become an issue of critical significance to the Government, SA Water and the wider community.

In March 2007, the South Australian Minister for Water Security announced the formation of a Desalination Working Group to investigate desalination technology and other potential water security measures for the State in the future, along with:

- Managing use - including demand reduction initiatives;
- Recycling - stormwater and wastewater projects; and
- Catchments - namely increasing storage capacity in the Mount Lofty Ranges to better manage climate variability.

The proposed project is one part of the South Australian Government's 4-Way Strategy to secure water supplies into the future.

1.2 Project Aims and Objectives

The aim of the Adelaide Desalination Project is to provide a sustainable and secure supply of drinking water for metropolitan Adelaide. This is to be achieved by delivering a climate independent water source that will supplement and secure the metropolitan area's water supply and reduce the reliance on traditional water sources.

Supporting objectives of the Adelaide Desalination Project include:

South Australia's Strategic Plan and SA Water's Strategic Plan	To achieve South Australia's strategic plan targets which are embraced within SA Water's strategic objectives particularly in respect of sustainability, obligations to the owner (the State), customers, water quality and security. SA Water will also require the achievement of the highest standards of safety compliance with the aim of zero harm.
Water Availability Date and Quality	To produce safe desalinated drinking water by December 2010 and within specified quality and quantity specifications.
Customer Confidence	To improve water security in the medium and long term. To enhance SA Water's ability to meet and secure its customer's needs and expectations including community consultation.
Environmental Performance	To ensure that any potential adverse environmental impacts of the plant are either avoided, mitigated or minimised.
Optimum Risk Transfer	To enable an optimum allocation of risks between SA Water and the private sector, providing SA Water with an optimised value for money outcome.
Expandability of the Plant	To accommodate possible capacity upgrade of the plant size in a cost effective manner after construction.
Technological improvements	To provide an asset that has the flexibility to accommodate innovation and technological improvements in the future, sharing the benefits with SA Water's customers.
Knowledge Transfer	To ensure a high level of effective knowledge transfer to SA Water in all aspects of the project including the operations phase.
Cost Optimisation	To deliver a cost efficient outcome for SA Water over the life of the project.
Operating Performance	To maximise operational efficiencies of the new asset through the achievement of key performance indicators.

1.3 Purpose and Scope

As part of the development assessment process for the Adelaide desalination plant, the Minister for Urban Development and Planning has determined that the level of assessment for the proposed plant would be that of an Environmental Impact Statement (EIS). The Minister has also issued a set of guidelines outlining the key environmental, social and economic issues that the EIS should address.

The following report has been prepared for the South Australian Water Corporation (SA Water) to provide technical information for input into the EIS. This report forms part of the detailed environmental and technical investigations that have been undertaken to support the proposed desalination plant and presents in particular the underwater noise assessment carried out for both the construction and operation of the intake and outfall components of the proposed Desalination Plant. In doing so it:

- Defines underwater noise descriptors, and parameters that affect the transmission of noise underwater
- Outlines legislated Policies and Regulations affecting Marine Fauna
- Defines the existing Geo-acoustic and Oceanographic Environment (bathymetry, temperature and salinity profile with depth, wind, current and tidal conditions)
- Considers the type and sensitivity of marine fauna to sound, and the seasonal movements of marine fauna within the region
- Defines the type and intensity of anthropogenic noise sources (pumps, dredging, tunnelling, blasting)
- Outlines the computational model used to predict noise transmission underwater
- Assesses the impact of noise on marine fauna and defines measures to mitigate the impact

2. Legislation and Policy

2.1 Legislation

The legislation for regulating the creation of underwater noise is limited to guidelines outlined by the Department of Environment and Heritage which fall under the *Environment Protection and Biodiversity Conservation Act* 1999 (EPBC Act).

The EPBC Act is the Australian Government's central piece of environmental legislation. It provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places, defined in the Act as matters of national environmental significance.

2.2 Policy

EPBC Act policy statements are the Department's public policy documents which provide guidance on the practical application of EPBC Act. The policy statements include:

2.2.1 Significant Impact Guidelines

The significant impact guidelines (EPBC Act Policy Statement 1.1, May 2006) provide over arching guidance on determining whether an action is likely to have a significant impact on a matter of national environmental significance protected by the EPBC Act. The matters of national environmental significance include:

- Listed threatened species and communities (http://www.deh.gov.au/biodiversity/threatened/species/index.html)
- Listed migratory species (http://www.deh.gov.au/epbc/matters/migratory.html)
- Ramsar wetlands of international importance
- The Commonwealth marine environment
- World Heritage properties
- National Heritage places
- Nuclear actions

"Listed threatened species and communities", and "Listed migratory species" relevant to the marine environment in the vicinity of the proposed development, are considered in Section X with regard to their sensitivity to sound.

An action is likely to have a significant impact on a "Listed threatened species and communities" if there is a real chance or possibility that it will:

- lead to a long-term decrease in the size of a population;
- reduce the area of occupancy of the species;
- fragment an existing population into two or more populations;
- adversely affect habitat critical to the survival of a species;
- disrupt the breeding cycle of a population;
- modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline;
- result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat;
- introduce disease that may cause the species to decline; or
- interfere with the recovery of the species.

An action is likely to have a significant impact on a "Listed migratory species" if there is a real chance or possibility that it will:

- substantially modify (including by fragmenting, altering fire regimes, altering nutrient cycles or
- altering hydrological cycles), destroy or isolate an area of important habitat for a migratory species;
- result in an invasive species that is harmful to the migratory species becoming established in an area of important habitat for the migratory species; or
- seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.

Information for industry sectors are provided within this policy, which specifically notes:

> *Offshore exploratory drilling would be expected to have a significant impact if it is undertaken in an area that contains habitat for threatened or migratory species and the seismic activity is likely to interfere with breeding, feeding or migration, or if habitat critical to the survival of the species (or important habitat for a migratory species) is damaged by the drilling.*
>
> *Dredging to maintain existing navigational channels would not normally be expected to have a significant impact on the environment where the activity is undertaken as part of normal operations and the disposal of spoil does not have a significant impact.*

2.2.2 Industry Guidelines

Industry guidelines provide specific guidance for industry sectors and should be read in conjunction with the significant impact guidelines.

<u>EPBC Act Policy Statement 2.1 – Interaction between offshore seismic exploration and whales</u>

Seismic surveying is widely used in the marine environment to define and analyse subsurface geological structures, mainly by the oil and gas exploration and production industry. Seismic surveying utilises a technique that directs acoustic energy (sound) into the rock beneath the sea floor from equipment towed behind a purpose-built seismic vessel. The loudest sound sources used in seismic survey operations are produced by air-guns which generate short, intense pulses of sound directed at the seafloor.

The aim of the Policy is to:

- provide practical standards to minimise the risk of acoustic injury to whales in the vicinity of seismic survey operations;
- provide a framework that minimises the risk of biological consequences from acoustic disturbance from seismic sources to whales in biologically important habitat areas or during critical behaviours; and
- provide advice to operators conducting seismic surveys on their legal responsibilities under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act).

This Policy has been written with the goal of minimising the likelihood of injury or hearing impairment of whales based on current scientific understanding. Calculations are primarily based on received sound energy levels that are estimated to lead to a temporary threshold shift (TTS) in baleen whale hearing. This Policy is not intended to prevent all behavioural changes, which might occur in response to detectable, but non-traumatic sound levels. In fact, it is likely that whales in the vicinity of seismic surveying will avoid the immediate area due to an aversive response to the sound. This aversion is relied upon as a form of mitigation to prevent whales from approaching or being approached closely enough to cause acoustic injury from intense or prolonged sound exposure. At the scale of a seismic survey, such temporary displacements are unlikely to result in any real biological cost to the animals unless the interaction occurs during critical behaviours (e.g. breeding, feeding and resting), or in important areas such as narrow migratory corridors.

For proposed seismic surveys that can demonstrate through sound modelling or empirical measurements that the received acoustic signal at 1km will not likely exceed 160dB re $1\mu Pa^2s$ for 95% of the time, the following safety zones are recommended:

- Observation zone: 3+ km horizontal radius from the acoustic source.
- Low power zone: 1 km horizontal radius from the acoustic source.
- Shut-down zone: 500m horizontal radius from the acoustic source.

For all other proposed seismic surveys:

- Observation zone: 3+ km horizontal radius from the acoustic source.
- Low power zone: 2 km horizontal radius from the acoustic source.
- Shut-down zone: 500m horizontal radius from the acoustic source.

In the observation zone whales and their movements should be monitored to determine whether they are approaching or entering the low power zone. When a whale is sighted within or appears to enter the low power zone, the acoustic source should immediately be powered down to the lowest possible setting (e.g. a single small gun firing at ~10s intervals). When a whale is sighted within or appears to enter the shut-down zone, the acoustic source must immediately be shut down completely.

3. Marine Fauna Sound Sensitivity

3.1 Sensitivity to Sound

The use of sound for communication and detection in the marine environment is important for survival for marine animals. Marine animals depend on their hearing sensitivity to retain cohesion in groups, for echolocation (among marine mammals), to locate and capture food, for detection of predators, for sensing their physical and biological environment and for avoiding dangerous situations (including anthropogenic threats). There is great variation in hearing sensitivity among animals due to evolutionary diversification of anatomical structures involved in hearing and selection pressures on the way different animals utilise sound. The measure of a species' ability to perceive sound is the audiogram, which presents the lowest level of sound, or threshold, at which a species can hear as a function of frequency. The audiogram thus represents the filter characteristics of the animal's hearing. Levels of sound lower than the hearing threshold defined in the audiogram of a species cannot be perceived by that species; the degree of perception of the sound relates to the amount it is above the threshold. Figure 1 shows the audiograms of humans relative to a number of marine fauna species.

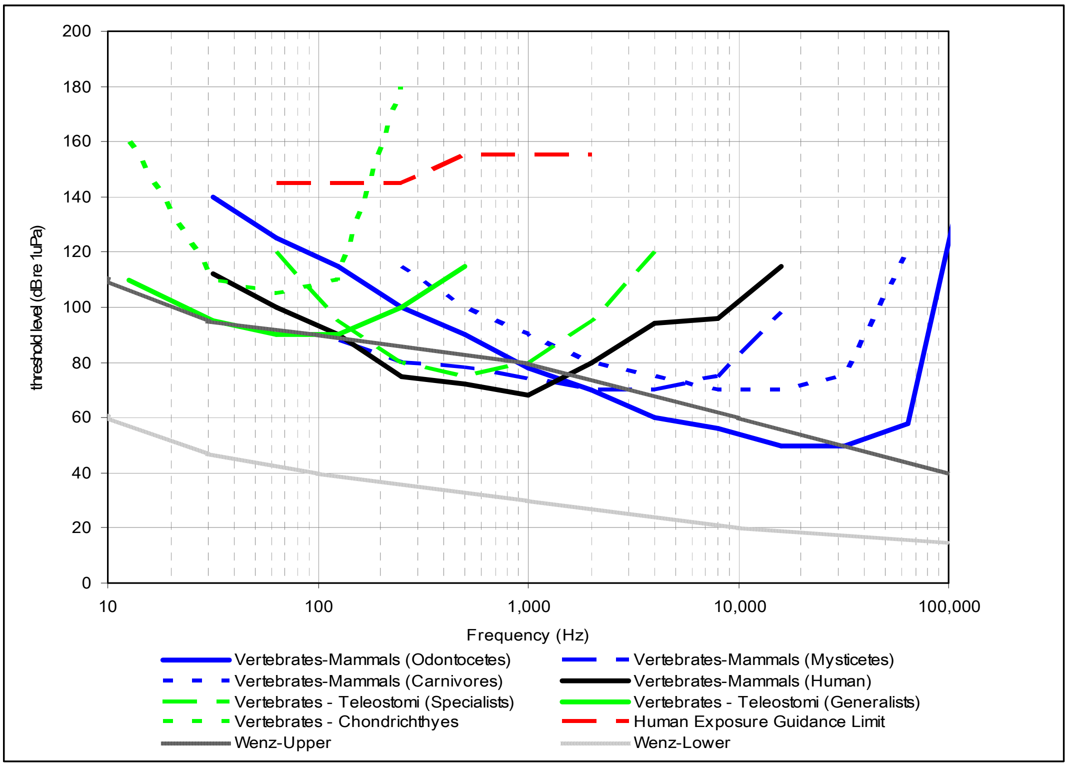

Figure 1 Audiograms of Marine Fauna

3.2 Vertebrates

3.2.1 Mammals

Marine mammals are a diverse group and the potential effects of man-made sound depend on the type of animal involved. Marine mammals occur in three orders: *Cetacea, Sirenia* and *Carnivora*, with the later order being both terrestrial and marine based.

There are two main types of living ***cetaceans**: odontocete* or toothed whales, and *mysticete* or baleen whales. *Odontocetes* communicate at moderately high frequencies (eg. 1-20kHz), and have highly developed echolocation systems operating at high and very high frequencies (20-150kHz). *Mysticetes* are apparently sensitive mainly to low and moderate frequency sounds (eg. 12Hz to 8kHz) and lack a high frequency echolocation system.

Of marine ***carnivores*** (*pinnipeds*, sea otters, and polar bears), only *pinnipeds* are relevant to the local area. The *pinnipeds* include three families : *Pocidae*, which are the "true" or "hair" seals; *Otariidae* or eared seals, including the fur seals and sea lions; and the *Odobenidae*, represented by the walrus.

Sirenians are *herbivores* that inhabit shallow coastal waters or rivers of the tropics and subtropics. They are not present in local waters and will not be considered further.

Marine mammals, and cetaceans in particular, present an interesting hearing paradox. On one hand, marine mammal inner ears physically resemble land mammal inner ears, although the external ears are typically absent and the middle ear extensively modified. Since many forms of hearing loss are based in physical structure of the inner ear, it is likely hearing damage occurs by similar mechanisms in both land and marine mammal ears. On the other hand, the sea is not, nor was it ever, even primordially silent. Whales and dolphins, in particular, evolved ears that function well within this context of natural ambient noise. This may mean they developed "tough" inner ears that are less subject to hearing loss under natural ocean noise conditions. Recent anatomical and behavioral studies do indeed suggest that whales and dolphins may be more resistant than many land mammals to temporary threshold shifts (TTSs), but the data show also that they are subject to disease and aging processes.

Audiograms are available for only 10 species of *odontocetes* and 11 species of *pinnipeds*. All are smaller species that were tested as captive animals (Figure 2). However, there are 119 marine mammal species, and the majority are large, wide-ranging animals that are not approachable or testable by normal audiometric methods.

The combined data from audiograms and models show there is considerable variation among marine mammals in both absolute hearing range and sensitivity. Their composite range is from ultra- to infrasonic. *Odontocetes*, like bats, are excellent echolocators, capable of producing, perceiving, and analysing ultrasonic frequencies well above any human hearing. *Odontocetes* commonly have good functional hearing between 200 and 100,000 Hz, although some species may have functional ultrasonic hearing to nearly 200 kHz. The majority of *odontocetes* have peak sensitivities (best hearing) in the ultrasonic ranges, although most have moderate sensitivity to sounds from 1 to 20 kHz. No *odontocete* has been shown audiometrically to have acute, that is, best sensitivity or exceptionally responsive, hearing (<80 dB re 1 μPa) below 500 Hz.

Based on functional models, good lower-frequency hearing appears to be confined to larger species in both the *cetaceans* and *pinnipeds*. No *mysticete* has been directly tested for any hearing ability, but functional models indicate their hearing commonly extends to 20 Hz, with several species, including blue, fin, and bowhead whales, that are predicted to hear at infrasonic frequencies as low as 10–15 Hz. The upper functional range for most *mysticetes* has been predicted to extend to 20–30 kHz.

Most *pinniped* species have peak sensitivities between 1 and 20 kHz. Some species, like the harbor seal, have best sensitivities over 10 kHz. Only the northern elephant seal has been shown to have good to moderate hearing below 1 kHz (Kastak and Schusterman, 1999). Some *pinniped* species are considered to be effectively double-eared in that they hear moderately well in two domains, air and water, but are not particularly acute in either. Others, however, are clearly best adapted for underwater hearing alone.

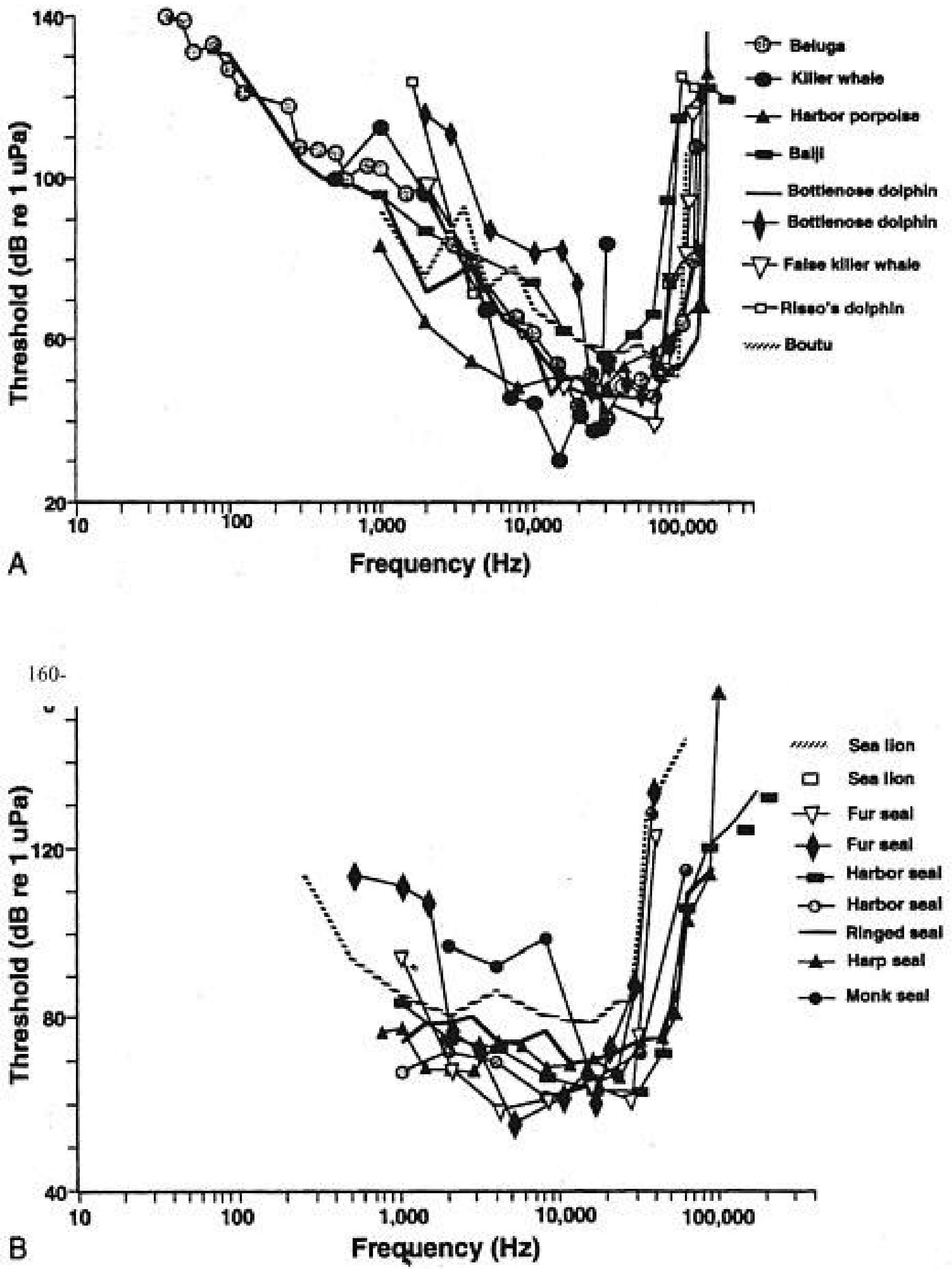

Figure 2 Audiogram for Cetaceans (A) and Pinnipeds (B)

Cetaceans

Kemper *et al*. (2008) identified 23 species of cetacean that are found within Gulf St Vincent, Investigator Straight and Backstairs Passage, many of which are likely to be infrequent visitors to the coast. Of these 23 cetacean species, 19 are protected by legislation (*Environment Protection Biodiversity Conservation Act* 1999, *National Parks and Wildlife Act* 1972 at a regional, state and national level. However as migratory mammals they are all protected under the *Environment Protection Biodiversity Conservation Act 1999*.

- *Mysticetes*
  Of the whale species identified in Kemper *et al*. (2008), the majority of the species are infrequently or rarely sited. However, the southern right whale *(Eubalaena australis)* is regularly recorded within GSV.

- *Odontocetes*
  The dusky dolphin (*Lagenorhynchus obscurus)* and Risso's dolphin (*Grampus griseus)* are rare visitors to GSV. Two common species of dolphin found in GSV are the Short-beaked common dolphin (*Delphinus delphis*) and the bottle nose dolphin (*Tursiops truncates*).

Carnivores

Five *pinnipeds* species across two families (the *Otariidae* family and the *Phocidae* family) have been recorded in Gulf St Vincent, Investigators Straight, and Backstairs Passage (Kemper *et al.* 2008). The following *Pinniped* species have been identified as species most likely to occur in GSV and/or protected under legislation.

- Australian sea lion (*Neophoca cinerea*)
- New Zealand fur seal (*Arctocephalus forsteri*)
- Leopard Seal (*Hydruga leptonyx*)

3.2.2 *Teleostomi* (Fish) and *Chondrichthyes* (*Elasmobranchs*)

The inner ear of fishes and *elasmobranchs* (sharks and rays) is very similar to that of terrestrial vertebrates [see Popper and Fay (1999) for review]. While there are data on hearing capabilities for fewer than 100 of the 25,000 extant species, investigations of the auditory system of evolutionarily diverse species support the suggestion that hearing is widespread among virtually all fishes, as well as *elasmobranchs*.

Most species of fish and *elasmobranchs* are able to detect sounds from well below 50 Hz (some as low as 10 or 15 Hz) to upward of 500-1,000 Hz. Moreover, a number of fish species have adaptations in their auditory systems that enhance sound detection and enable them to detect sounds to 3 kHz and above and have better sensitivity than non-specialist species at lower frequencies. Goldfish and American shad are examples of specialist species, while Atlantic salmon and Atlantic cod are examples of species without specialisations. It has been further suggested that those fish with specialist structures have been classified as 'high' sensitivity, non-specialists with a swimbladder are 'medium' sensitivity and non-specialists with no swimbladders are termed 'low' sensitivity.

Elasmobranches rely on low frequency sound (as well as electro-chemical receptors) to locate distressed prey (Myrberg, 1978). The hearing sensitivity of elasmobranches is thought to be low since they do not possess swimbladders.

Many *syngnathids* have been documented to produce sound (loud clicks), suggesting that sound is important for communication in the aquatic environment (Bergert and Wainwright, 1997; Colson et al., 1998; Ripley, 2006). Vocalisation at frequencies around 2kHz suggests these species can be classified as hearing specialists.

Chondrichthyes

In a recent assessment of *chrondrichthyan* species, found that 46 species had been recorded in GSV (Baker *et al.* 2008). Some species were likely to occur in GSV, while others are rare visitors (mainly deeper water species) which visit gulf waters infrequently. There are a number of shark species present within GSV that are listed as endangered or vulnerable on the IUCN Red List species. Of the 46 species, the Great white shark (*Carcharodon carcharias*), is the only species of conservation significance found in GSV.

The following *Chondrichthyan* species have been identified as species most likely to occur in GSV and/or protected under legislation.

- Great white shark (*Carcharodon carcharias*)
- White spotted spurdog (*Squalus acanthias*)
- Coastal stingaree (*Urolophus orarius*)
- Elephant fish (*Callorhynchus milii*)

Teleostomi

A number of recreational fish species are known to breed, spawn or feed within GSV. The following recreational species were identified by Bryars (2003) as species likely to be found in the Port Stanvac area

- Bream (*Acanthopagrus sp*)
- Snapper (*Pagrus auratus*)
- Western blue groper (*Achoerodus gouldii*)
- Harlequin fish (*Othos dentex*)
- Southern bluefin tuna (*Thunnus maccoyii*)

Fish and shark audiograms in Figure 3 show the hearing capabilities of several fish species and a shark, in particular showing the lowest sound level that an animal can detect at each frequency. SOURCES: American shad: Mann et al. (1997); goldfish: Jacobs and Tavolga (1967); Atlantic salmon: Hawkins and Johnstone (1978); Atlantic cod: Chapman and Hawkins (1973); bull shark: Kritzler and Wood (1961).

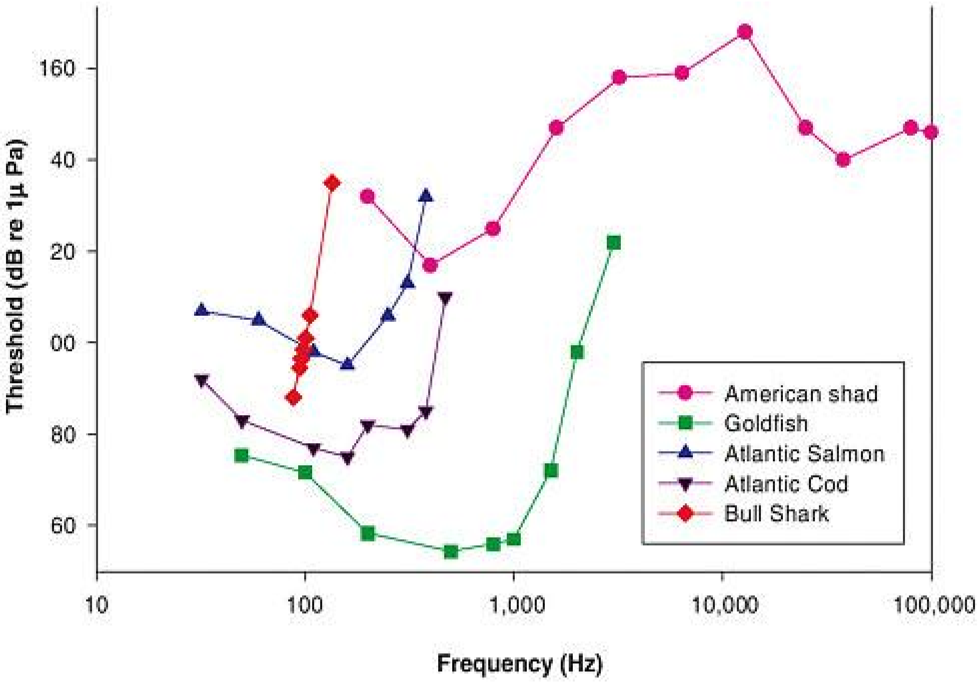

Figure 3 Fish and shark audiograms. Hearing capabilities in several fish species and a shark showing the lowest sound level that an animal can detect at each frequency.

Syngnathids

Gulf St Vincent supports a high diversity of fishes from the *Syngnathidae* family. They are found in a variety of habitats including shallow sheltered mud flats, abundant seagrass meadows, a number of reef types with high algal cover, and extensive mangrove forests. Seagrass meadows can include a mixture of *Posidonia* and *Zostera/Heterozostera* species and is the home to many *syngnathids* . They tend to live in and above the beds which also contain rock patches with *macroalgae* (Browne *et al.* 2008).

It is important to note that while thresholds here are presented in units of pressure, it is very likely that a number of species, including the sharks, respond best to particle acceleration and had experiments been done in terms of acceleration the shapes of the hearing curves might be somewhat different, though it is likely that the range of detection would not change very much. The stimuli in some of these experiments were in the near field where particle acceleration and pressure are not directly related.

3.3 Invertebrates

There are very few data on hearing by marine invertebrates, although a number of species have highly sophisticated structures, called *statocysts*, that have some resemblance to the ears of fishes (Offutt, 1970; Budelmann, 1988, 1992). The *statocysts* found in the *cephalopods* (*octopods* and squid) may primarily serve for determination of head position in a manner similar to the components of the vertebrate ear that determine head position for vestibular senses. It is possible, but not yet demonstrated, that *cephalopods* use their *statocysts* for detection of low-frequency sounds. *Statocysts* and/or proprioception (the sensing of movement of bodily tissue by acoustic energy) may be involved in the ability of squid to detect sound. A study on the impact of a single air gun on squid behaviour demonstrated its sensitivity to sound, in that alarm response (increased swimming behaviour) was observed for a steadily approaching air gun at received sound pressure levels of 156-161 dB re 1µPa, and strong startle response at 174 dB re 1 µPa (firing of ink from ink sacs; McCauley et al. 2000).

There is also some evidence that a number of *crustacean* species, such as crabs, have *statocysts* that are somewhat similar to those found in cephalopods, although they have evolved separately. While there are no data for hearing by marine crabs, a number of species of semiterrestrial fiddler and ghost crabs are not only able to detect sounds but also use special sounds for communication (reviewed in Popper et al., 2001). In addition, a number of physiological studies of *statocysts* of marine crabs suggest that some of these species are potentially capable of sound detection (Popper et al., 2001).

3.3.1 Mollusca

Cephalods

Over 20 species of Cephalopods are found in GSV including squid, cuttlefish and octopuses. The most common to GSV are the southern calamary, red arrow squid, giant Australian cuttlefish, pink cuttlefish, slender cuttlefish, blue ringed octopus, pale octopus, Maori octopus, and the frilled pygmy octopus (Triantafillos 2008). Cephalopod species most likely to be found in the Port Stanvac area include the southern calamary (*Sepioteuthis australis*), the giant Australian cuttlefish (*Sepia apama*) and striped pyjama squid (*Sepioloidea lineolata)*.

- Southern calamary (*Sepiotheuthis australis*)
- Giant Australian cuttlefish (*Sepia apama*)
- Sriped pyjama squid (*Sepioloidea lineolata*)

4. Oceanography and Geology

4.1 Oceanography

Gulf St Vincent is classified as a confined 'inverse estuary', where the salinity levels are higher in the north, at the top of GSV compared to the mouth, varying from 35.5 to 42.0 psu. Waters are transitional warm to cold temperate, with mean sea surface temperatures varying from 12°C in winter to 25.9°C in summer (Baker 2004).

In broad terms, Gulf waters circulate in a clockwise direction with saline water flowing out through Backstairs Passage seasonally, via a gravity current travelling along the eastern sides of GSV from April through to December (Baker 2004).

Currents along the Adelaide's metropolitan coastline travel along the north/south axis, which are seasonally influenced by a variety of different factors including wind direction, temperature and salinity gradients (Pattiaratchi *et al.* 2006).

Tidal range is considered to be microtidal to mesotidal, which equates to approximately 1.2 to 3.3 metre range in the upper Gulf areas, although there are regular periods of minimal tidal movement, known locally as "dodge tides" (Baker 2004). Current speeds range up to 0.5 $m.s^{-1}$ (Pattiaratchi *et al.* 2006).

Gulf waters are generally shallow with a mean depth of 21 m. A maximum depth of approximately 40m occurs in the southern central areas of GSV (off Port Stanvac).

4.2 Bathymetry and Geology

Bathymetry for the site was measured by Marine & Earth Sciences using seismic survey techniques, and the results compare well with the results from a side scan sonar survey (by 3D Marine Mapping). The seabed profile is shown in Figure 4, with contours also shown in Appendix A.

Marine & Earth Sciences also carried out a seismic survey, which involved the use of the seismic reflection and seismic refraction investigation techniques to identify ground conditions at the site. The ground conditions are discussed generally below, and in more detail with regard to the geo-acoustic properties of the various sub-layers. It should be noted that the seismic survey requires the use of an underwater air-gun to provide a high intensity acoustic impulse, with reflections from the various layers of water, sediment and rock used to calculate the type of material under the sea floor.

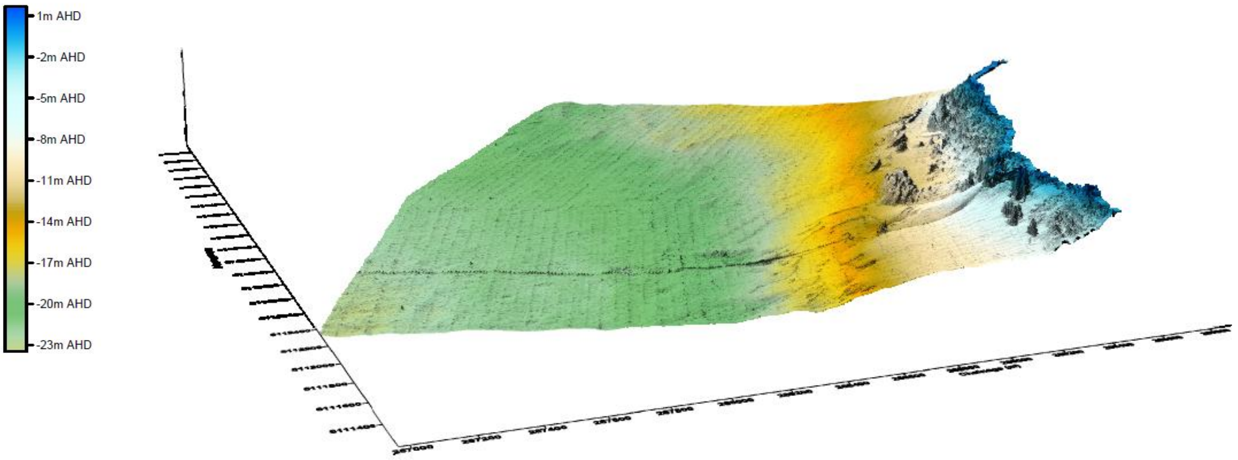

Figure 4 3D Image of bathymetry

4.3 Acoustic Properties

4.3.1 Water

Sound velocity was calculated (Mackenzie 1981) from Conductivity, Temperature, Acidity and Depth casts taken in the area as noted above. The sound speed profiles calculated from the casts were examined and several were excluded for reasons including data anomalies. Sound speed profiles were averaged to determine the sound speed gradient. This representative sound speed profile, based on the average sound speed profile, was used as the input to the noise propagation model to determine the transmission loss. Refer to Table 2 for results.

4.3.2 Geology

Geoacoustic models of the sea floor are basic to underwater acoustics and to marine geological and geophysical studies of the earth's crust, including stratigraphy, sedimentology, geomorphology, structural and gravity studies, geologic history and many others. A "geoacoustic model" is defined as a model of the real sea floor with emphasis on measured, extrapolated, and predicted values of those properties important in underwater acoustics and those aspects of geophysics involving sound transmission. In general, a geoacoustic model details the true thicknesses and properties of sediment and rock layers in the sea floor. A complete model includes water-mass data, a detailed bathymetric chart, and profiles of the sea floor (to obtain relief and slopes). The information required for a complete geo-acoustic model should include the following for each sediment and rock layer:

- Identification of sediment and rock types at the sea floor and in the underlying layers
- True thicknesses and shapes of layers, and locations of significant reflectors (which may vary with sound frequencies)
- Compressional wave (sound) velocity (P-Waves)
- Shear wave velocity (S-Waves)
- Attenuation of compressional waves
- Attenuation of shear waves
- Density
- Additional elastic properties

These properties were measured during the seismic survey, with the results presented in the Technical Report by Marine & Earth Sciences. Three layers of differing seismic velocity were identified at the site. These are presented as velocity contour plots in Appendix A, with the interpreted top of each contoured and overlaid on the plan. The velocity distribution within each layer indicates a more dense/harder band offshore approximately parallel with the coast. The properties of each layer are summarised below:

- Layer 0 : Refer to water quality measurements and estimated sound speeds based on salinity, pH, density and temperature.
- Layer 1 : This layer is located between the sea floor and the top of Layer 2. Interpreted seismic velocities of this layer range from 1,500m/s to 2,180m/s consistent with loose soft sediments to weathered rock/cemented sands and is thickening toward the west (offshore).
- Layer 2 : This layer is located between the base of Layer 1 and the top of Layer 3. Interpreted seismic velocities of this layer range from 1,550m/s to 2,860m/s consistent with loose soft sediments to fresh rock. The level of this layer ranges from-10m AHD near shore up to -30m AHD offshore.
- Layer 3 : This layer is located below the level of Layer 2 and extends to the level of investigation at around 20m sub-bottom. Interpreted seismic velocities of this layer range from 1,600m/s to 4,500m/s consistent with loose soft sediments to fresh, very high strength rock. The top of this layer is very variable and ranges from -22m AHD to -44m AHD

Based on the results of the seismic survey inconjunction with the further detail given by Hamilton (1980), the properties of the sub-floor have been summarised in Table 1 below.

Table 1 Geo-Acoustic parameters for the site to be used in the Acoustic Model for the prediction of underwater noise levels

	Layer 0	Layer 1	Layer 2	Layer 3
Description	Water	Loose soft sediments to weathered rock/cemented sands	Loose soft sediments to fresh rock	Loose soft sediments to very high strength rock
Density (*):	1.0 g/cm^3	1.8 g/cm^3	2.4 g/cm^3	3.0 g/cm^3
Pressure Waves (P-Waves)				
Sound speed:	1545m/s	1750 m/s	2200 m/s	3000 m/s
Sound speed gradient:	0.25 m/s /m	0.5 m/s /m	0.5 m/s /m	0.0 m/s /m
Attenuation (*):	0.0 dB/λ	0.3 dB/λ	0.07 dB/λ	0.10 dB/λ
Shear Waves (S-Waves)				
Sound Speed:	0 m/s	600 m/s	1100 m/s	1500 m/s
Sound speed gradient	0.0 m/s /m	0.5 m/s /m	0.2 m/s /m	0.0 m/s /m
Attenuation (*):	0 dB/λ	15 dB/λ	6 dB/λ	0.20 dB/λ

(*) Gradients could also be input into the model for these parameters.

5. Underwater Noise Concepts and Terminology

5.1 Definition of Underwater Sound

Waves of sound energy travel through air or water as vibration of the fluid particles, with pressure variations exerted on a membrane (or drum, similar for both terrestrial and marine fauna) and converted to electrical stimuli to the brain via sensory cells within the inner ear (this is discussed in greater detail within Section 6.3 and within Nedwell *et al*. (2004)). Frequency is the rate of oscillation or vibration of the fluid particles, measured in cycles per second or Hertz. Sound may be considered to be transient (short duration impulse, eg. blasting) or continuous (eg. noise from shipping).

5.2 Sound Level

Most sound receivers are sensitive to sound pressure (force per unit area), which is measured in micropascals (μPa). Acoustic Intensity (power per unit area) is the fundamental measure of propagating sound, and it is proportional to the average of the pressure squared. The ear responds logarithmically to the intensity of sound, with 1pW/m^2 the threshold of hearing, while 10W/m^2 the threshold of pain. The sound intensity level, and the sound pressure level are referenced to 1pW/m^2 for intensity, and 1μPa (or 20μPa for airborne noise) for pressure, using the following equations:

$$Sound\ Intensity\ Level = 10\log(I / I_{ref})$$

$$Sound\ pressure\ Level = 20\log(P / P_{ref})$$

Typical noise levels for both airborne and underwater noise levels are shown in Table 2. Sound intensity, and sound pressure, decrease with distance from a noise source, and are therefore also referenced to the distance relative to a noise source.

Table 2 Typical airborne and underwater noise levels

Pressure			Typical Airborne Sounds and Human Thresholds	Typical Underwater Sounds and Marine Mammal Thresholds
Pa	dB re 1μPa	dB re 20μPa		
1,000,000	240	214		2kg high explosive, 100m
100,000	220	194		Belluga echolocation call, 1m
10,000	200	174	Some military guns	Airgun array, 100m
1,000	180	154		
100	160	134	Sonic Booms	Large ship at 100m
10	140	114	Discomfort threshold 500m from jet airliner	Fin whale call, 100m
1	120	94		
0.1	100	74	15m from car, 55km/h Speech in noise, 1m	Beluga threshold, 1kHz Ambient, SS4, 1/3 OB at 1kHz
0.01	80	54	Speech in quiet at 1m	Seal threshold, 1kHz
0.001	60	34		Ambient, SS0, 1/3-OB at 1kHz
0.0001	40	14		Beluga threshold, 30kHz
20μ	26	0	Open ear threshold (1kHz)	
10μ	20	-6	Open ear threshold (4kHz)	
1μ	0	-26		

Continuous sound is averaged over time, with the root mean square (RMS) pressure used. However transient sound should be measured in terms of energy, because the sound pressure occurs over a short period of time, and averaging over this period does not allow a comparative measure of the impulse characteristics. Instead, energy is used, as it integrates the power, thereby including time as a variable. The term Sound Exposure Level (SEL) is used with units of dB re 1μPa^{2}s. Transient sound may also be described by the peak sound pressure level.

5.3 Sound Spectra

The distribution of sound power as a function of frequency is termed the sound spectrum. An animal's sensitivity to sound varies with frequency, and its response to a sound is expected to depend strongly on the presence and levels of sound in the frequency band (range of frequencies) to which it is sensitive.

The power spectral density (PSD), is the mean square pressure per unit frequency, in $\mu Pa^2/Hz$ (converted and referenced to a reference unit of $1\mu Pa^2/Hz$, though it is also common to refer to a reference value of $1\mu Pa/\sqrt{Hz}$), obtained by dividing the mean square pressure (from a set of contiguously spaced filter bands) for each filter band by the filter bandwidth.

Integrating the power spectral density over a frequency band of interest gives the power spectrum with the units dB re 1μPa. Two types of proportional bandwidth filters have been adopted as standards: octave band and one-third octave band filters, with the bandwidth proportional to the filter centre frequency.

5.4 Sound Propagation

Sound propagates between two points as follows:

- Refraction : Sound rays are refracted or bent when the physical properties (eg. Sound speed) changes. This could occur at the interface between two media (ie. Water/air or water/soil), or more gradually within a single media (eg. Variation of temperature and density with depth of water).
- Reflection : Sound is reflected at the boundary between two media (eg. Water/air or water/soil).
- Spreading : Sound intensity reduces with distance due to the dispersion of sound waves. Spreading can be spherical (forms in free space without reflection boundaries or refraction), with reduction in the sound pressure level by 6dB per doubling of distance, or cylindrical (forms when sound is constrained between two levels due to reflection or refraction) with reduction in the sound pressure level by 3dB per doubling of distance. Close to a noise source, the reduction with distance does not follow this principle given near field effects (phase relationship between pressure and particle velocity). The maximum distance of near field effects is given by $d = (fa^2)/c = a^2/\lambda$, where f is the frequency (Hz), a is the longest active dimension of the source (m), c is the sound speed in water, and λ is the wavelength (m)
- Absorption : As sound travels, sound power is absorbed by the medium. Absorption losses depend strongly on frequency, becoming greater with increasing frequency.
- Scattering : Process by which sound energy is diverted from a regular path by inhomogeneities in the medium (volume scattering) or roughness at a boundary (boundary scattering).
- Directivity : Sound may be more efficiently radiated from a source in some directions than in others. This is defined by the Directivity Index which is the ratio of sound intensity in a given direction relative to the total source sound power.

The speed of sound within a medium changes according to the density, salinity (or conductivity), acidity (pH) and temperature, all of which vary with oceanographic and geotechnical conditions based on locality.

A sound wave travelling from a source to a receiver reduces in amplitude based on the above parameters (spreading, scattering, absorption, reflection, refraction and directivity). The Transmission Loss (TL) defines the reduction in amplitude at a given distance from a source, or between two locations. The TL is generally expressed in dB, and represents a ratio of powers, intensities or energies of a sound wave between two points.

5.5 Shallow Water Propagation

Whilst the ocean is, in general, a much better carrier of sound than the atmosphere, to the point that whales are known to communicate through vocalisations over distances of hundreds of kilometres, it should be noted that such extremes of propagation can only be achieved for very low frequencies in very deep water. The relatively near shore, shallow water environment of the Pt Stanvac area is much less conducive to long-range sound propagation due mainly to the important attenuating influences of the seabed and sea surface.

The reason for greater sea surface and seabed influence on noise propagation conduction in shallow water than in deep water is that in shallow water the sound reflects from these interfaces quite frequently while in deep water sound can travel significant distances before interacting with the bottom or surface. Hard sea-bed, such as rock, tends to reflect more acoustic energy back into the water than soft sea-bed, such as mud. In shallow depths, as a consequence, seas with hard bottoms are normally better at propagating sound for longer distances than seas with soft bottoms. The situation in shallow water is further complicated for low frequency noises, such as those produced by industrial operations. In these cases there are conditions that can result in very good or very poor sound conduction characteristics that only a sophisticated numerical model can accurately predict.

5.6 Acoustic Model

Various computational models have been developed that allow for the calculation of transmission loss (or the solution of the differential equation relating the space and time variables in an acoustic field), and these are detailed by Jensen *et al.* (2000). These are well summarised by Duncan *et al*.(2006) and Richardson et al (1995), and each of these models represents a different approach to simplifying either the acoustic wave equation (the fundamental mathematical equation that contains all the basic physics of sound propagation) or the model of the environment, or both. Simplification is required in order to allow computer codes to be constructed and to make them computationally efficient. The following types of models have been developed:

- *Modal Theory (range independent)* : Useful for solving the wave equation in shallow water, where the water column acts as a waveguide for a limited number of propagating modes. The wave equation is simplified and so,lved using one of two methods:
  - *Normal Modes* : The wave equation is solved for the most efficient modes of propagation (normal modes). Models developed include : AW, COUPLE, KRAKEN, MOATL, NLAYER, and WKBZ
  - *Wavenumber Integration* : The wave equation is solved for various modes of propagation, which are then integrated. Models developed include : OASES, RPRESS, SCOOTER/FIELDS, and SPARC
- *Ray and Beam Theory* : Useful for deep water, where a small number of rays transmit most of the acoustic energy from a source to a receiver, where there is a direct path from source to receiver, and where only a limited number of surface and bottom reflected paths contribute. Inherently accurate only for high frequencies, and must be modified where they predict infinite intensity (as in focusing, or caustics) or zero intensity (as in shadow zones, where no rays penetrate). Models developed include : BELLHOP, HARPO, RAY, TRIMAIN
- *Parabolic Equation (range dependent)*: This method assumes a solution of the wave equation in the form of an outgoing cylindrical wave. Making the further assumption that energy is propagating at small angles to the horizontal, leads to a simplified parabolic form of the wave equation. Recent developments of this solution have removed this latter impediment, with solutions to this equation using small incremental steps in range and depth to accommodate changes in propagation parameters without developing large errors. Models developed include : FOR3D, MMPE, PDPE, RAM, UMPE

Accuracy of all four model types is dependent on the frequency of sound being modelled and the environmental characteristics. In general, the Parabolic Equation model is used for range-dependent environments at frequencies below 1,000 Hz. Normal mode models can be significantly more efficient for modelling in some environments at frequencies below 1,000 Hz. The accuracy of most normal mode models is limited in strongly range-dependent environments such as the continental shelf and slope. Wavenumber integration models are usually limited to frequencies below 1,000 Hz and are typically limited to range-independent environments, although this approach recently has been extended to range-dependent environments. Ray and Beam Theory models are accurate and efficient for most environments but are limited to frequencies usually above 1,000 Hz.

For all the models mentioned, azimuthal coupling resulting from three-dimensional medium variability (i.e., the transfer of acoustic energy propagating in one azimuthal direction into energy propagating in a different azimuthal direction) is not modelled and is considered less important than the effects of environmental uncertainty.

5.7 Semi-Empirical Models

To accommodate the variability of real world data, semi-empirical propagation models have been designed for application to shallow water. One of these, developed by Marsh and Schulkin (1962) and summarised in Urick (1983), was based on a large number of shallow water measurements from 100Hz to 10kHz. This model includes three basic equations covering different spreading loss conditions:

- Near Source : Sound energy spreads spherically outwards as the rate “20 log R”.
- Intermediate Range : Sound energy spreads outwards at the rate “15 log R”, in between spherical and cylindrical spreading. This range has been termed the mode-stripping range, with higher-order modes with steep grazing angles attenuated more quickly than lower-order modes with shallow grazing angles.
- Long Range : Sound energy spreads outwards at the rate “10 log R”. Only low order modal energy remains.

Marsh and Schulkin give criteria based on water depth and mixed layer depth for determining the ranges where each loss rate applies. Weston (1976) notes the use of these formulas to make reasonable propagation predictions if sound speed is nearly independent of water depth and if the bottom is either flat or slopes uniformly and gradually.

6. Assessment Criteria

6.1 Impacts of Underwater Noise on Marine Fauna

In terms of noise impact, there are several levels to consider. Listed in increasing order of severity, impacts include:

- **Masking** – Man-made noise can interfere with detection of calls, echolocation sounds, and environmental sounds at frequencies similar to the noise. Except for sonars, most sources of man-made noise are at lower frequencies, where masking is largely unstudied in marine mammals.
- **Behavioural Response** – Many marine fauna tolerate man-made noise that is apparently audible but not unduly intense. However, when the level is high enough, they often exhibit avoidance or other behavioural reactions. Few studies have attempted to determine the threshold noise levels that elicit behavioural reactions.
- **Hearing Loss, Discomfort, Injury and Death –** There are limited published data on sound levels, continuous or transient, necessary to cause either temporary or permanent hearing impairment. Criteria have been adapted based on criteria for humans and other terrestrial mammals.

6.1.1 Continuous Noise

Whales may be disturbed by continuous noises above a criterion level of 120 dB re 1 µPa (rms) according to current NMFS standards. Baleen whales have been shown to respond to drillship noises at or above 120 dB (Richardson et al. 1990). The same criterion levels are currently used for *pinnipeds*. Based on the literature reviewed in Richardson et al. (1995), it is apparent that most small and medium-sized toothed whales exposed to prolonged or repeated underwater sounds are unlikely to be displaced unless the overall received level is at least 140 dB re 1 µPa. The 120 dB re 1 µPa (rms) criterion has been adopted in the present analysis.

Smith et al (1996) has measured sound pressure levels between 167-179 dB re 1uPa, and shown that these levels cause a 10dB Temporary Theshold Shift (TTS) bareheaded divers after a 15 minute continuous noise exposure. Fothergill et al (2000,2001) have carried out studies on divers to assess their aversion to low and mid frequency noise, with the results summarised in Table 3 and Table 4.

Table 3 Bio-effects of underwater sound (100 to 500Hz)

Sound Pressure Level (dB re 1uPa)	Effect (100-500 Hz)
>184	Based on animal models liver haemorrhage and soft tissue damage are likely.
>170	Tolerance limit for divers and swimmers. Sound causes lung and body vibration.
148-157	The loudness and vibration levels become increasingly aversive. Some divers will contemplate aborting an open water dive.
140-148	A small number of divers rate the sound as 'very severe
136-140	The sound is clearly audible. The majority of divers tolerate the sound well with only "Slight" aversion.
130	Divers and swimmers able to detect body vibration
80-100	Auditory Threshold

Table 4 Bio-effects of underwater sound (500 to 2500Hz)

Sound Pressure Level (dB re 1uPa)	Effect (500-2500 Hz)
>190	Hooded diver tolerance limit
167-185	Tolerance limit for barehead divers and swimmers. Sound causes dizziness and disorientation. Divers in suit and hood are able to tolerate the sound well.
155-166	Divers tolerate these sounds well, although an increasing number of bareheaded divers indicate a 'severe' aversion rating.
140-154	Sound is clearly audible to divers. Sound is tolerated well with only slight aversion.
100-140	Divers hear underwater sound, but it is masked by exhaust bubble noise.
80	Hearing threshold for hooded divers
65	Hearing threshold 65 for barehead divers

6.1.2 Transient Noise

For pulsed sounds, a broadband received sound pressure level of 180 dB re 1 μPa (rms) or greater is to be used as an indication of potential concern about temporary and/or permanent hearing impairment (Level A Harassment) to cetaceans (Madsen 2005; NMFS 2003). Level A Harassment is defined as "any act of pursuit, torment, or annoyance which has the potential to injure a marine mammal or marine mammal stock in the wild" (NRC 2003). The criterion to reduce the potential for Level A Harassment to *pinnipeds* from pulsive sounds is exposure to received levels of 190 dB re 1 μPa (rms) or greater.

A broadband received sound pressure level of 160 dB re 1 μPa (rms) or greater is currently the best estimate available to indicate potential concern to cause disruption of behavioural patterns (Level B Harassment) to marine mammals. Level B Harassment is defined as "any act of pursuit, torment, or annoyance which has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioural patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering but which does not have the potential to injure a marine mammal or marine mammal stock in the wild" (NRC 2003).

6.2 Proposed Assessment Criteria

The assessment criteria have been based on limits with respect to the most sensitive mammals, namely humans, cetaceans and carnivores (Table 5).

Table 5 Assessment Criteria

Species	Source Character	Unit	Organ Damage	Hearing Damage (PTS or TTS)	Behavioural Response
Marine Fauna	Continuous	dB re 1μPa (RMS)	185	140	120
	Impulse		200	*170*	160
Human	Continuous		185	155	140
	Impulse		200	170	160

7. Ambient Noise Survey

7.1 General

The dominant physical mechanisms of naturally occurring sound in the ocean occur at or near the ocean surface. Most are associated with wind fields acting on the surface and the resulting surface wave activity (Table 6). In the absence of man-made, biological, and transient sounds, ambient noise is wind dependent over the band from below 1 Hz to at least 50 kHz. Below 5-10 Hz, the dominant ambient noise source is the nonlinear interaction of oppositely propagating ocean surface waves. Across most of the remainder of this band, the primary sources are bubbles that are oscillating, both individually and collectively in a cloud, in the water column. Several good references on natural physical sources of ocean noise and the properties of the ambient noise field are available (e.g., Urick, 1984; Zakarauskas, 1986; Ross, 1976; Kerman, 1988, 1993; Buckingham & Potter, 1995; Leighton, 1997; Deane, 1999).

The average ocean noise spectrum can be empirically described and parameterized according to sea state (Knudsen *et al*. 1948). These Knudsen curves are straight lines of spectral density as a function of frequency when plotted on a logarithmic scale. The parallel nature of the “curves” for various sea states signifies that the noise level increases with increasing sea state by the same amount at all frequencies. Although developed more than a half-century ago, the Knudsen curves continue to be widely used to predict natural ocean noise levels at frequencies from 1 to 100 kHz. The pioneering Knudsen’s curves of noise as a function of sea state have been very useful for many years and are remarkably effective, but it is now well established that the noise is correlated much better with wind speed than with sea state or wave height (correlation of wind speed and sea state only occurs in equilibrium conditions). This correlation with wind speed allows much more effective prediction and forecast (from wind forecasts) than could be obtained from sea state, which is difficult to estimate reliably. Probably the most widely used models of the ambient component of ocean noise continue to be the curves developed by Wenz (1962); (see also Richardson *et al*. 1995). These provide a summary of average ambient noise spectra from various sources, as shown in Figure 5.

Table 6 Interrelationships of wind speed, Beaufort wind force, sea state, and wave heights on the open sea

<table>
<tr><th colspan="2">Wind Speed</th><th rowspan="2">Beaufort Wind Force</th><th rowspan="2">Description</th><th rowspan="2">Sea State (SS)</th><th rowspan="2">Wave Heights (m)</th><th rowspan="2">Description</th></tr>
<tr><th>Knots</th><th>(m/s)</th></tr>
<tr><td><1</td><td><0.5</td><td>0</td><td>Calm</td><td>0</td><td>0</td><td>Glassy</td></tr>
<tr><td>1-3</td><td>0.5-1.5</td><td>1</td><td>Light air</td><td>0.5</td><td><0.1</td><td>Ripples</td></tr>
<tr><td>4-6</td><td>2.1-3.1</td><td>2</td><td>Light breeze</td><td>1</td><td>0 - 0.1</td><td>Calm</td></tr>
<tr><td>7-10</td><td>3.6-5.1</td><td>3</td><td>Gentle breeze</td><td>2</td><td>0.1 - 0.5</td><td>Smooth</td></tr>
<tr><td>11-16</td><td>5.7-8.2</td><td>4</td><td>Moderate breeze</td><td>3</td><td>0.5 - 1.25</td><td>Slight</td></tr>
<tr><td>17-21</td><td>8.7-10.8</td><td>5</td><td>Fresh breeze</td><td>4</td><td>1.25 - 2.5</td><td>Moderate</td></tr>
<tr><td>22-27</td><td>11.3-13.9</td><td>6</td><td>Strong breeze</td><td>5</td><td>2.5 - 4</td><td>Rough</td></tr>
<tr><td>28-33</td><td>14.4-17.0</td><td>7</td><td>Near gale</td><td rowspan="3">6</td><td rowspan="3">4-6</td><td rowspan="3">Very rough</td></tr>
<tr><td>34-40</td><td>17.5-20.6</td><td>8</td><td>Gale</td></tr>
<tr><td>41-47</td><td>21.1-24.2</td><td>9</td><td>Strong gale</td></tr>
<tr><td>48-55</td><td>24.7-28.3</td><td>10</td><td>Storm</td><td>7</td><td>6-9</td><td>High</td></tr>
<tr><td>56-63</td><td>28.8-32.4</td><td>11</td><td>Violent storm</td><td>8</td><td>9-14</td><td>Very high</td></tr>
<tr><td>>64</td><td>>33</td><td>12</td><td>hurricane</td><td>9</td><td>14</td><td>Phenomenal</td></tr>
</table>

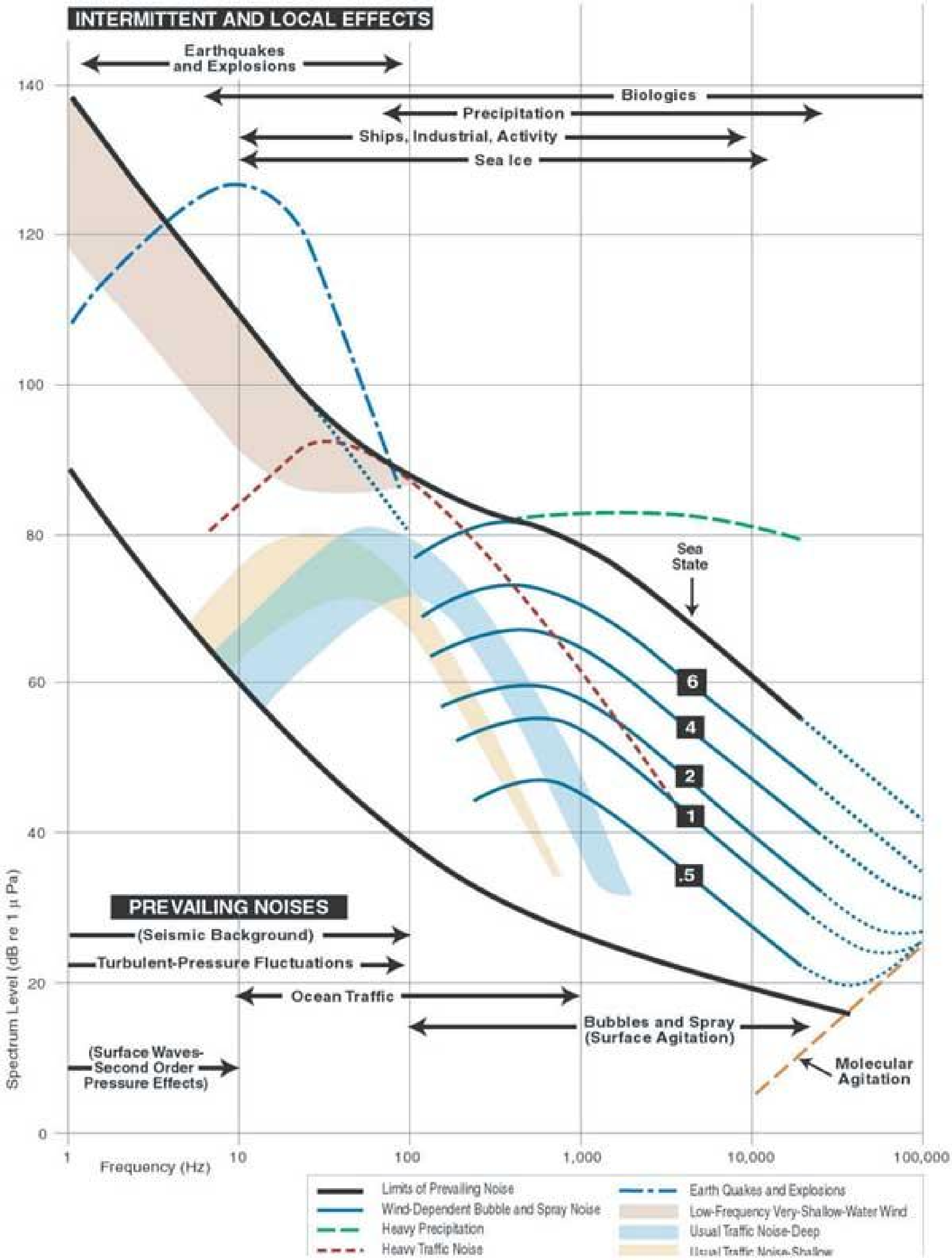

Figure 5 Wenz Curves for Ambient Underwater Noise

Although open-ocean breaking wave noise is correlated with wind speed, local winds are not required to create the sounds from breaking surf. The sound created by spilling breakers (breaking begins at the wave crest and proceeds down the face of the wave) is primarily at the higher frequencies, whereas that from plunging breakers (the water at the wave crest leaps ahead of the wave in a jet, encompassing a large column of air) is significantly greater in levels and in frequency bandwidth. Plunging surf can raise underwater noise levels by more than 20 dB a few hundred meters outside the surf zone across the band from 10 Hz to 10 kHz (Wilson *et al*. 1985).

Precipitation on the ocean surface also contributes sound to the ocean. Rain can increase the naturally occurring ambient noise levels by up to 35 dB across a broad range of frequencies extending from several hundred hertz to greater than 20 kHz. For drizzle in light winds, a broad spectral peak 10-20 dB above the background occurs near 15 kHz (Nystuen & Farmer 1987; measurements made at 7.5 m depth in an 8 m deep spot in a soft-bottom lake (Nystuen 1986).

7.2 Shallow Water Ambient Noise

Zakarauskas (1986) characterised shallow water as an area where the acoustic wavelength is of the same order as the water depth (eg. 7.5Hz has a wavelength of 200m). A wider range of ambient noise levels occur in shallow than in deep water under corresponding wind and wave conditions. In shallow water, the highest level can be higher, and the lowest level lower than those in deep water. Above about 500Hz, levels are often 5-10dB higher in coastal than in deep water with corresponding wind speeds (Urick 1983). However, when shipping and biological noise are absent, low frequency noise levels (less than 300Hz) in shallow water can be lower than expected in deep oceans (Urick 1983). Bottom conditions have a large influence on shallow water ambient noise (Urick 1983). Ambient noise levels tend to be high where the bottom is very reflective and low where it is absorptive.

7.3 Instrumentation and Methodology

Measurements were made using a Reson TC4034 (sensitivity of -220dB re 1V/Pa) hydrophone together with a Voltage Preamplifier/Filter (Model EC6081), used to provide the ability to increase the signal strength (i.e., add gain), so that measurements were made within the dynamic range of the instruments used to analyse the signals. The Voltage Preamplifier/Filter was also used as a low pass filter to eliminate any possible aliasing effects. The signal was fed into both a Larson Davis Model 2900 Real Time Analyser, to provide narrow-band frequency and waveform analysis (1Hz to 20kHz), and a Fostex FR2 Field Memory Recorder to record a Broadcast Wave Format audio file (sampled at 192kHz, with 24bit resolution) that could be later analysed in Matlab to extend the frequency range to 100kHz. The hydrophone was suspended from a bouy to minimise mechanical self-generated noise from boat movements. Calibration certificates for the equipment are also provided in Appendix B. The audio specifications of this equipment are provided in Appendix C.

7.4 Results

The meteorological conditions during the survey were as noted in Table 7 below, with a gentle to moderate breeze and smooth to slight waters. The sound power density spectrum was measured at a range of positions as noted in Table 8, with the location confirmed on a GPS, and the depth confirmed from a sonar.

Table 7 Meteorological Conditions

Parameter	9am	3pm
Wind Speed	22 km/h	33 km/h
Wind Direction	NNE	NNW
Temperature (Air)	19°C	24°C
Temperature (Sea)	16°C	16°C
Swell	0.5 m	0.5 m

Table 8 Survey locations for ambient noise

Location	X	Y	Depth
#23	268821	6112040	15.95
#31	268321	6112540	22.00
#41	268821	6113040	20.50
#52	269821	6113540	13.50
#59	268821	6114040	21.00

Ambient noise measurements are shown in Figure 6 at a range of survey locations. The results are consistent with those expected based on the Wenz curves. Low frequency noise levels were considered excessive due to the difficulty of minimising noise from wave motion of the hydrophone, and passing currents. Noise measurements were also taken of a ship movement during passage along the Outer Harbour Channel, with the results shown in Figure 7. These results will be compared with auditory thresholds of marine fauna.

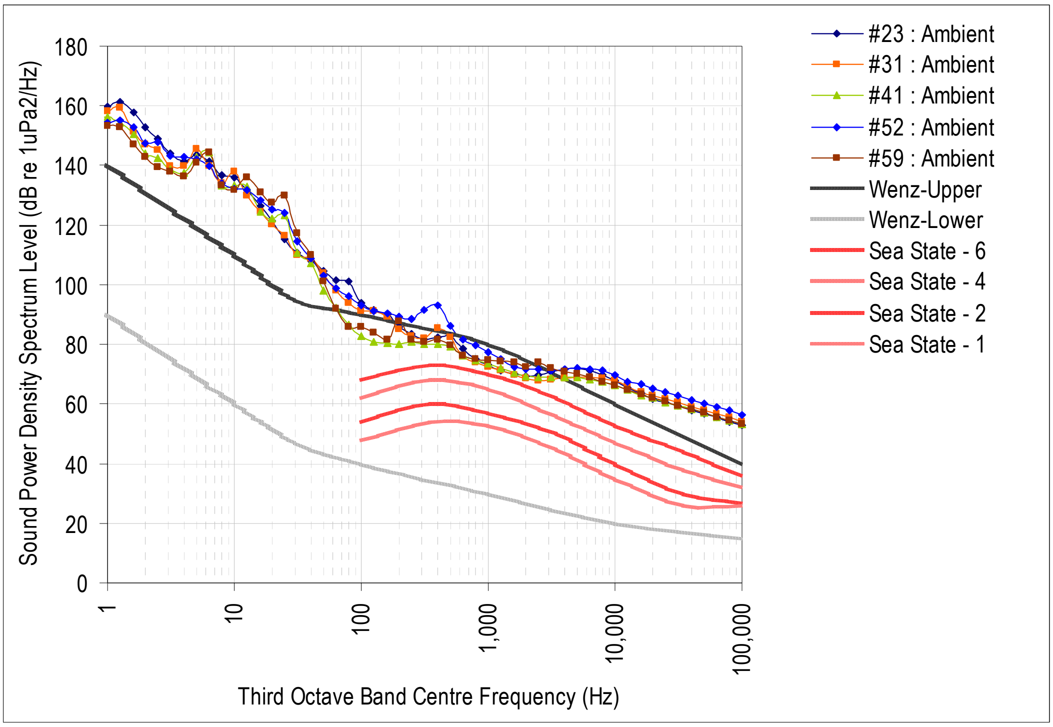

Figure 6 Ambient noise monitoring results using a hydrophone

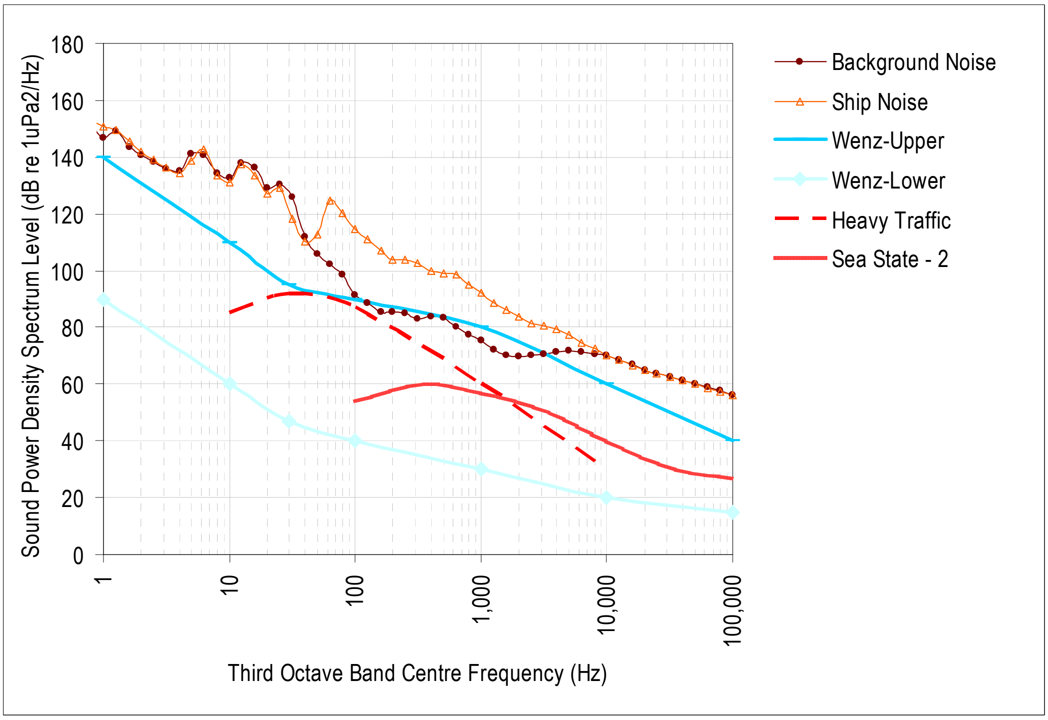

Figure 7 Survey of ambient and ship noise alongside the Outer Harbour shipping channel

Anthropogenic Noise Sources

A summary of the sound pressure levels measured at 1m and the types of noise sources to be used in the noise model are summarised below in Figure 8. A detailed discussion outlining the basis for these source levels is given below (note that the Dredge, Drilling and Ship operations all overlay). The sound power density spectrum was measured at a range of positions as noted in Table 8, with the location confirmed on a GPS, and the depth confirmed from a sonar.

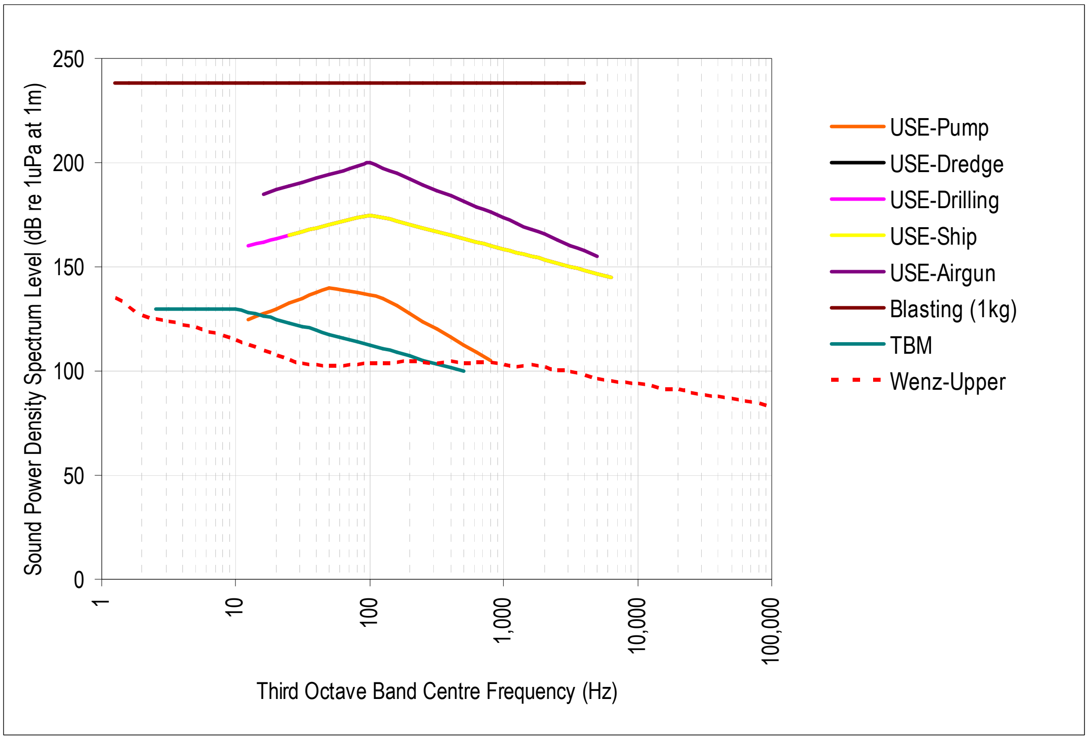

Figure 8 Source sound pressure levels (dB re 1uPa at 1m) to be used in the noise model.

Table 9 Broadband source sound pressure levels approximated from 1m levels to other distances.

Source	Sound Pressure Level (dB re 1uPa at 1m)				
	At 1m	At 10m	At 100m	At 1km	At 10km
Explosives	246-254	226-224	216-224	206-214	196-204
Airgun	206	186	176	166	156
Dredge Drillship Support Vessels	182	162	152	142	inaudible
Pump	147	127	inaudible		
Tunnel Boring Machine	140	120	inaudible		
Ambient Noise	137-142				

7.5 Construction

7.5.1 Airguns, Boomers & Sparkers

Airguns are the most common energy source for marine geophysical surveys. Airguns function by suddenly venting high pressure air into water. This produces an air filled cavity that expands violently, then contracts, and re-expands; sound is created with each oscillation. Although a single airgun is sometimes used, seismic surveys are usually conducted by towing an array of airguns at a depth of 4-8m behind a small ship. Typical sound pressure levels for an airgun as reported by Miles *et al.* (1987), are shown on Figure 10. The seismic survey used a Bolt 600b Airgun with a 40cu inch chamber. The source levels noted by Miles were for an airgun with a 28.7 (about 900 cu.inch) litre chamber, and given the reduced chamber capacity of the airguns used previously, and the peak pressure versus chamber volume, the source level to be used in the noise model has been modified.

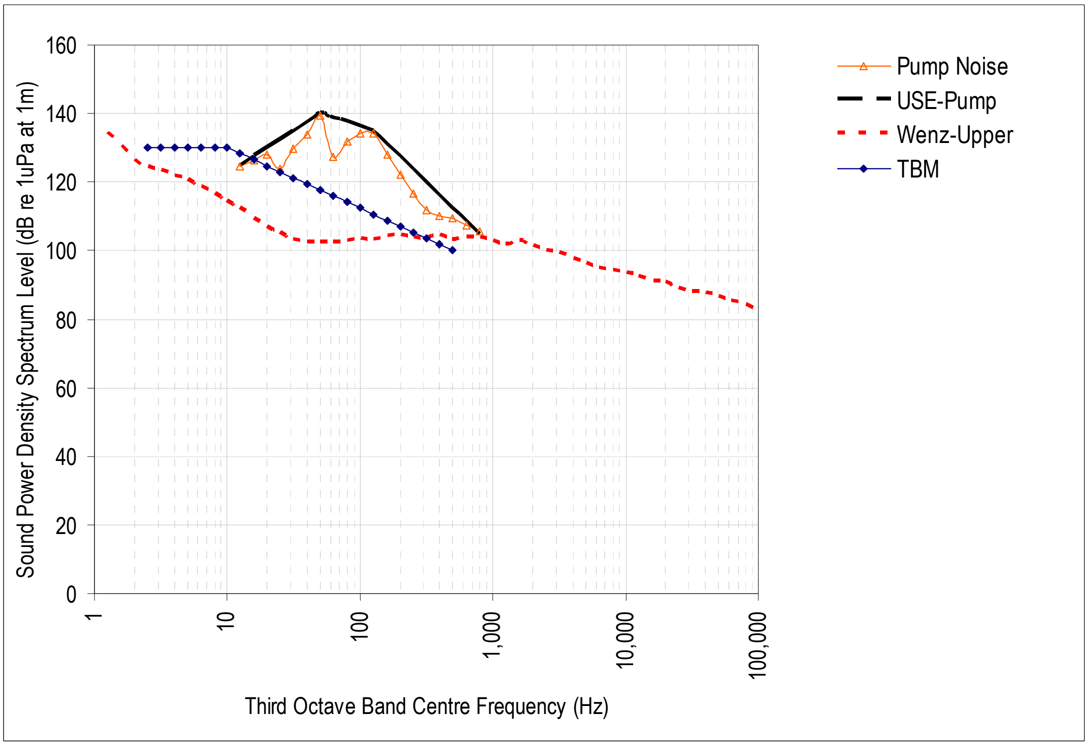

Figure 9 Source levels for underwater noise from pumps and tunnel boring machines (TBMs), and the proposed source levels to be used in the noise model.

7.5.2 Blasting

The underwater pressure signature of a detonating explosion is composed of the intial shock pulse followed by a succession of oscillating bubble pulses if the explosion is sufficiently deep not to vent through the surface. The peak pressure is given by:

$$P_{peak} = 5.24.10^{13}(W^{1/3}/R)^{1.13} \quad \mu Pa$$

The peak pressure from explosives of 1kg and 10kg charge weight are shown in Figure 10.

7.5.3 Dredging

As an alternative to tunnel boring, a dredge will be used to cut and fill the trench for the intake and outfall pipelines. There are typically three types of dredges :

- Cutter-Suction Transfer : Moored or anchored ships that extends suction pipes to the seafloor and discharge pipes to a barge or discharge site. A cutter head loosens gravel, which is pumped through a pipe to the discharge site.
- Hopper : Ship that moves over a dredging site, fills its hoppers, then travels to a discharge site to offload material, or alternatively offloads underwater alongside the trench.
- Clamshell : Pulls up large scoops of gravel within opposing buckets that clamp together, with barges used the dredged material to site.

It is assumed that a Hopper Suction Dredge will be used for the proposed works. Noise levels from these different types of dredges are comparable. Appendix C provides a database of measured sound pressure levels, with sound pressure levels from both the Geradus Mercator and Taccola used to define the source levels used herein and shown on Figure 11.

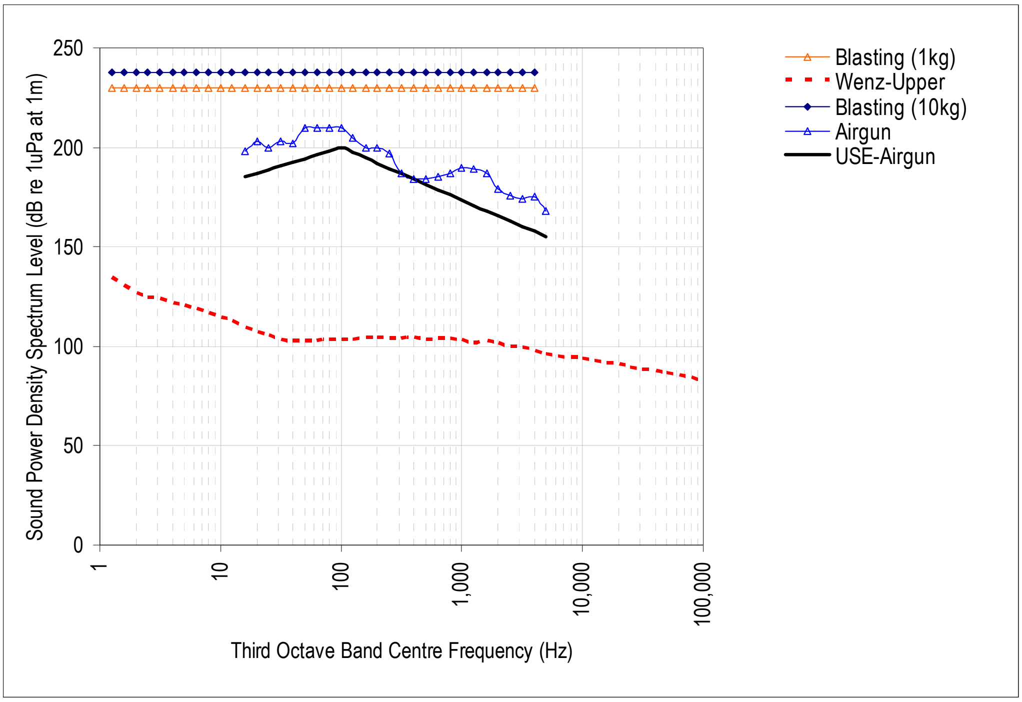

Figure 10 Source levels for airguns and explosives

7.5.4 Support Vessels

The primary sources of noise from all vessels are propeller cavitation, propeller singing, and propulsion or other machinery. Propeller cavitation is usually the dominant noise source (Ross, 1976). Propeller singing arises when vortex shedding frequencies reinforce a resonant vibration frequency of a propeller blade. Propulsion machinery originates inside the vessel and radiates into the water via structural connections to the hull. Appendix C provides a database of measured sound pressure levels from various types of vessels, with these summarised on Figure 11, together with the proposed source level to be used in the noise model.

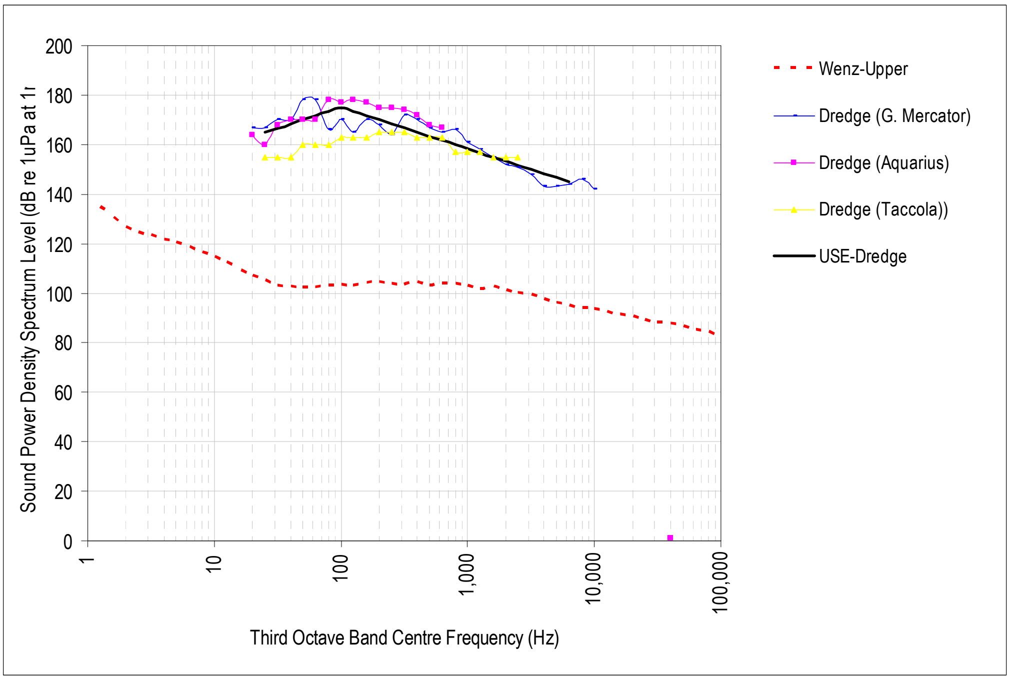

Figure 11 Source levels for Dredges

7.5.5 Drilling

Vessels used for offshore drilling include semi-submersibles, and drillships. They can be either anchored firmly or dynamically positioned, and they are accompanied by supply vessels. Drillships are apparently noisier than semisubmersibles, as the drillship hull contains the rig generators, drilling machinery and the rig itself. It is assumed that a drillship will be used for this development, with source level to be used in the noise model, in comparison with measured source levels from drill ships (refer to Appendix C) shown on Figure 12.

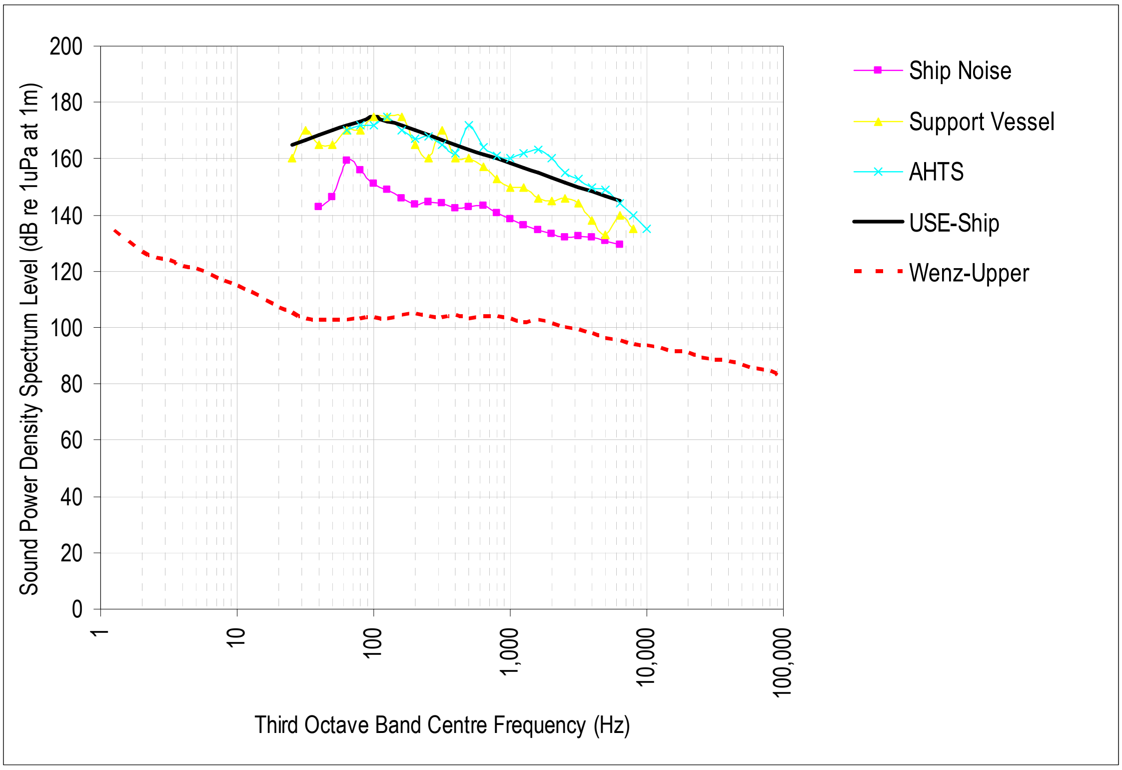

Figure 12 Source levels for a variety of vessels, and the proposed source level for support vessels to be used in the noise model.

7.5.6 Tunnelling

As an alternative to dredging, a tunnel boring machine will be used to pipe-jack the intake and outfall pipelines. A study conducted by Malme and Krumhansl (1993) to evaluate the effects of noise associated with a tunnel boring machine (50 head Robbins machine) used to construct the new sewage outfall for the Massachusetts Water Resources Authority (8m diameter tunnel) measured maximum sound pressure levels of about 120-130dB below 10Hz, reducing in energy with increasing frequencies up to about 500Hz. Typical sound pressure levels for this operation are shown on Figure 13.

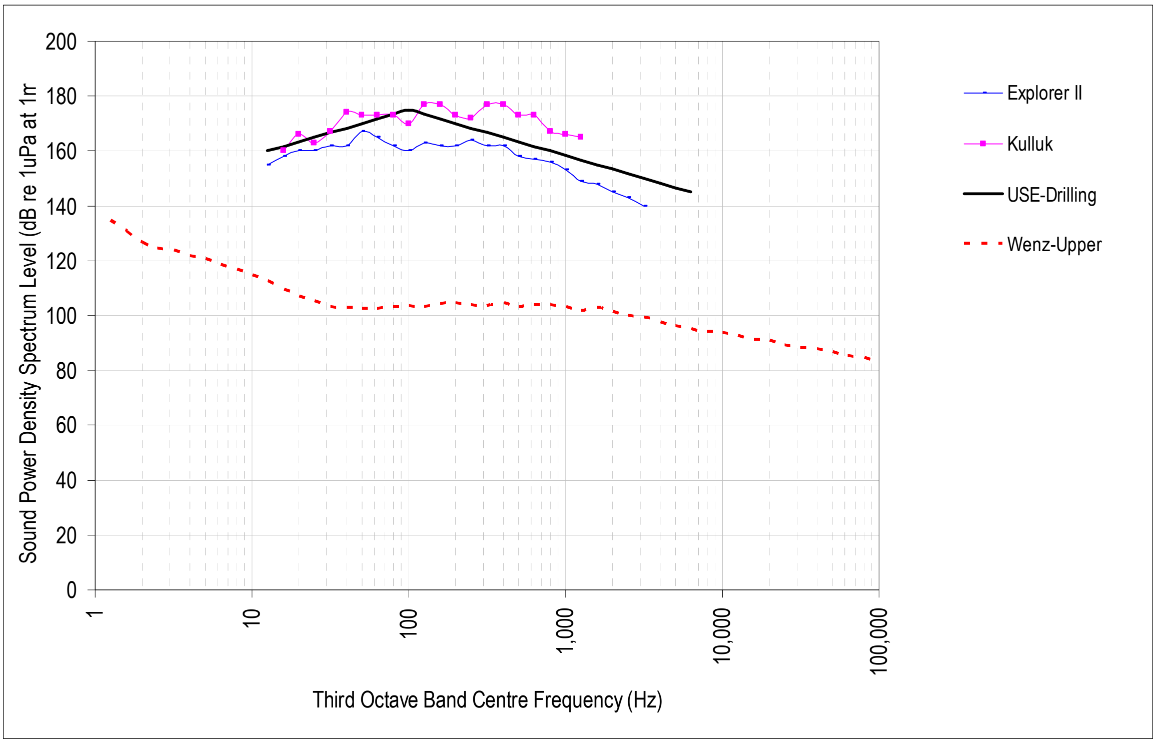

Figure 13 Source levels for drill ships, and the proposed source level to be used in the noise model.

7.6 Operation

7.6.1 Pumps

Pumps used for typical ship applications have been seen to create fluid-borne source levels in the fluid being pumped with amplitudes of 130 -180 dB re 1 µPa at low frequencies (<200 Hz), and possibly higher for very large pumps. Note that these levels are dependent on the type of pump, impeller dimensions, speeds of operation, load, etc. (Spence, 2006). On this basis, and from previous underwater noise measurements in the vicinity of similar large scale pump installations, the source noise level to be used in the noise model in shown on Figure 13.

7.7 ADP potential impacts

There are a number of potential activities relating from the proposed ADP. The constructions of the intake and outfall pipelines in particular pose the largest potential impact in terms of noise and vibration within the marine environment. The concept design and the Request For Proposal (RFP) documents have both included an 'envelope' within which the intake and outfall structures should be located. The envelope has been defined by water quality, hydrodynamic attributes and habitat sensitivity.

The concept design for the Intake and Outfall structures presents three possible options for the construction of the intake and outfall conduits from the ADP out to the respective intake structure/s and diffusers. These options include: a full pipeline option (FPO); a hybrid tunnel option (HTO); and a full tunnel option (FTO). The details are presented in the following section.

Only the hybrid tunnel and the full tunnel option are considered in the final design of the ADP due to substantial environmental concerns associated with the full pipeline construction method. In addition to this, the requirement for no blasting within the marine environment has also been incorporated within the ADP EIS.

7.7.1 Hybrid Tunnel Option

This option is a combination of the FPO and FTO, and involves the construction of a tunnel or tunnels out past the shore rocky platform and then trenched pipelines out to the intake structure and diffusers. This option would be generally constructed as follows:

- The construction of a deep shaft or shafts adjacent to the desalination plant to enable the tunnel/s construction. For the intake conduit/s a shaft would be used to house the pump station required to pump the seawater up to the desalination plant. For the outfall conduit/s, a shaft would be used for a drop structure, which would house energy dissipation systems required to prevent the water aerating when it is dropped into the shaft. Whilst aeration is encouraged for water quality benefits, excess aeration leads to foaming and hydraulic inefficiency;
- The first section of the main conduits would be constructed by tunnelling methods beneath the cliffs and seabed from the shafts at the desalination plant out to a point past the shore rocky platform. The tunnels would most likely be constructed by a pipe jack machine or tunnel boring machine;
- Riser structures are then required from the end of the tunnel/s up to the sea bed. These risers are generally constructed by sinking a shaft from a barge and then casting the structure into the shaft; and
- The remaining sections of the intake and outfall conduits would be trenched and backfilled out from the point beyond the shore break to their respective intake structure/s and diffuser locations. These trenches would be approximately 3 m deep.

7.7.2 Full Tunnel Option

The FTO, involves the construction of a tunnel or tunnels the full distance out to the intake structure/s and diffusers off shore. This option would be generally constructed as follows:

- The construction of a deep shaft or shafts adjacent to the desalination plant to enable the tunnel/s construction. For the intake pipeline a shaft would be used to house the pump station required to pump the seawater up to the desalination plant. For the outfall pipeline a shaft would be used for a drop structure, which would house energy dissipation systems required to prevent the water aerating when it is dropped into the shaft;
- The main intake / outfall structures would be constructed by tunnelling beneath the cliffs and seabed from the shafts at the desalination plant out to the respective intake structure/s and diffusers. The tunnels would be likely excavated by tunnel boring machines; and
- Riser structures are then required from the end of the tunnel/s up to the sea bed at the intake structure/s, and diffuser locations. These risers are generally constructed by sinking a shaft from a barge and then casting the structure into the shaft.

As such the main impacts of the ADP in terms of noise impacts on the marine environment during construction are likely to be:

- Rock removal (utilising non-explosive blasting or vibrocoring)
- Dredging and excavation
- Support vessels
- Tunnelling (either pipe-jack or tunnel boring machine)

During operations the likely noise sources would be the pumps and the water moving through the pipelines.

8. Noise Model and Predicted Underwater Noise Levels

8.1 Noise Model

The acoustic propagation algorithm used is a modified version of the programme RAM (acronym for Range-Dependent Model) by Michael Collins, U.S. Naval Research Laboratory. Because the original RAM model does not account for shear wave losses caused by the significant bottom interactions that occur in shallow or near-shore environments, shear wave losses have therefore been incorporated into the noise model using the complex density approach outlined by Zhang and Tindall (1995), with the extended model termed RAMSGeo.

Furthermore the self-starter (procedure to generate the initial acoustic field at the source) from RAM has been replaced by a weighted Gaussian approach, known as Green's starter, to account for the partially depth distributed nature of noise from large vessels in the near field. This enhanced starter provides essentially identical results as Collins' self-starter in the far field, but is more accurate in the prediction of noise at closer ranges.

8.2 Sensitivity of Input Parameters

The parameters that define the running of the model are primarily related to the acoustic environment in which the sound propagates both in the water column and in the sea bottom. Table 10 below provides an overview of all the parameters on which modelling is based, their influence on the results, their variability in time and location, and the degree of confidence to which they are known. On the basis of this analysis the model can be considered a sufficiently reliable forecasting tool for use in noise control planning and decision-making.

Table 10 Acoustic model sensitivity to input parameters

Model Parameter	Influence on results	Topographic variability	Seasonal variability	Confidence level
Source noise spectrum	High	n/a	n/a	Adequate (based on a database of measured source noise levels)
Bathymetry	High	Moderate	None	High (based on survey results)
Sound velocity vertical profile in water column	Moderate	Moderate	Moderate	Adequate (based on water quality survey results)
Sound velocity vertical profile in bottom sediment	Moderate	Moderate	Moderate	Adequate (based on seismic survey results)
Sound attenuation vertical profile in bottom sediment	Low	Moderate	None	Adequate (based on published data for measured results for geology, Hamilton (1980))
Density vertical profile of bottom sediment	Low	Moderate	None	Adequate (based on published data for measured results for geology, Hamilton (1980))
Shear wave velocity in bottom sediment	Moderate	Moderate	None	Adequate (based on published data for measured results for geology, Hamilton (1980))
Shear wave attenuation in bottom sediment	Low	Moderate	None	Adequate (based on published data for measured results for geology, Hamilton (1980))

8.3 Accuracy and Validation

The algorithm has been benchmarked against test data sets provided in the open scientific literature and is compliant with recognized underwater acoustic modelling standards. This model has been used in past contracted work for precise estimation of noise produced by sub-sea construction noise, marine facilities operation and seismic exploration in locations that include the Gully oceanic region off Nova Scotia, the Beaufort Sea, Queen Charlotte Basin in British Columbia and Sakhalin Island in Eastern Russia.

The model has been extensively validated against field measurements in the course of complex undersea construction operations. Figure 14 provides an example of the accuracy of the model in predicting the aggregate noise levels over an area from four vessels performing a dredging and pipe-laying operation. The spectral source levels of the individual vessels, which had been measured independently and in different locations, were used as input to the model along with locally measured water column and geo-acoustic parameters. The actual received levels from a line of sonobuoys are in agreement with the model results to within about 2 dB.

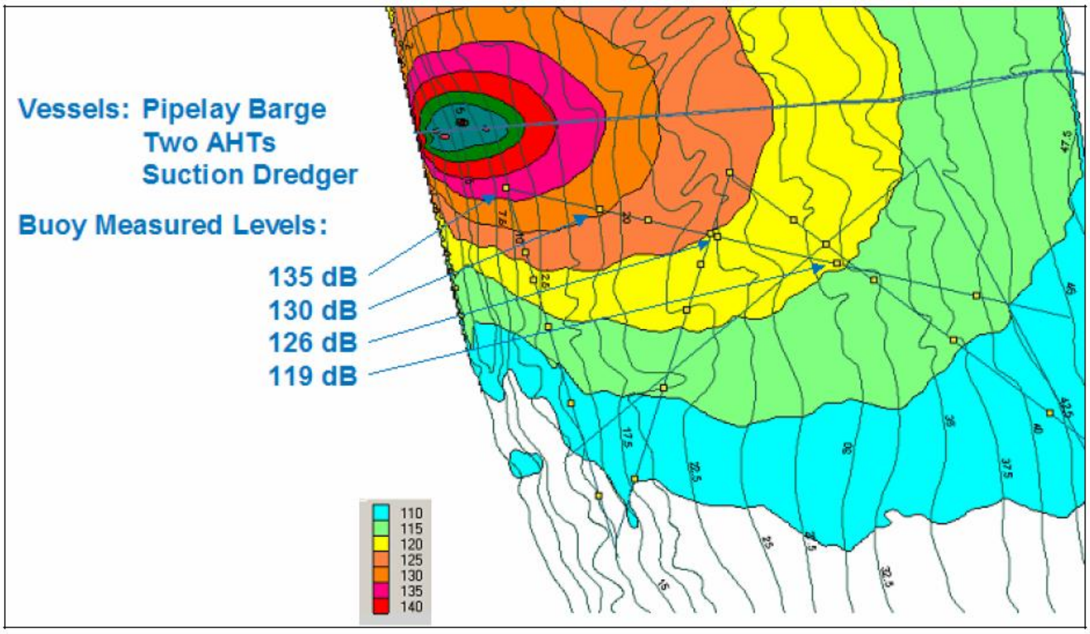

Figure 14 Accuracy of prediction model.

8.4 Method

RAMSGeo computes frequency-dependent sound transmission loss parameters along tracks originating from each point in a specified set of source positions. The modelling is performed in individual third-octave spectral bands covering frequencies from 10Hz to 2 kHz, which encompasses the overlap between the auditory frequency range of marine mammals and the spectral region in which sound propagates significantly beyond the immediate vicinity of the source. The transmission loss values produced by the model for each source location are used to attenuate the spectral acoustic output levels of the corresponding noise source to generate absolute received sound levels along each track; these are then summed across frequencies to provide broadband received levels.

9. Predicted Noise Levels

Based on the bathymetry and the geo-acoustic parameters for the sub-layers (refer to Appendix A), the transmission loss was predicted versus depth and range for two tracks:

- Track A : Runs North-South parallel to the shore. Bathymetry was assumed constant with a depth of 20m. The transmission loss versus range and depth is shown in Figure 16 and Figure 17.
- Track B : Runs East-West, with the West track equivalent to Track A, while the sea floor converges with proximity to the shore. The transmission loss versus range and depth is shown in Figure 18 and Figure 19.

Curves of transmission loss were generated for each track and for each octave band. The results were then applied to the sound pressure levels of the noise sources to provide an estimate of noise levels at given distances from the source, as presented in Figure 15.

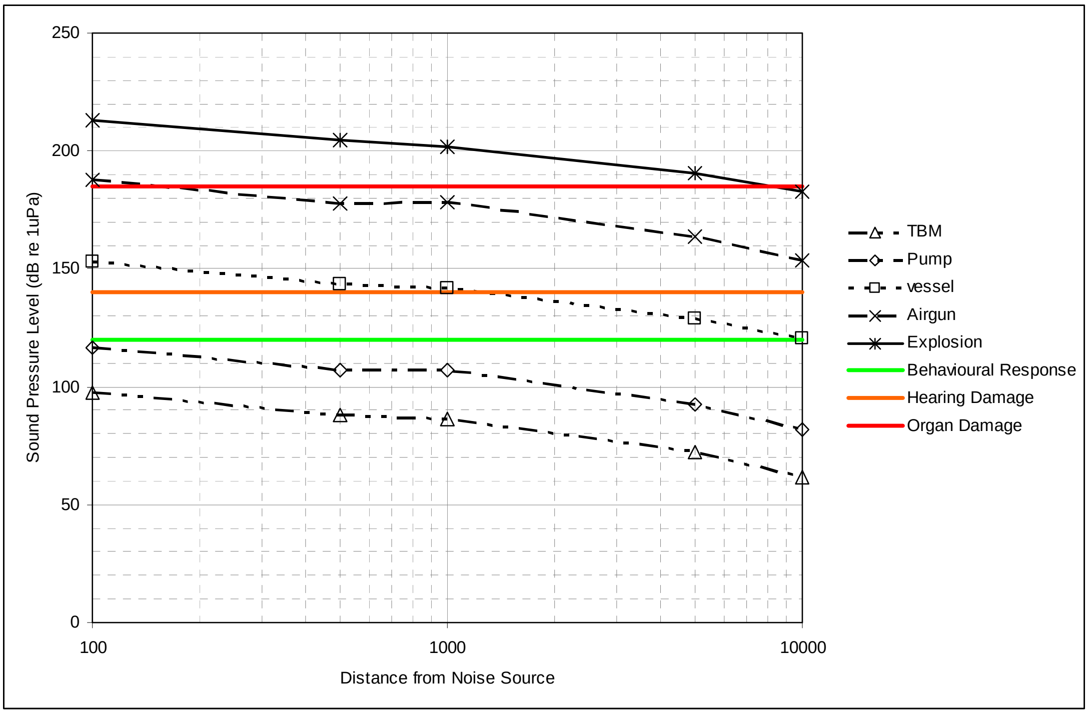

Figure 15 Predicted broadband noise levels

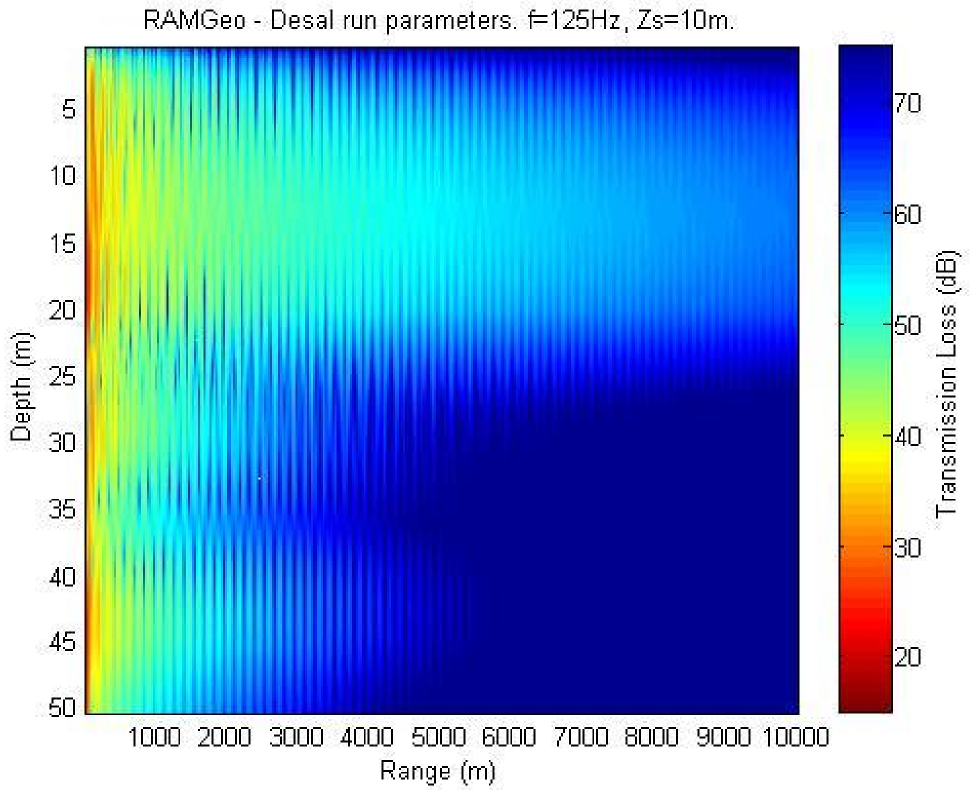

Figure 16 Transmission Loss versus Range and Depth for Track A (North-South) for an octave band frequency of 125Hz

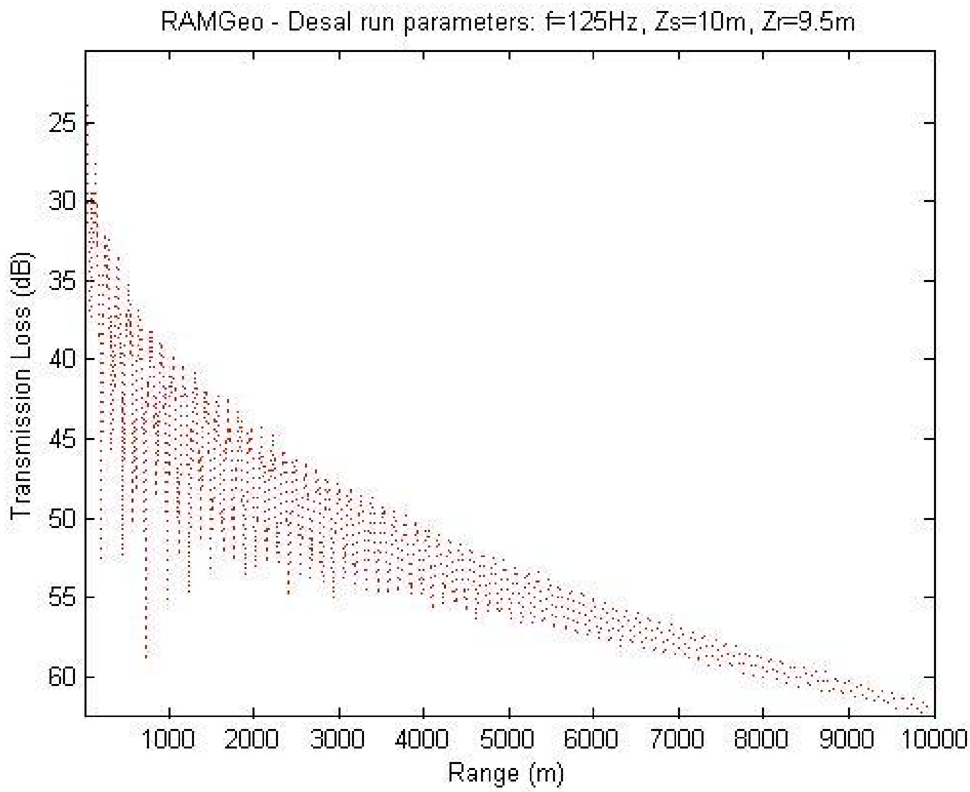

Figure 17 Transmission loss versus range for a depth of 10m and an octave band frequency of 125Hz.

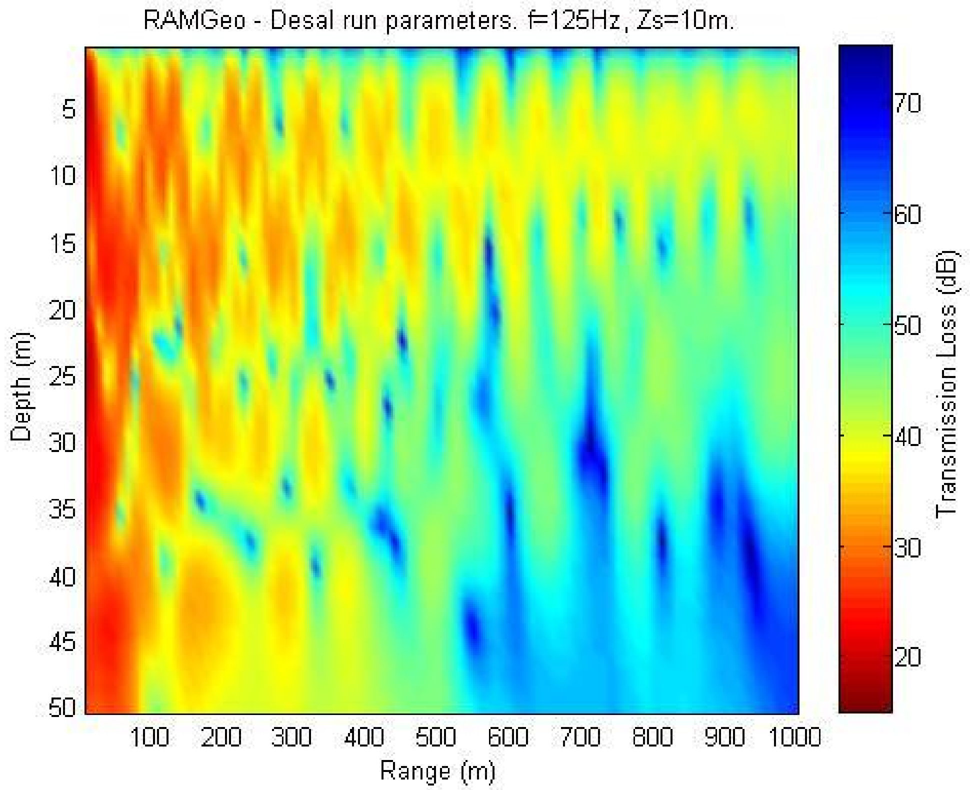

Figure 18 Transmission Loss versus Range and Depth for Track B (East, West is equivalent to Track A) for an octave band frequency of 125Hz.

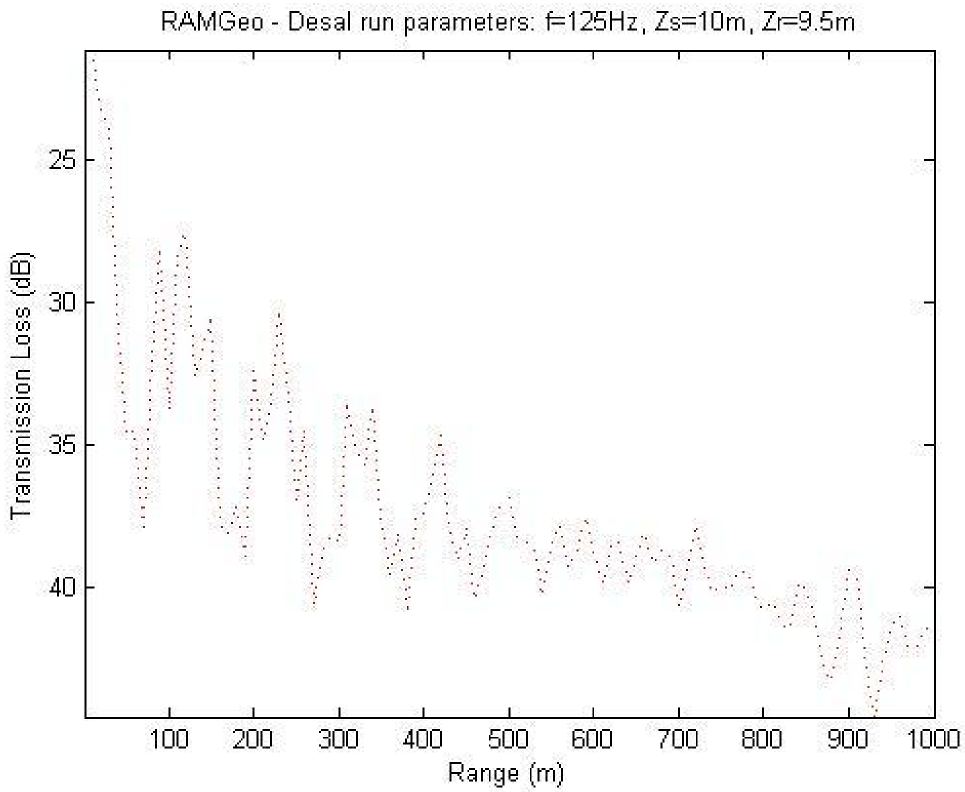

Figure 19 Transmission loss versus range for a depth of 10m and an octave band frequency of 125Hz.

10. ADP Noise and Vibration Impact Assessment

10.1 Risk Analysis

A risk assessment process was completed to identify hazards, causes and likelihood/consequence of risks and to identify potential environmental impacts associated with the construction of the ADP (Appendix F and G).

10.2 Impact Assessment

Impacts were assessed with regard to the predicted broadband noise levels at given distances from the proposed activities, and their overlap with the noise limits provided in the assessment criteria.

The following sections detail the likely impacts of potential noise sources in relation to the ADP. The following relate to activities that have the potential to occur during construction and operations. It should be noted however that some activities such as blasting are included but will not occur as non-explosive blasting and rock removal will be utilised if the hybrid tunnel option goes ahead. The full tunnel option requires no rock removal.

10.2.1 Construction Impacts and Mitigation Measures

The construction impacts and their corresponding risk and residual risk are summarised in Table 11.

Table 11 Construction Impacts Summary Table

Project Activity	Risk	Residual Risk
Blasting	High	Low
Seismic Survey	Medium	Low
Dredging	Medium	Low
Support Vessels	Medium	Low
Drilling	Medium	Low
Tunnelling	Low	Low

Blasting, dredging, drilling & tunnelling

Construction noise is likely to generate the greatest noise impact on marine fauna. Within construction noise, blasting and pile driving are likely to cause the highest mortalities rates and physical trauma to marine fauna. Noise from blasting has the capacity to injure and kill marine mammals, fishes and possibly even invertebrates and reptiles. Broad-band pulsed sounds, from pile driving and blasting, compared to continuous pure tones are more effective at altering fish behaviour (WSDOT, 2006). Drilling, dredging and tunnel boring may mask important sounds and induce behavioural changes. *Mysticetes* and fish, especially generalist, are most likely to be affected.

The health limit for organ damage is exceeded at 10km from the source for an explosive charge weight of 1kg. Blasting must be avoided, or special measures put in place to limit wide spread hazards to marine fauna. As can be seen in the impacts summary table (Table 11), the pre-mitigation risk of the construction noise impacting upon marine species is likely to be of a medium impact if the blasting option is removed.

The tunnel option has a significant reduction in the requirement for dredging and entrenching than the hybrid tunnel as the pipelines and rock armour are not required. Where the intake and outfall diffusers surface through the sediments there will be a small amount of sediment removal and disturbance but these effects will be relatively short lived and minimal when compared to the Hybrid tunnel option. Some construction noise is likely but this will be short duration and minimal in impact. The issues arising from the tunnel option are therefore also considered to have a **medium** impact due to the limited works required within the benthic zones.

Mitigation measures

The marine iconic species review undertaken for the ADP project (Connell Wagner, 2008) noted that although many of the large cetacean species do utilise the Gulf of St Vincent they rarely visit the Port Stanvac region. Risks to the mobile marine species can be mitigated by not using explosives during the known migratory months, when southern right whales visit South Australian coastline to breed and when females give birth. Warning signals should be initiated before blasting in order that any marine mammals such as dolphins are alerted and have the opportunity to move away from the area.

If dredging and entrenchment is required during construction then the following should be considered to reduce the impacts on marine species:

- Conducting explosive work when fish and/or marine mammal activity or sensitivity is lowest such as outside of the known migratory months (Approximately June to late November) ,
- Using bubble curtains air curtains to disrupt the shock wave,
- Using noise generating devices, such as an air compressor discharge line, to scare fish and/or marine mammals away from the site, and
- Aerial surveillance and boats on the water should be used to minimise detonating explosive charges whilst dolphins or sharks are in the region
- Marine mammals spotters should be employed during the dredging and entrenching campaign and an exclusion zone established whereby dredging stops if a marine mammal is spotted within 500m of the dredging vessel
- Impact minimization measures- e.g. prevent steel on steel noise sources by using a buffering substance on either surface of impact.

Provided that the mitigation measures outlined above are utilised the predicted residual impact of the ADP related construction noise on marine species is likely to be **low** for both options.

Seismic Survey

The noise and vibration impacts from seismic surveys are likely to relate to the airguns, boomers and sparkers used within seismic survey work. Noise levels from airguns does not reach acceptable limits within 10kM of the source, with noise levels remaining excessive and above 150 dB re 1uPa (RMS), but assuming a 10dB increase for peak sound pressure levels, this is within the health limit for impulsive sound which ensures limited hearing loss. The impulsive health limit would be exceeded within about 2km of the source.

As can be seen in the impacts summary table (Table 11), the pre-mitigation risk of seismic surveys impacting upon marine species is likely to be of a **medium** impact.

If seismic surveys are required during construction then the following should be considered to reduce the impacts on marine species:

- Not using airguns during the known migratory, when southern right whales visit South Australian coastline to breed and give birth
- Warning signals should be initiated before firing the airguns to ensure that any marine mammals such as dolphins are alerted and have the opportunity to move away from the area.
- Aerial surveillance and boats on the water should be used to avoid firing airguns whilst whales, dolphins or sharks are in the region.
- Compliance with EPBC Regulations/Guidelines

Provided that the mitigation measures outlined above are utilised the predicted residual impact of the ADP related seismic survey noise on marine species is likely to be **low** for both options.

Dredging, support vessels and drilling

The primary sources of noise from all vessels are propeller cavitation, propeller singing, and propulsion or other machinery. Propeller cavitation is usually the dominant noise source (Ross, 1976). Propeller singing arises when vortex shedding frequencies reinforce a resonant vibration frequency of a propeller blade. The health limit for dredging, support vessel activities and drilling is achieved within 1km of the noise source. Human divers can operate underwater for limited periods of time without risk of hearing damage. Behavioural response limits are achieved within 10km of the noise source.

As can be seen in the impacts summary table (Table 11), the pre-mitigation risk of noise from support vessels impacting upon marine species is likely to be of a **medium** impact.

Following should be considered to reduce the impacts of noise from support vessels on marine species:

- Conducting construction work involving support vessels when fish and/or marine mammal activity or sensitivity is lowest such as outside of the known migratory months (Approximately June to late November) ,
- Minimise the volume and length of the use of support vessels
- Ensure engines and equipment are not unnecessarily running or idling during periods of no work.

Provided that the mitigation measures outlined above are utilised the predicted residual impact of the ADP related support vessel noise on marine species is likely to be **low** for both options.

Tunnelling

The full tunnel option will utilise a tunnel boring machine to drill through from directly under the ADP plant to the mid and deep benthic zones. Noise from the tunnel boring machine is well contained within 100m of the source. Although marine fauna may show behavioural responses within 10m of the sea floor during the tunnelling this impact will be of a small significance. As such the predicted impact is **low** and no mitigation measures are proposed.

10.2.2 Operational Impacts and Mitigation Measures

The operational impacts and their corresponding risk and residual risk are summarised in Table 12.

Table 12 Operational Impacts Summary Table

Project Activity	Risk	Residual Risk
Pump Intake & Outfall	Low	Low
Maintenance	Medium	Low

Pump Intake and Outfall

Noise from the operation of the intake and outfall pump of the ADP is likely to be low and as such, as can be seen in the impacts summary table (Table 12), the pre-mitigation risk of noise from impacting upon marine species is likely to be of a **low** impact.

The following should be considered to reduce the impacts of noise during operations on marine species:

- Ensure design features of intake and outfall structure and pump ensure optimal (low) noise and vibration levels
- Ensure maintenance of intake and outfall structures are conducted appropriately to ensure optimum operational conditions

Provided that the mitigation measures outlined above are utilised the predicted residual impact of the ADP related intake and outfall operation on marine species is likely to be **low** for both options.

Maintenance

Due to the sub-marine location of the intake and outfall systems, access for inspection and maintenance will be highly restricted and therefore fairly minimal and infrequent in nature. The majority of the conduit length, between the intake and pump station and between the shaft and outfall, will be inaccessible to operations and maintenance teams and can only be inspected through the use of ROV's (remotely operated underwater vehicles).

However the intake and outfall structures will be designed to be accessible to teams of divers who may be required to visit in the event of a problem with the system. Activities that they will be able to carry out will be necessarily superficial and therefore likely to have a negligible effect on the local environment. This might include manual removal of material including marine fauna and flora obstructing the intake grills and outfall diffusers and light repair work to the surfaces of structures. There may also be a limited infrequent (less than every 5-10years) requirement for pigging which would generate a small amount of noise.

As can be seen in the impacts summary table (Table 12), the pre-mitigation risk of noise during operational maintenance impacting upon marine species is likely to be of a **medium** impact.

Following should be considered to reduce the impacts of noise from operational maintenance on marine species:

- Minimise the frequency and length of maintenance events as practicable
- Minimise pigging to as low frequency as possible
- Conduct maintenance outside of the known migratory months (Approximately June to late November)

Provided that the mitigation measures outlined above are utilised the predicted residual impact of the ADP related maintenance on marine species is likely to be **low** for both options.

10.3 Noise Management Plan and Monitoring

A construction noise (including marine noise) management plan should be developed for the construction and operation of the ADP which shall describe:

- Individuals responsible for each aspect of the plan
- Key environmental issues
- Key environmental regulations
- Key environmental controls
- Monitoring
- Audit

Monitoring may be required before, during and after commissioning of the intake and outfall pipelines. Measurements for example could be taken continuously in 1/3 octaves over a one week period every month, and sound recordings being made and used to identify maximum noise events occurring above a threshold of 120dB re 1μPa. Measurements would be made with a hydrophone moored from the sea floor to minimise mechanical self-noise. Measurements shall also be taken of salinity, water temperature and wind and current speed.

11. Conclusion

The use of sound for communication and detection in the marine environment is important for survival for marine animals. Marine animals depend on their hearing sensitivity to retain cohesion in groups, for echolocation (among marine mammals), to locate and capture food, for detection of predators, for sensing their physical and biological environment and for avoiding dangerous situations (including anthropogenic threats). Activities within the marine zones have the potential to impact upon marine species and can cause a range of impacts including behavioural responses and stress to marine species.

Marine noise generated during the construction and operation of the ADP has the potential to impact upon the marine fauna of Gulf St Vincent. The highest predicted impact was demonstrated for activities such as blasting. However, blasting is not proposed as part of the construction activities for the ADP and as such these impacts are not applicable.

Rock removal will be required if the Hybrid Tunnel Option is utilised. It is proposed that non-explosive rock removal be undertaken (such as non-explosive blasting or vibrocoring / diamond drilling). The remaining potential noise source activities can be mitigated by ensuring that construction activities are undertaken when fish and/or marine mammal activity or sensitivity is lowest, such as outside of the known migratory months (approximately June to late November). A number of other mitigation measures are suggested which, if employed, will reduce the likely impacts on marine fauna from noise and vibration during construction to low.

Operationally the main noise source would likely be the pumps which pump water through the pipelines to and from the plant however this impact is likely to be low and reduce linearly as you move away from the pipeline to the marine environment.

Monitoring may be required before, during and after commissioning of the intake and outfall pipelines. Measurements for example could be taken continuously in 1/3 octaves over a one week period every month, and sound recordings being made and used to identify maximum noise events occurring above a threshold of 120dB re 1Pa. Measurements would be made with a hydrophone moored from the sea floor to minimise mechanical self-noise. Measurements shall also be taken of salinity, water temperature and wind and current speed.

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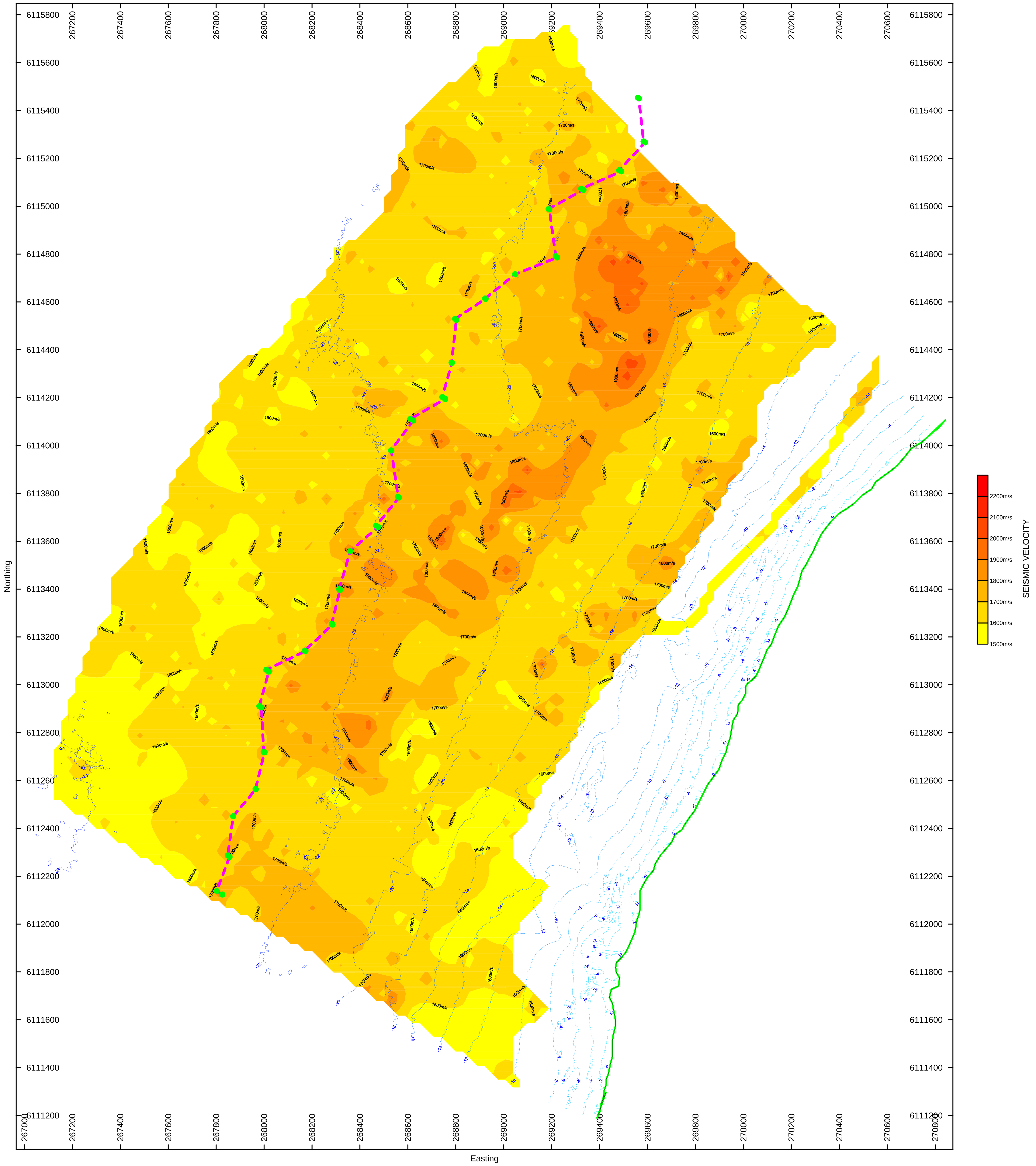
Appendix A – Geotechnical Conditions

Marine & Earth Sciences Survey results and p-wave velocity schedule



KEY:
MAJOR FAULT BOUNDARY

marine & earth sciences

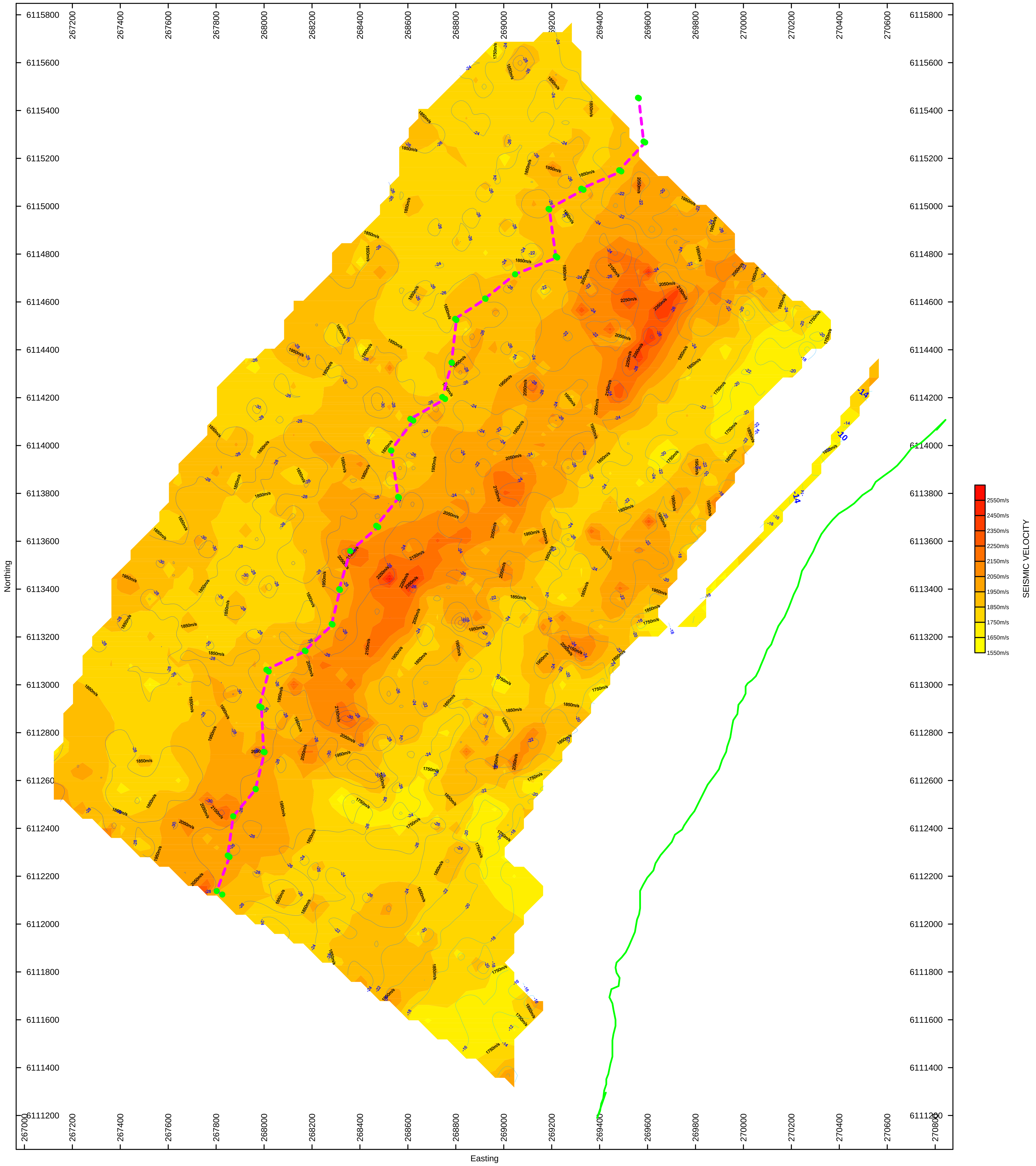
ACN 111 435 717 147 Hargrave Street Paddington 2021 NSW +61 409 844 605

Horizontal Datum	UTM Zone 54 MGA94	Survey Date	May 2008
Vertical Datum	AHD (m)	Geophysicist	DPK
Scale	1:1,000	Drawn	DPK
		DGPS	Navcom StarFire

SA WATER
CONNEL WAGNER PTY LTD
SA WATER DESALINATION PROJECT - PORT STANVAC
GEOPHYSICAL INVESTIGATIONS
OFFSHORE SEISMIC REFRACTION LAYER 1
INTERPRETED SEISMIC VELOCITY AND LEVEL

FIG 11

Ref: MES_211



KEY:
MAJOR FAULT BOUNDARY

marine & earth sciences

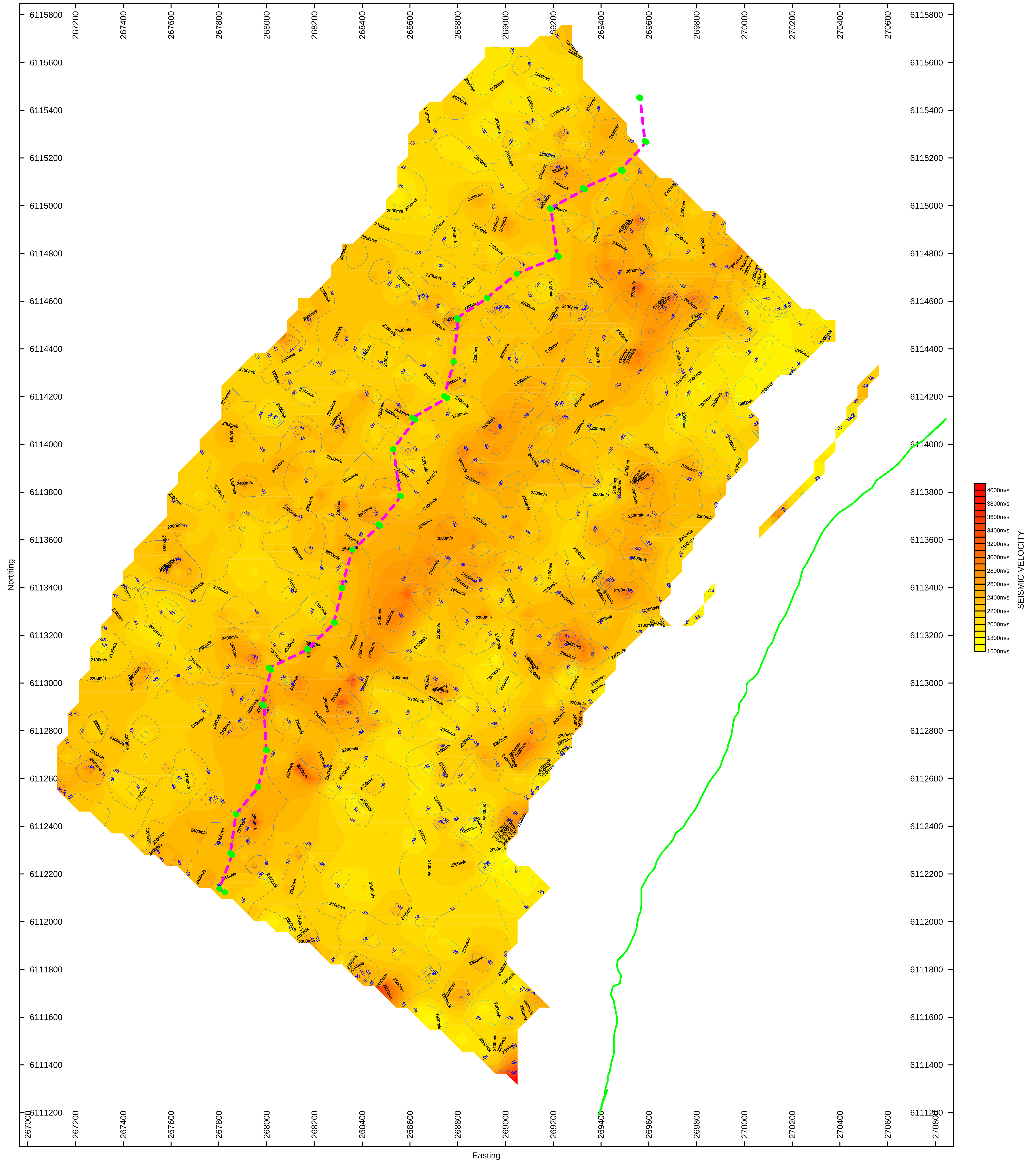
ACN 111 435 717 147 Hargrave Street Paddington 2021 NSW +61 409 844 605

Horizontal Datum	UTM Zone 54 MGA94	Survey Date	May 2008
Vertical Datum	AHD (m)	Geophysicist	DPK
Scale	1:1,000	Drawn	DPK
		DGPS	Navcom StarFire

SA WATER
CONNEL WAGNER PTY LTD
SA WATER DESALINATION PROJECT - PORT STANVAC
GEOPHYSICAL INVESTIGATIONS
OFFSHORE SEISMIC REFRACTION LAYER 2
INTERPRETED SEISMIC VELOCITY AND LEVEL

FIG 12

Ref: MES_211



KEY:
MAJOR FAULT BOUNDARY

marine & earth sciences

ACN 111 435 717 147 Hargrave Street Paddington 2021 NSW +61 409 844 605

Horizontal Datum	UTM Zone 54 MGA94	Survey Date	May 2008
Vertical Datum	AHD (m)	Geophysicist	DPK
Scale	1:1,000	Drawn	DPK
		DGPS	Navcom StarFire

SA WATER
CONNEL WAGNER PTY LTD
SA WATER DESALINATION PROJECT - PORT STANVAC
GEOPHYSICAL INVESTIGATIONS
OFFSHORE SEISMIC REFRACTION LAYER 3
INTERPRETED SEISMIC VELOCITY AND LEVEL

FIG 13

Ref: MES_211

Appendix B – Ambient Noise Survey

Calibration Certificates

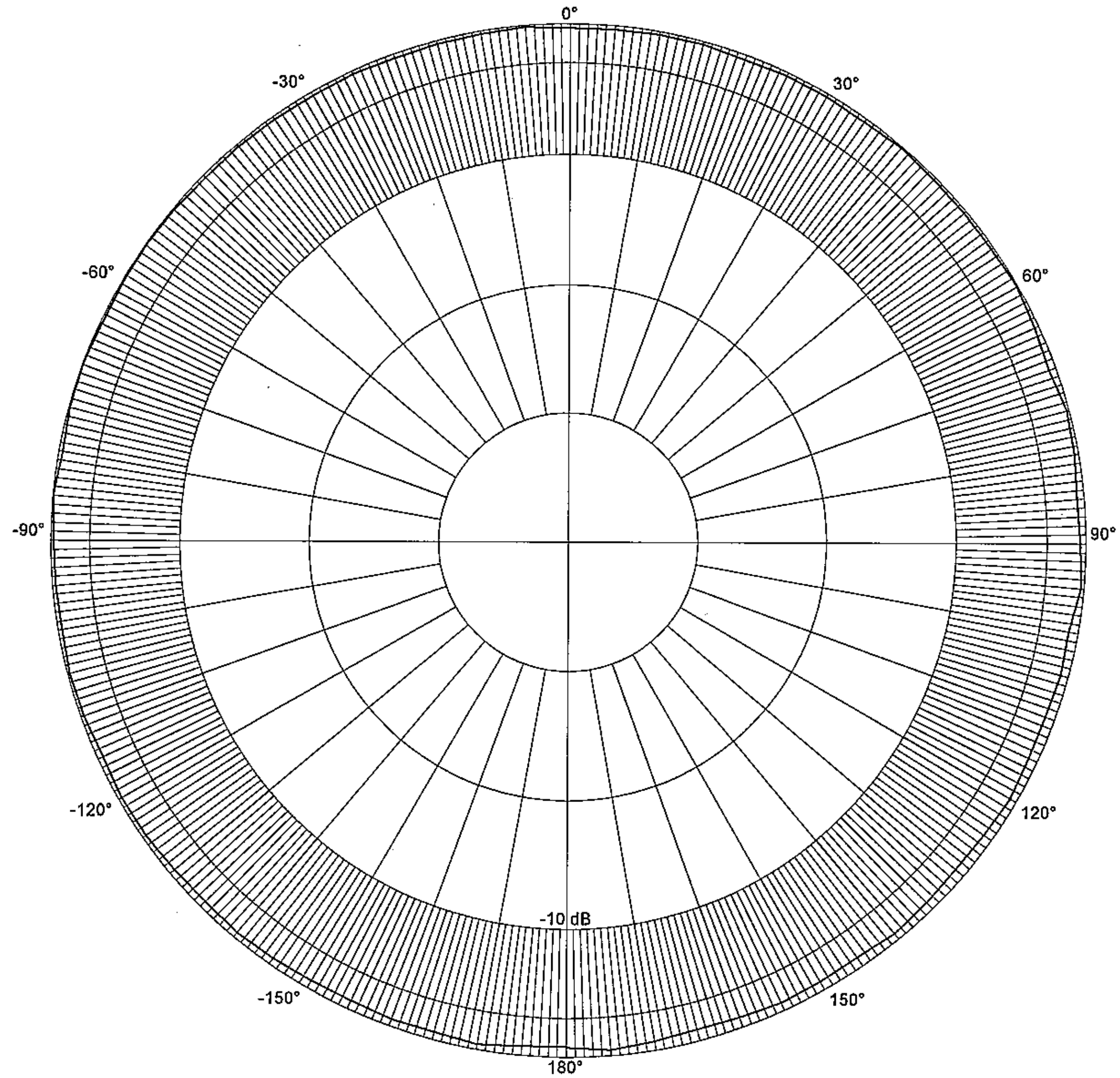
HYDROPHONE DIRECTIVITY

RESON

Under Test:	TC4034-3	Amplitude:	10.0 Vrms	Temperature:	20.98°C
S/N:	1107054	Pulse Width:	300.0 µs	Depth:	1.2 m
Reference:	TC4034	Angle:	-180.0° to 180.0°	Distance:	0.50 m
Date:	2008-02-04	Frequency:	100.00 kHz	Tested by:	PRA
Session, Run:	6925, 1				
Max RR:	-221.0 dB re 1µPa/V at 1m				
Comment:	Horizontal.				

PRA 08/02/04

All plots

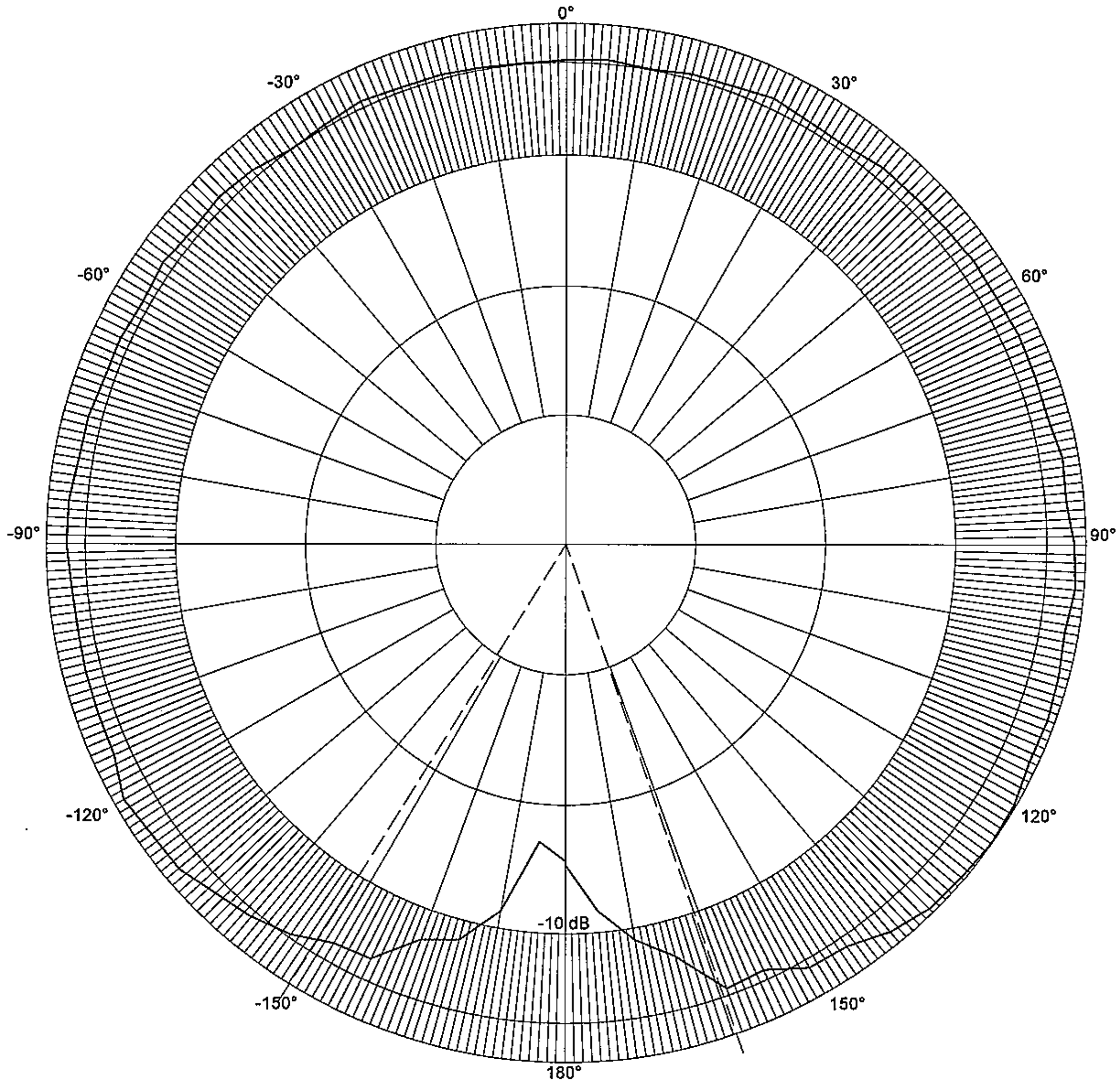


HYDROPHONE DIRECTIVITY

RESON

Under Test:	TC4034-3	Amplitude:	10.0 Vrms	Temperature:	21.15°C
S/N:	1107054	Pulse Width:	300.0 µs	Depth:	1.2 m
Reference:	TC4034	Angle:	-180.0° to 180.0°	Distance:	0.50 m
Date:	2008-02-03	Frequency:	100.00 kHz	Tested by:	PRA
Session, Run:	6918, 1				
Max RR:	-219.7 dB re 1µPa/V at 1m				
W:	308.8°				
Comment:	Vertical.				

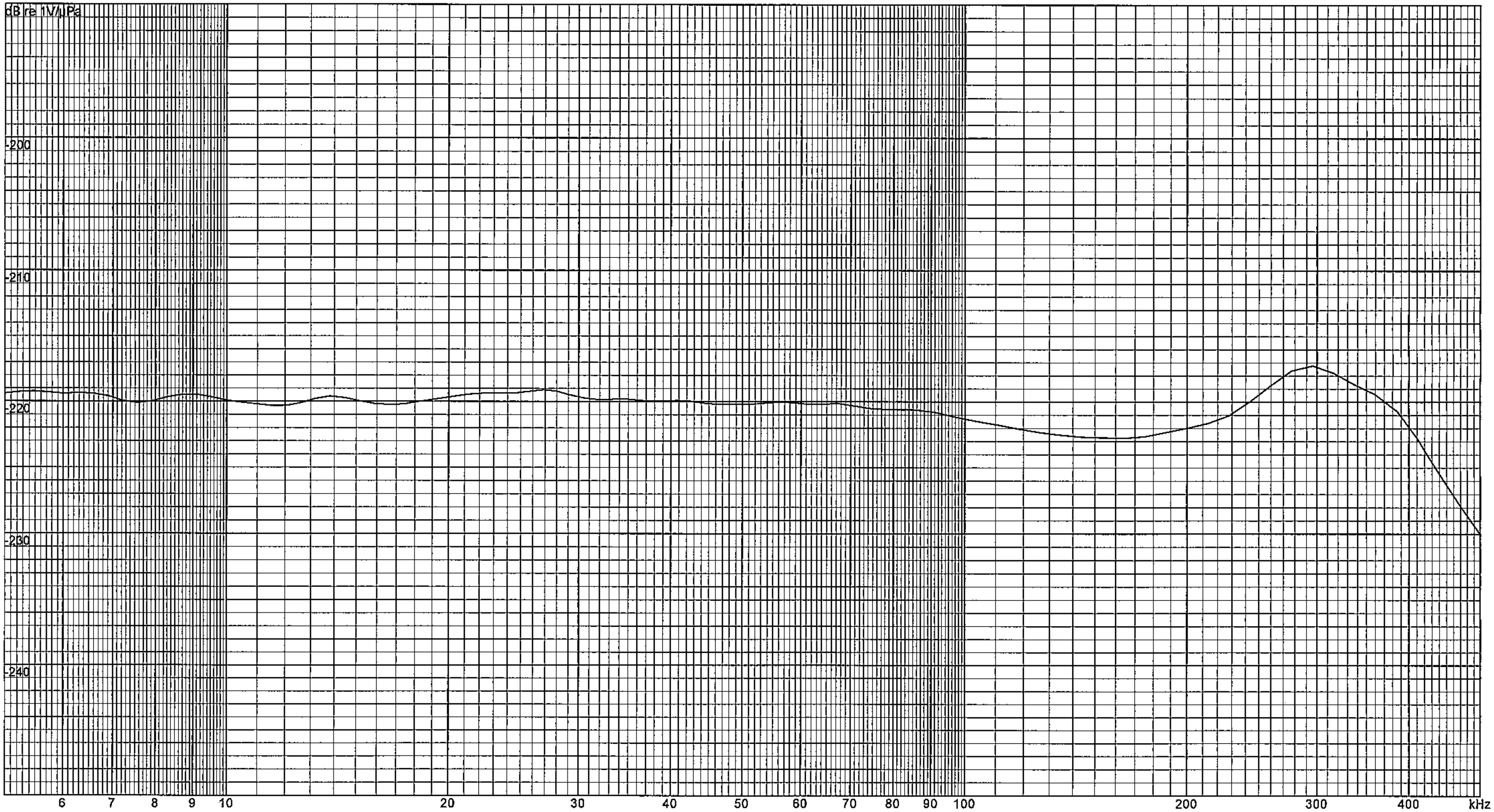
PRA 08/02/04



HYDROPHONE SENSITIVITY

Under Test:	TC4034-3	Amplitude:	10.0 Vrms	Temperature:	20.98°C
S/N:	1107054	Pulse Width:	428.6 µs	Depth:	1.2 m
Reference:	TC4034	Rep Rate:	33.3 ms	Distance:	0.50 m
Date:	2008-02-04	Averages:	8	Tested by:	PRA
Session, Run:	6925, 2				
Comment:	PHO @ 250Hz: -219.1 dB.				

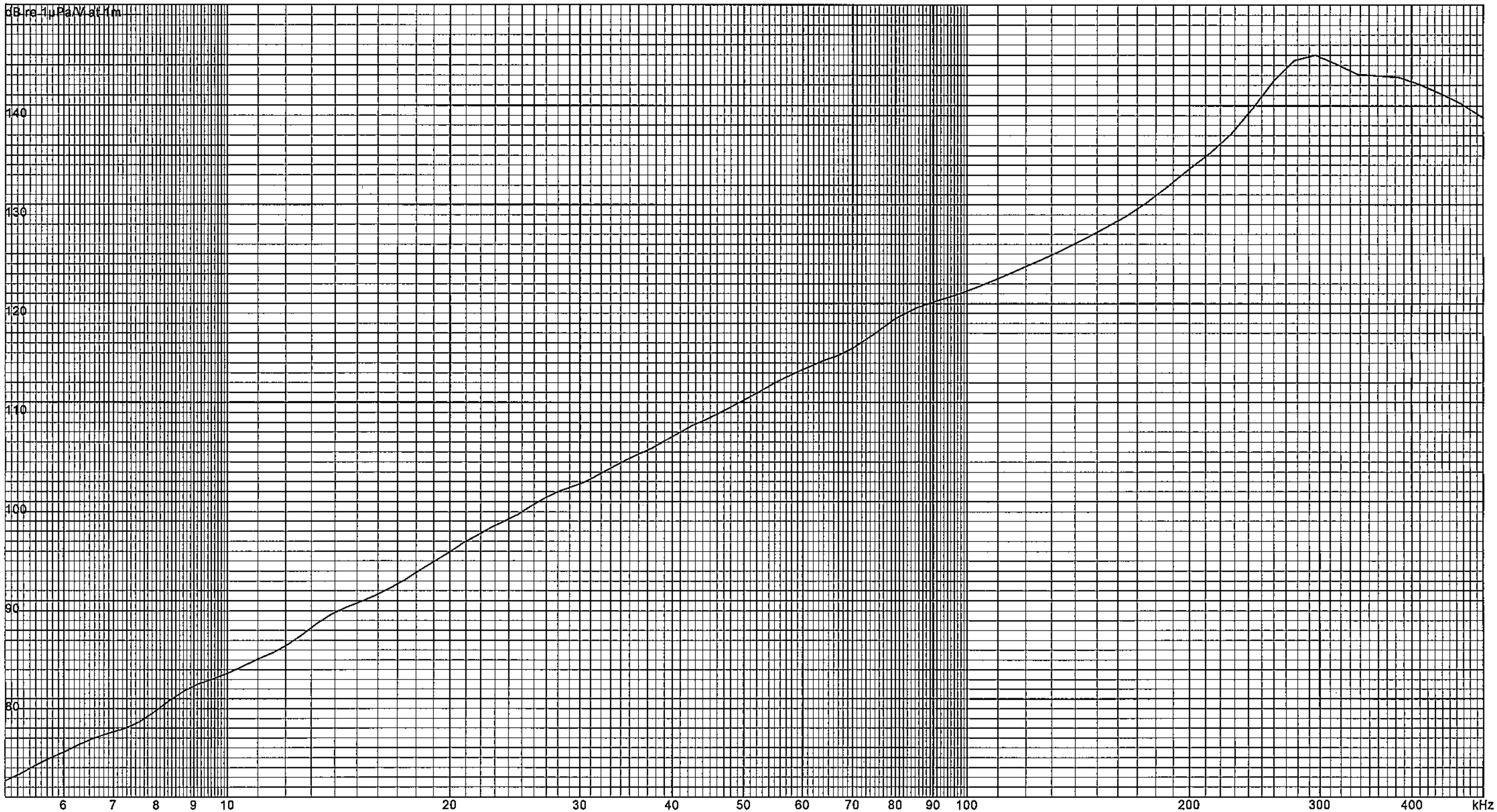
PRA 08/02/04



PROJECTOR SENSITIVITY

Under Test:	TC4034-3	Amplitude:	50.0 Vrms	Temperature:	20.98°C
S/N:	1107054	Pulse Width:	1400.0 µs	Depth:	1.2 m
Reference:	TC4033	Rep Rate:	100.0 ms	Distance:	0.50 m
Date:	2008-02-04	Averages:	8	Tested by:	PRA
Session, Run:	6925, 5				
100.00 kHz:	121.27 dB re 1µPa/V at 1m				
Comment:					

PRA 08/02/04

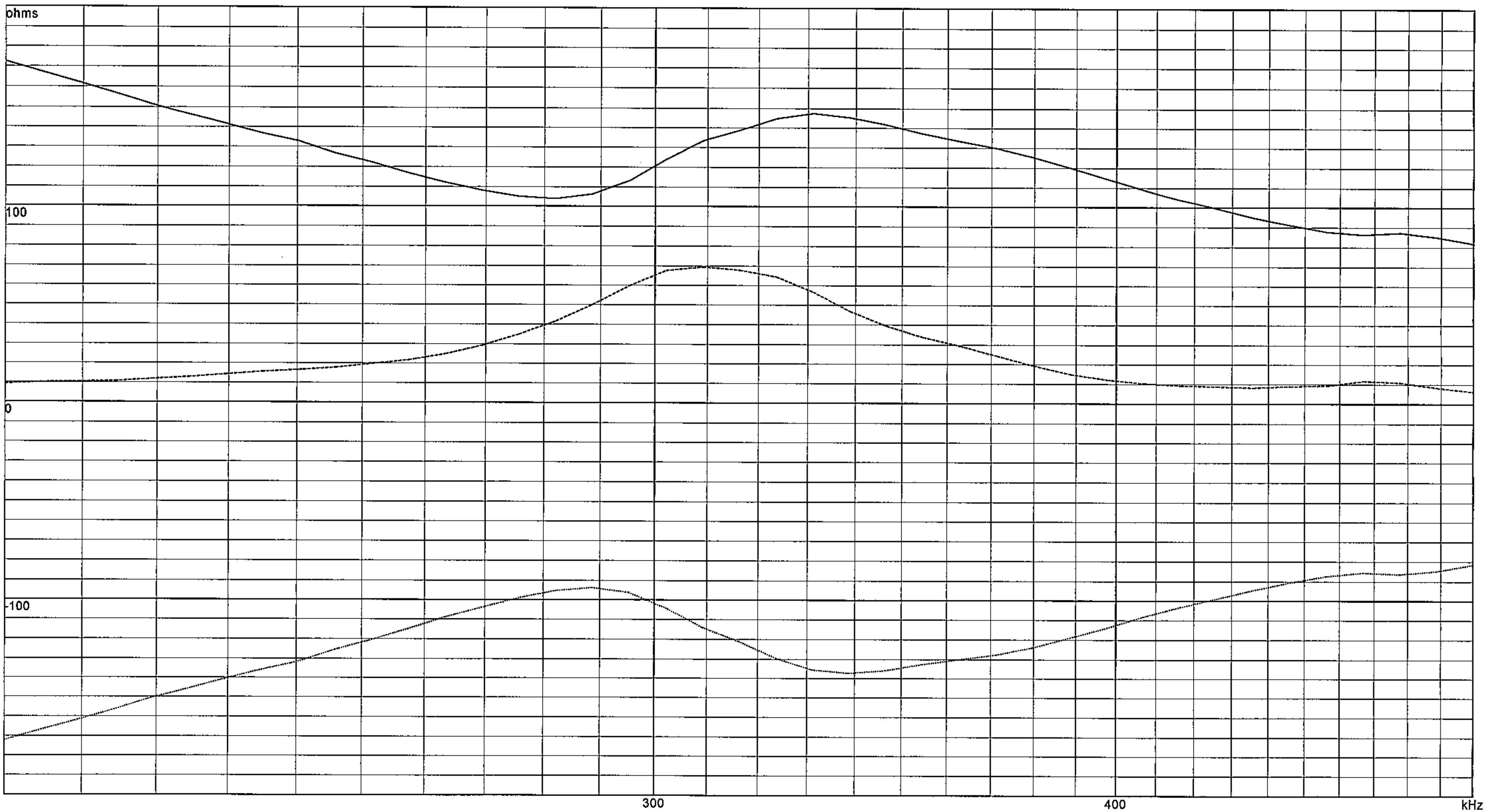


IMPEDANCE SUMARY

RESON

Under Test:	TC4034-3	Amplitude:	10.0 Vrms	Temperature:	20.98°C
S/N:	1107054	Pulse Width:	150.0 µs	Depth:	1.2 m
Date:	2008-02-04	Rep Rate:	66.7 ms	Cal Resistor:	0.0 ohms
Session, Run:	6925, 9	Averages:	4	Tested by:	PRA
Comment:					

PRA 08/02/04

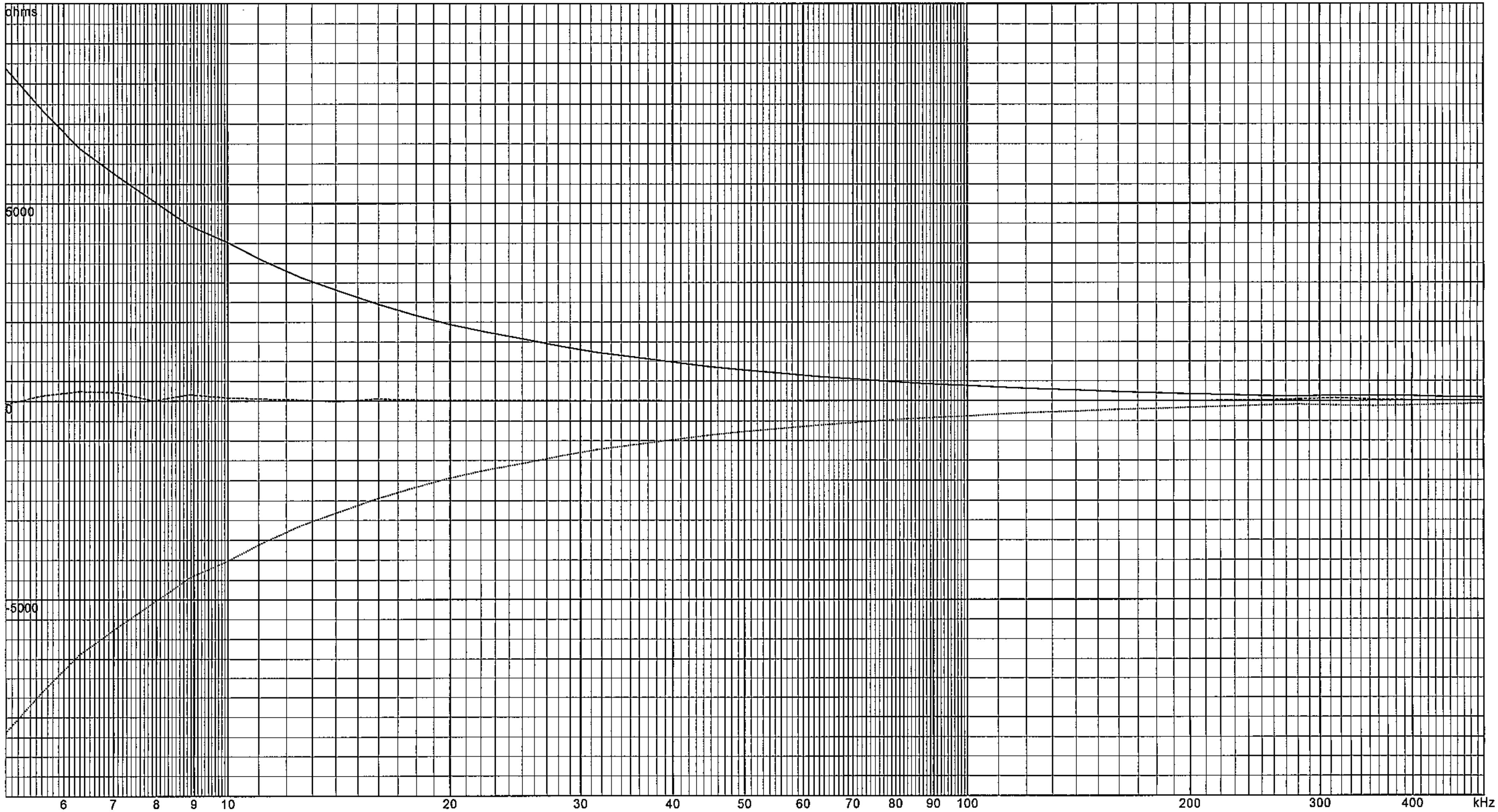


IMPEDANCE SUMARY

RESON

Under Test:	TC4034-3	Amplitude:	10.0 Vrms	Temperature:	20.98°C
S/N:	1107054	Pulse Width:	6000.0 µs	Depth:	1.2 m
		Rep Rate:	66.7 ms	Cal Resistor:	0.0 ohms
Date:	2008-02-04	Averages:	4	Tested by:	PRA
Session, Run:	6925, 6				
Comment:					

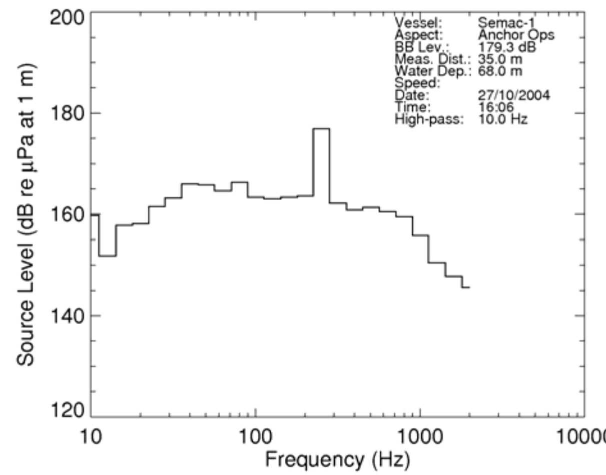
PRA 08/02/04



Appendix C – Noise Sources

PDF of noise source info from Sakhalin

Figure 4.7 Pipeline Construction Equipment and Noise Source Levels

Spread	Vessel	**Description**	**1/3-Octave Level Histogram**
Pipelay – for deepwater	*Semac One* 	Semi-submersible pipelay barge held on station with an anchor spread. Requires dedicated support from AHTS and supply vessels. Two AHTS vessels required to maintain lay rate, if vessels reduced then pipelay duration increases. Spread is usually supported by a survey vessel.	 **Figure:** 1/3-octave source levels of *Semac* performing anchor winch out. **BROADBAND LEVEL (dB re 1 µPa) = 179.3**

<table>
<tr><th>Spread</th><th>Vessel</th><th>Description</th><th>1/3-Octave Level Histogram</th></tr>
<tr>
<td></td>
<td>AHTS - Anchor Handler Tug Supply vessel

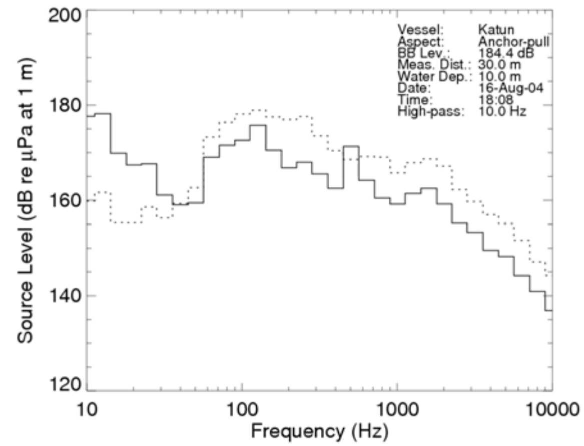
</td>
<td>Dedicated anchor handler vessels for the pipelay barge. Vessels used to reposition the anchors required to keep pipelay barge on station. Alternative vessels for Castoro 2 are being considered (see DH Delta catarmaran)</td>
<td>

Figure: 1/3-octave source levels of *Katun* while performing anchor pull.

BROADBAND LEVEL (dB re 1 µPa) = 184.4

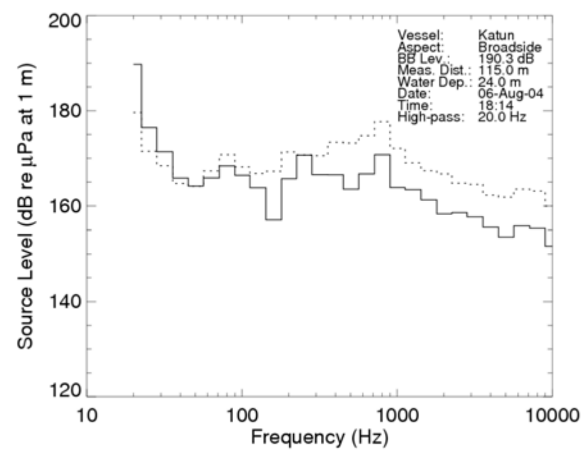
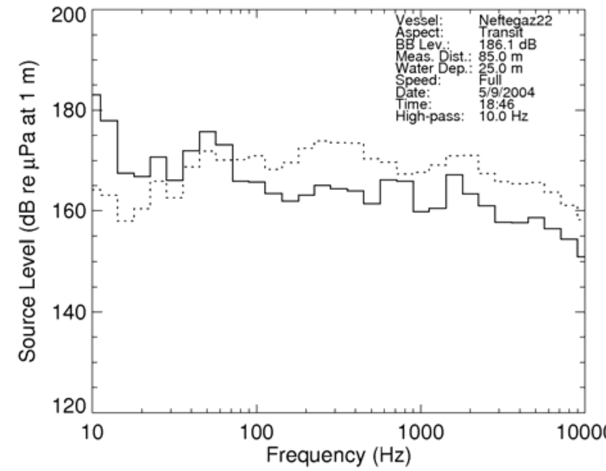
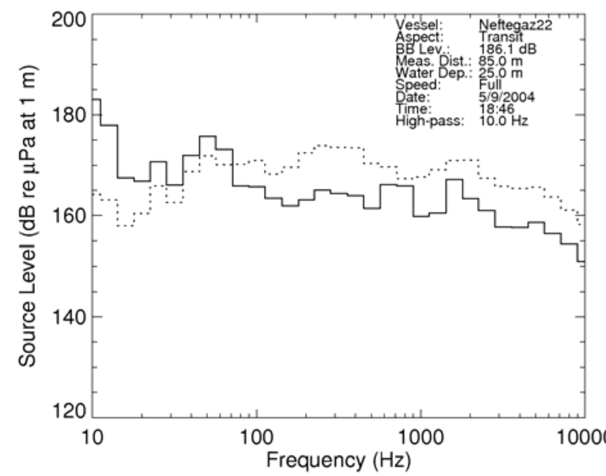
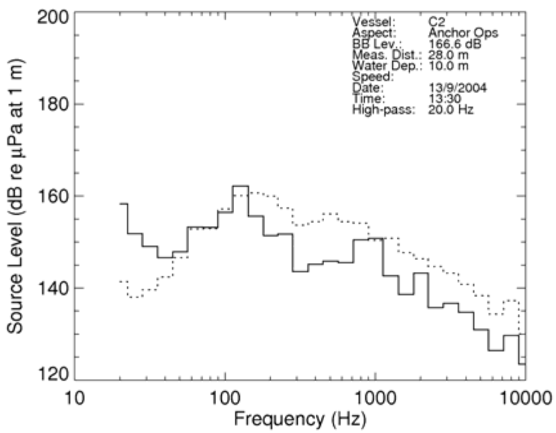
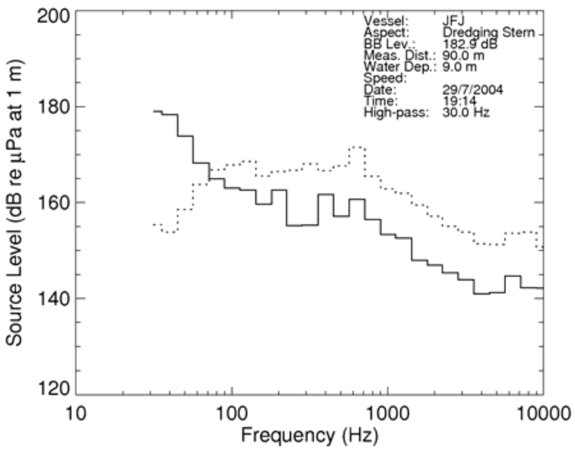


Figure: 1/3-octave source levels abeam of *Katun* while transiting.

BROADBAND LEVEL (dB re 1 µPa) = 190.3</td>
</tr>
</table>

Spread	Vessel	Description	1/3-Octave Level Histogram
	Pipe supply ship 	Vessel used to ship and store linepipe to be installed by pipelay barge. Vessel usually moored alongside pipelay barge during offloading.	 **Figure:** 1/3-octave source levels for *Neftegaz 22* transiting at full speed. **BROADBAND LEVEL (dB re 1 µPa) = 186.1**
	Supply vessel 	Supply of food, supplies and consumables to pipelay spread. Vessel located along side pipelay barge or off location getting supplies from shore. Picture typical of vessel type.	 **Figure:** 1/3-octave source levels for *Neftegaz 22* transiting at full speed. **BROADBAND LEVEL (dB re 1 µPa) = 186.1**

Spread	Vessel	**Description**	**1/3-Octave Level Histogram**
Pipelay - for shallow water	*Castoro II* 	Mono-hull pipelay barge held on station with an anchor spread. Requires dedicated support from one AHTS and supply vessels, with a 2^{nd} AHTS kept on standby to assist in the event of storms. See *Semac One* for description of pipelay support vessels.	 **Figure:** 1/3-octave source levels abeam of *Castoro II* during anchor line winch operations. **BROADBAND LEVEL (dB re 1 µPa) = 166.6**
Dredging - CSD	*JFJ de Nul* (Cutter Suction Dredger) 	Mechanical method of dredging, permitting CSD to work in harder soils/rock. Vessel can work in shallow waters to water depths of over 30m. Used normally for shore approaches. Vessel held on station by vertical pins which stab into the seabed, which are also used to pull the vessel forward.	 **Figure:** 1/3-octave source levels at stern of *JFJ de Nul* while dredging. **BROADBAND LEVEL (dB re 1 µPa) = 182.9**

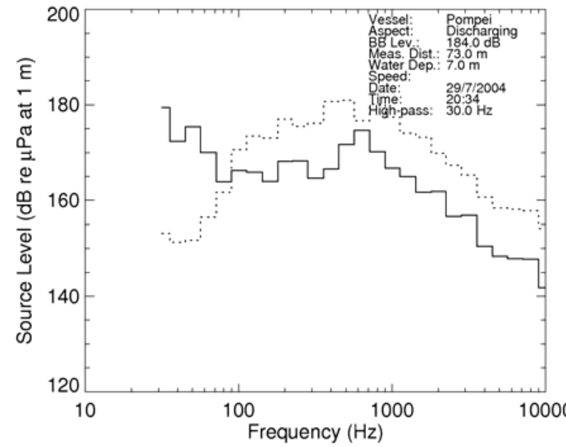
<table>
<tr><th>Spread</th><th>Vessel</th><th>Description</th><th>1/3-Octave Level Histogram</th></tr>
<tr><td></td><td>Support vessel – Pompei
</td><td>Support vessel to the CSD, principal duties to hold the end of the floating hose and tow the pipe in event of storm. Normal operations are on DP but can operate on anchors</td><td>

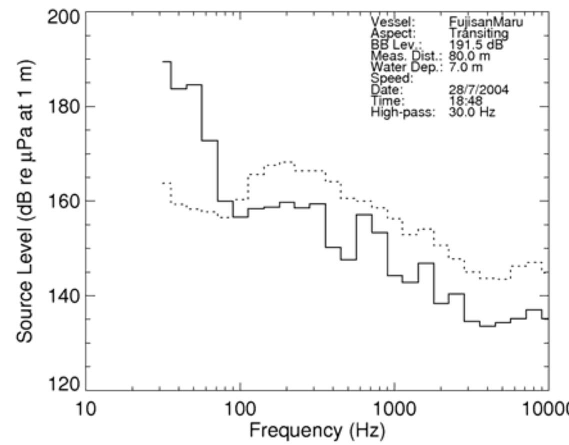
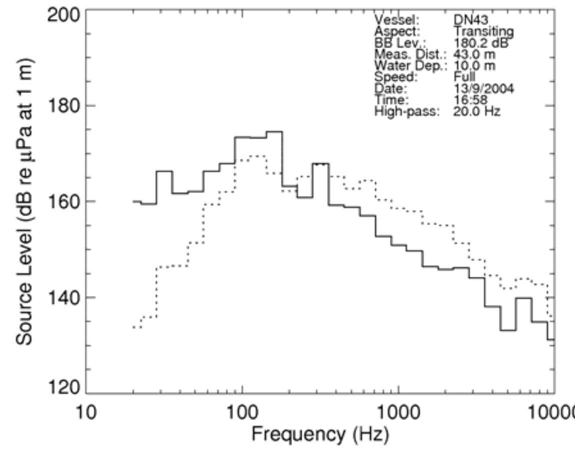
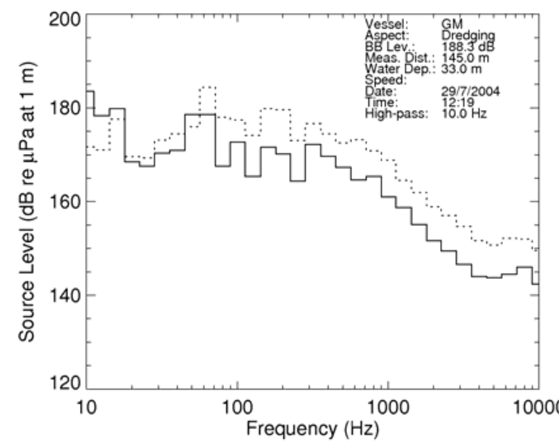
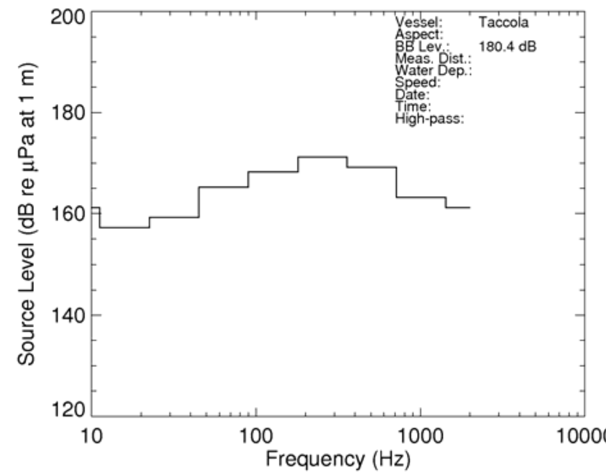
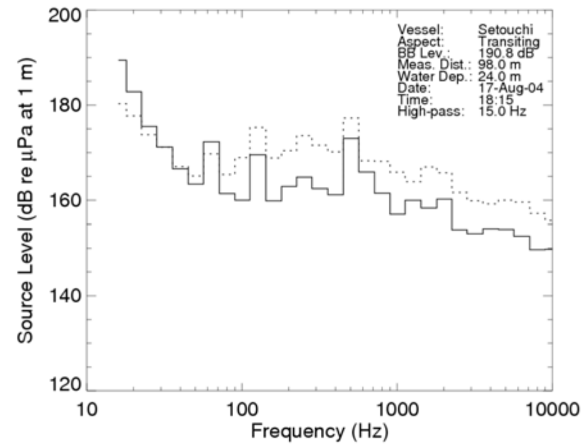
Figure: 1/3-octave source levels abeam of Pompei while discharging spoil.
BROADBAND LEVEL (dB re 1 µPa) = 184.0</td></tr>
<tr><td></td><td>Support vessel – Tug (Fujisan Maru)
</td><td>Support vessel to the CSD, used to keep the floating hose on station in event of rougher weather.</td><td>

Figure: 1/3-octave source levels abeam of Fujisan Maru while transiting.
BROADBAND LEVEL (dB re 1 µPa) = 191.5</td></tr>
</table>

Spread	Vessel	**Description**	**1/3-Octave Level Histogram**
	Support vessel –Shore approach survey, *DN 43* 	Can be used in connection with the CSD spread when performing shore approaches. Vessel is required to perform the survey in shallow water.	 **Figure:** 1/3-octave source levels abeam of *DN43* while transiting at full speed. **BROADBAND LEVEL (dB re 1 µPa) = 180.2**
Dredging THSD	*Gerardus Mercator*: Trailer Hopper Suction Dredger 	Trailer Hopper Suction Dredger (hopper size: 18,000m^3) using suction to excavate large volumes of soil to excavate the seabed. Spoil is stored on the side of the trench and is returned once pipeline has been installed. Vessel uses thrusters to maintain station.	 **Figure:** 1/3-octave source levels abeam of *Gerardus Mercator* while dredging. **BROADBAND LEVEL (dB re 1 µPa) = 188.3**

Spread	Vessel	**Description**	**1/3-Octave Level Histogram**
Dredging THSD (medium)	*Taccola*: Trailer Hopper Suction Dredger 	Smaller version of Geradus Mercator (hopper size: 4,400m^3).	 **Figure:** 1/3-octave source levels at broadside of *Taccola* while dredging (Langworthy *et al.* 2004) **BROADBAND LEVEL (dB re 1 µPa) = 180.4**
Dredging THSD (winter)	*James Cook*: Trailer Hopper Suction Dredger 	Ice class Trailer Hopper Suction Dredger (hopper size: 11,870m^3) using suction similar to *Geradus Mercator*.	1/3-OCTAVE SOURCE LEVELS NOT AVAILABLE NOTE: VESSEL OPERATION DURING WINTER SEASON ONLY – MARINE MAMMALS PRESENT DURING ICE FREE SEASON NOT EXPOSED TO VESSEL NOISE.

Spread	Vessel	**Description**	**1/3-Octave Level Histogram**
Survey	*Setouchi Surveyor* 	Survey vessel to support pipelay operations. Route is surveyed before dredging operations, before pipelay operations and after pipelay.	 **Figure:** 1/3-octave source levels to the side of the *Setouchi Surveyor* while transiting. **BROADBAND LEVEL (dB re 1 µPa) = 190.8**
Tie-in DSV	Diving Support Vessel – Bar Protector 	Diving support vessel used to perform the tie-in and commissioning of the pipelines. Vessel is usually kept on station with dynamic positioning, however it can be moored using anchors.	REPRESENTATIVE VESSEL NOT MEASURED – 1/3-OCTAVE SOURCE LEVEL PLOT NOT AVAILABLE NOTE: PRIMARY NOISE PRODUCED BY SUCH A VESSEL WOULD LIKELY BE ATTRIBUTED TO THE ONBOARD POWER PLANTS AND WINCH SYSTEM, NOT TO THE PROPULSION SYSTEM AS THE VESSEL WOULD BE ANCHORED AND NOT TRANSITING OR EMPLOYING THRUSTERS.

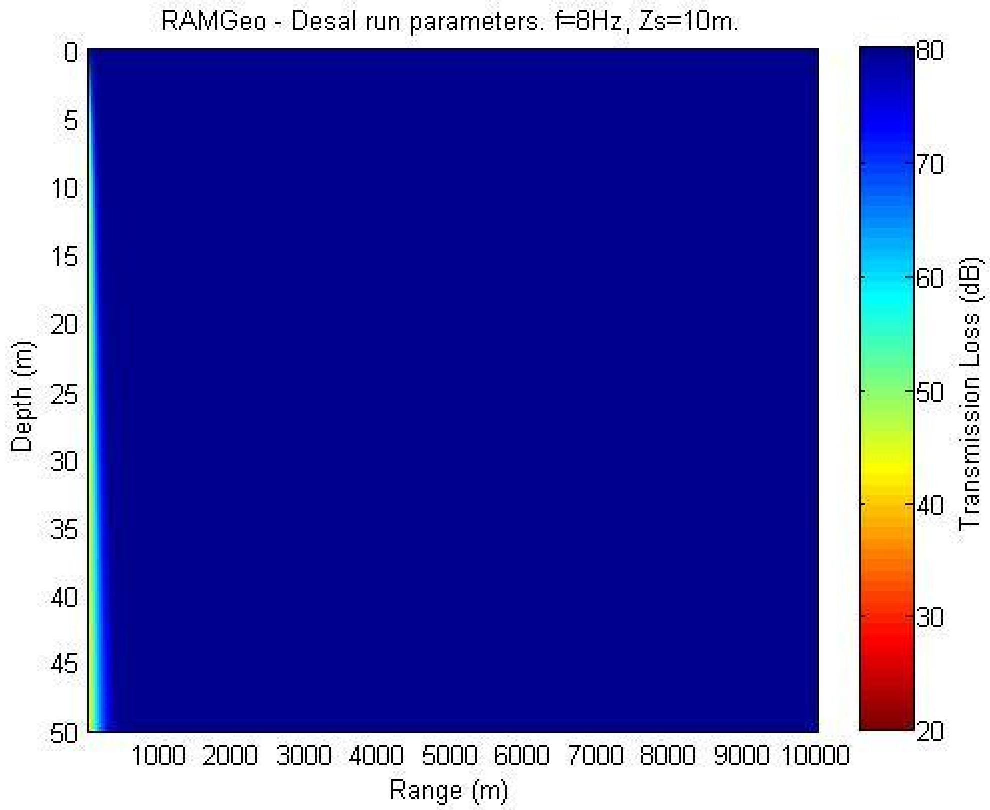
Spread	Vessel	**Description**	**1/3-Octave Level Histogram**
Anchor handling	Anchor handling for pipelay spread - DH Delta 	As alternative to conventional anchor handlers. Vessels are more weather sensitive.	REPRESENTATIVE VESSEL NOT MEASURED – 1/3-OCTAVE SOURCE LEVEL PLOT NOT AVAILABLE NOISE PRODUCED BY THIS TYPE OF VESSEL WOULD LIKELY BE SIMILAR TO THAT SHOWN FOR THE DN43 (SEE ABOVE HISTOGRAM).

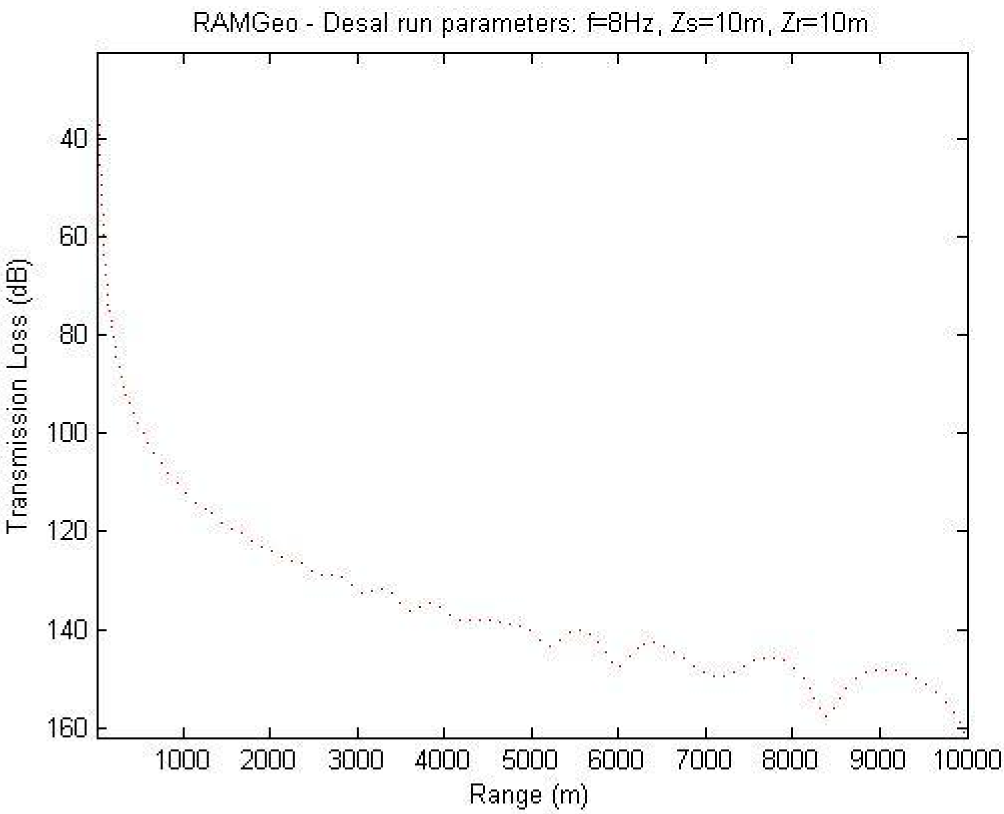
1) All 1/3-octave source level plots presented here represent only those activities used for the SEIC Marine Operation Noise Model. For other measured activities refer to Hannay *et al*. 2004. Sakhalin Energy – Source Level Measurements from 2004 Acoustics Programme.

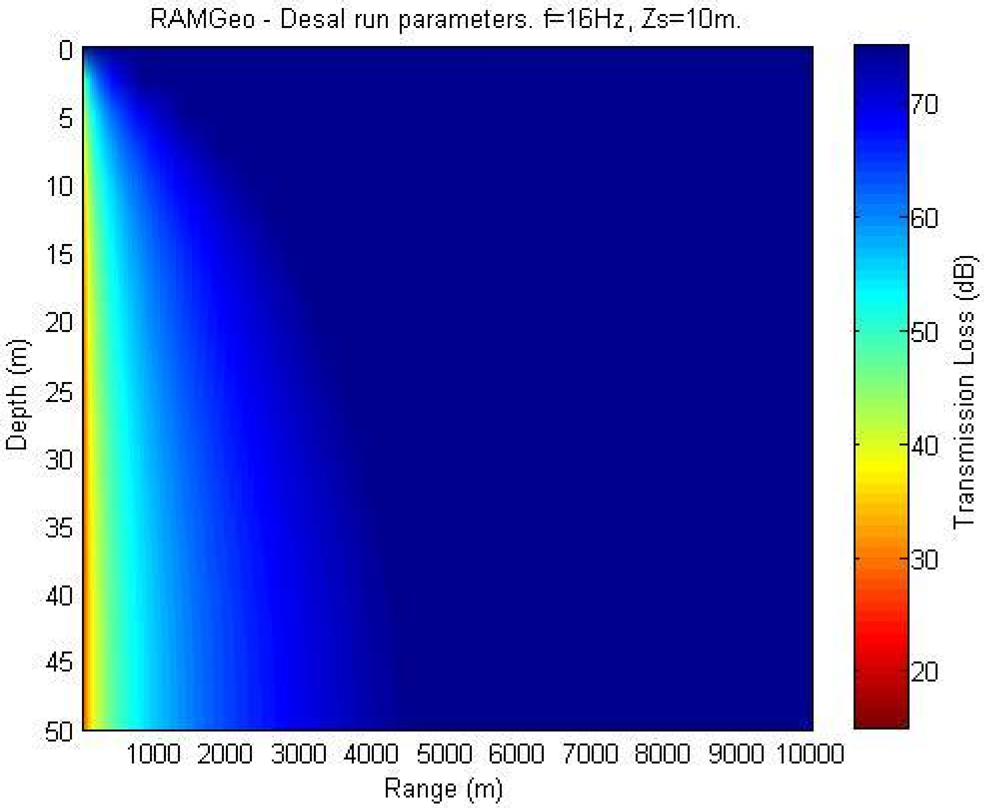
2) *Taccola* vessel source level information was drawn from: Langworthy, J., D. Howell, J. Nedwell. 2004. An assessment of the underwater noise radiated by the dredger *Taccola*. Report No. 614 R 0205.

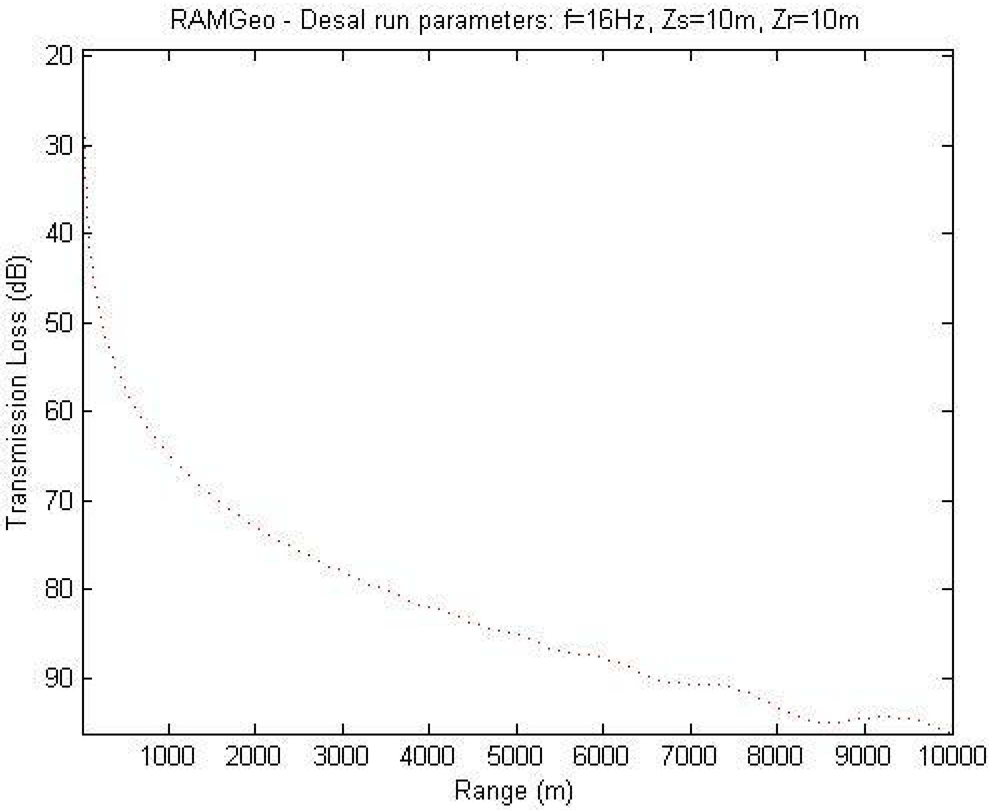
Appendix D – Transmission Loss Results : Track A

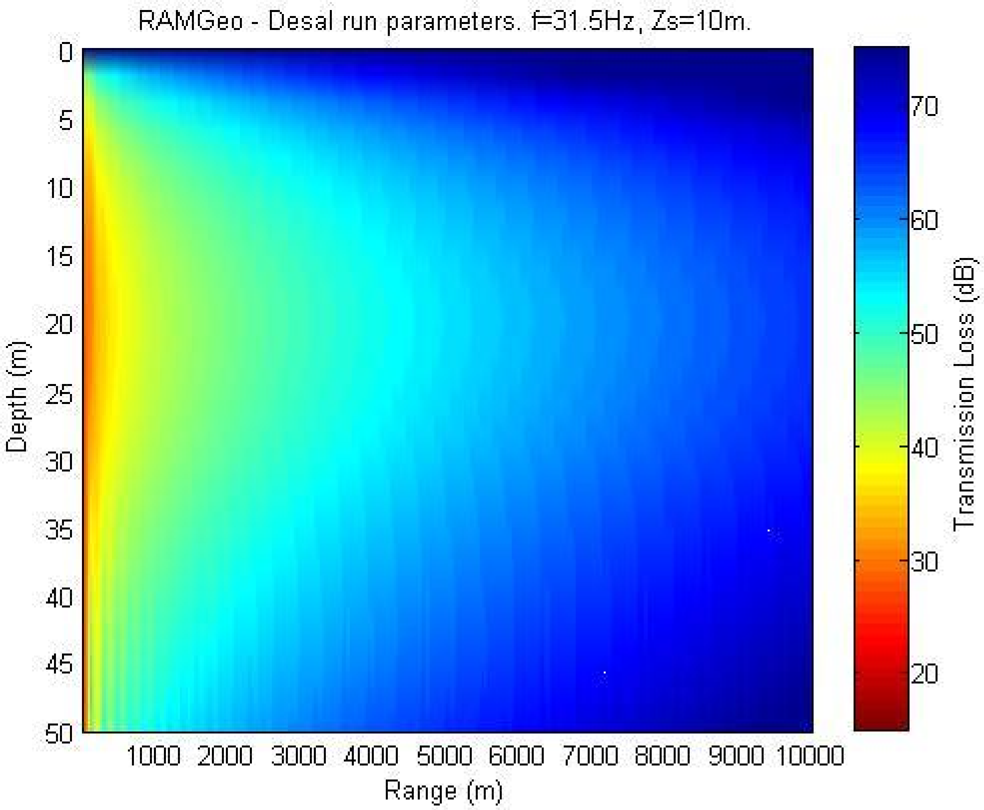
Images for each Octave Band

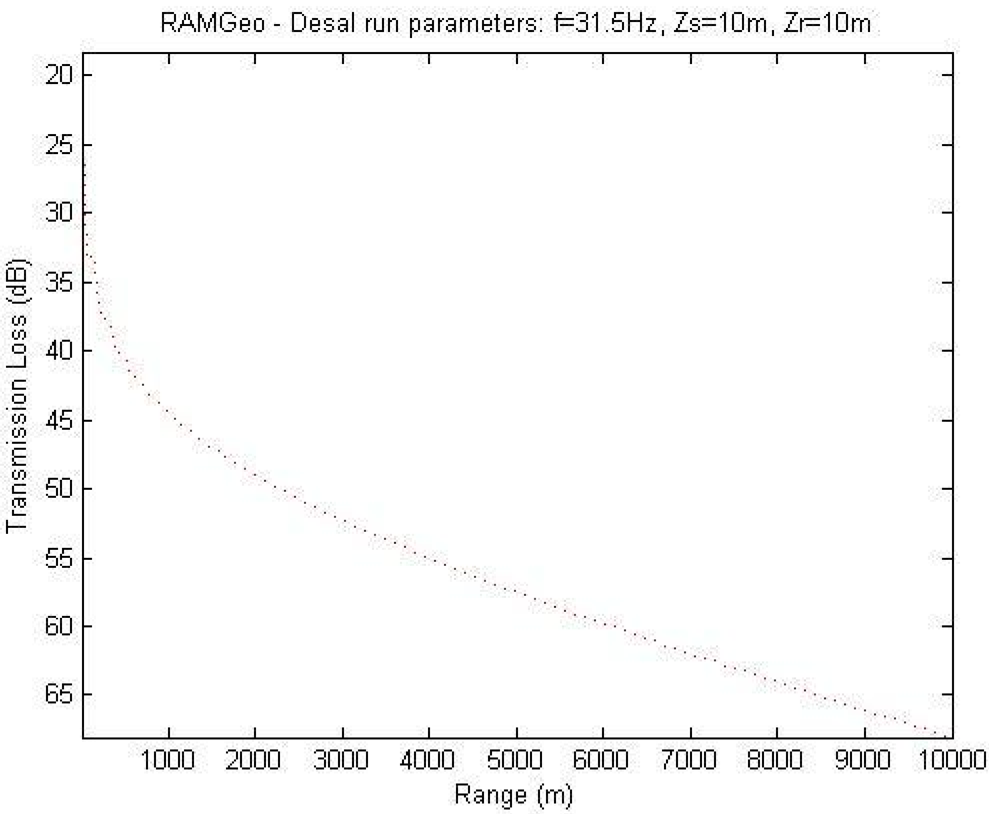

RAMGeo - Desal run parameters. f=8Hz, Zs=10m.
Depth (m)
Range (m)
Transmission Loss (dB)
0
5
10
15
20
25
30
35
40
45
50
1000 2000 3000 4000 5000 6000 7000 8000 9000 10000
80
70
60
50
40
30
20

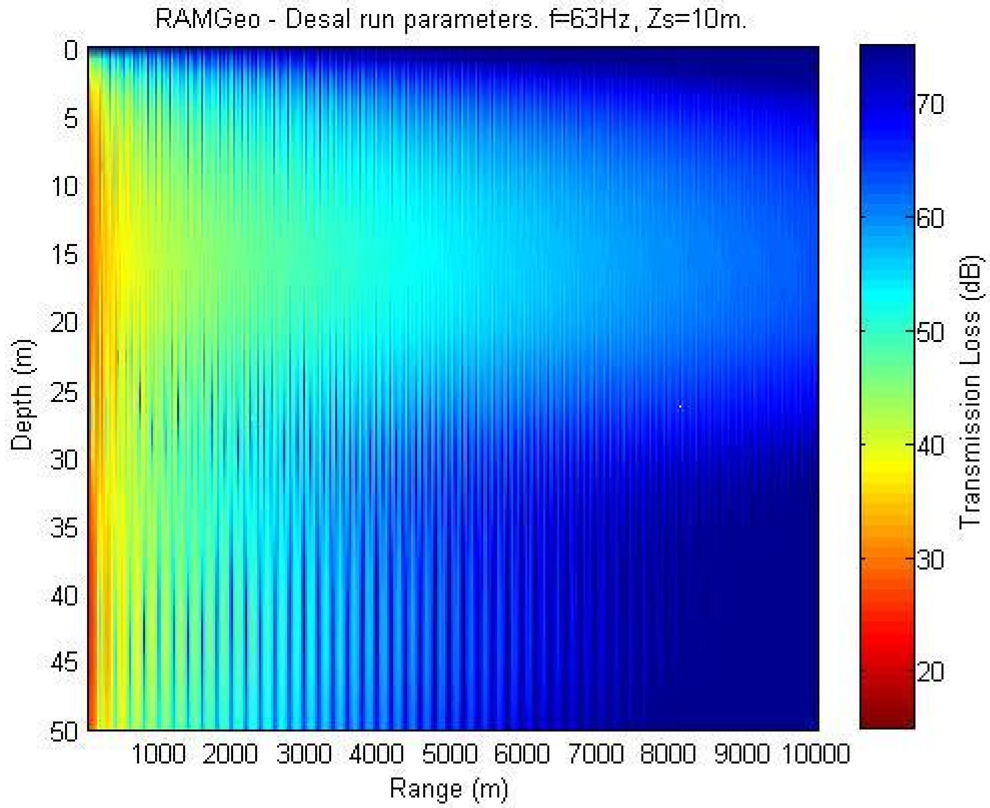

RAMGeo - Desal run parameters: f=8Hz, Zs=10m, Zr=10m
Transmission Loss (dB)
Range (m)
40
60
80
100
120
140
160
1000 2000 3000 4000 5000 6000 7000 8000 9000 10000

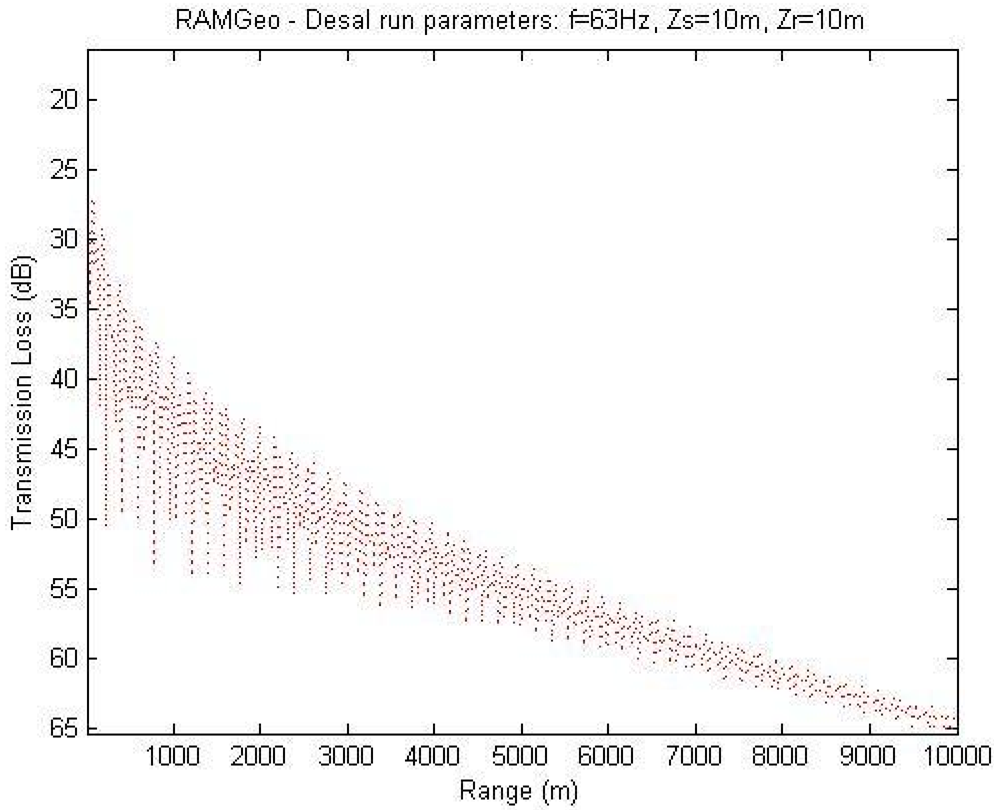

RAMGeo - Desal run parameters. f=16Hz, Zs=10m.
Depth (m)
Range (m)
Transmission Loss (dB)
0
5
10
15
20
25
30
35
40
45
50
1000 2000 3000 4000 5000 6000 7000 8000 9000 10000
70
60
50
40
30
20

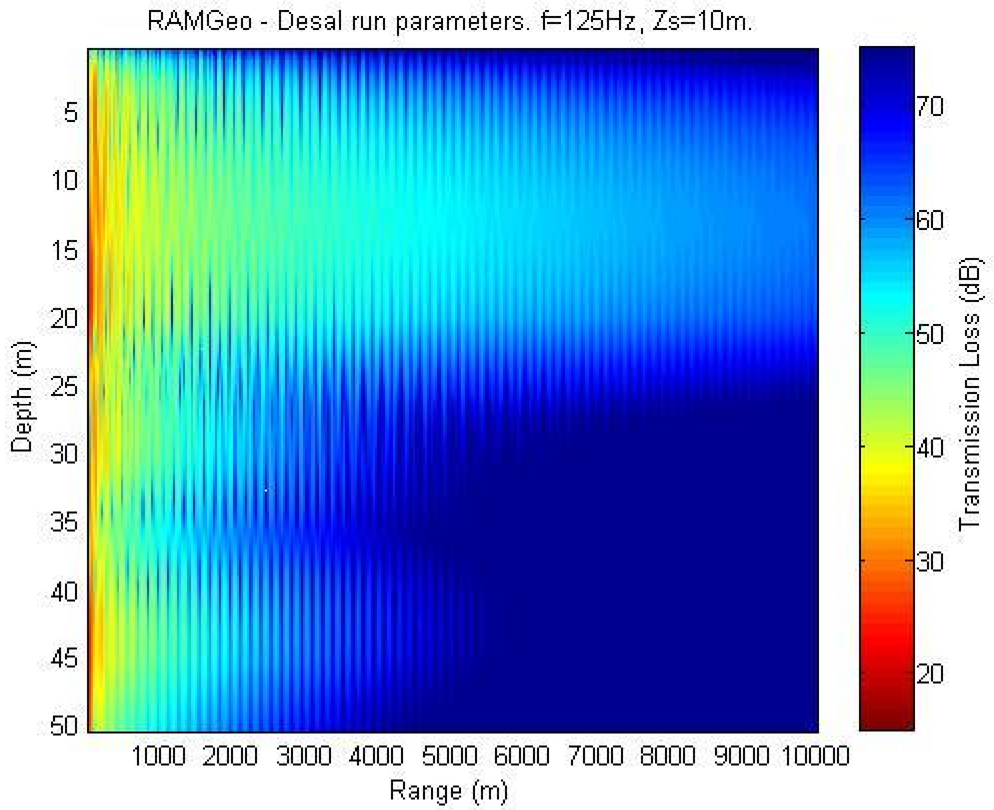

RAMGeo - Desal run parameters: f=16Hz, Zs=10m, Zr=10m
Transmission Loss (dB)
Range (m)
20
30
40
50
60
70
80
90
1000 2000 3000 4000 5000 6000 7000 8000 9000 10000

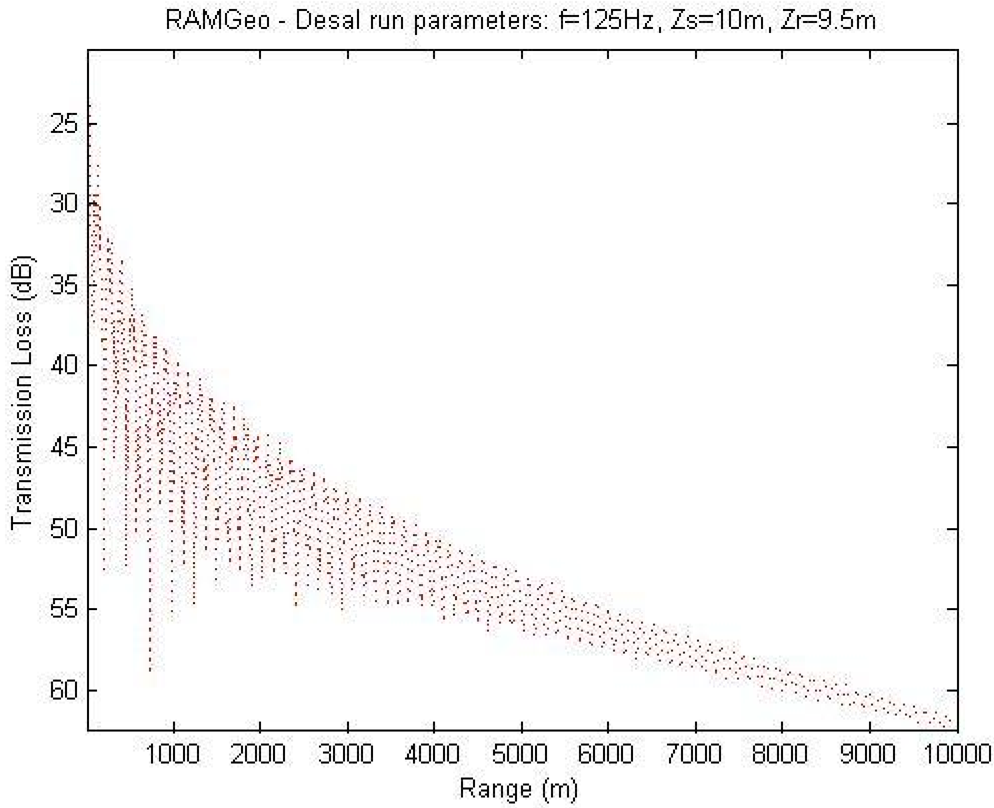

RAMGeo - Desal run parameters. f=31.5Hz, Zs=10m.
Depth (m)
0
5
10
15
20
25
30
35
40
45
50
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Range (m)
Transmission Loss (dB)
70
60
50
40
30
20

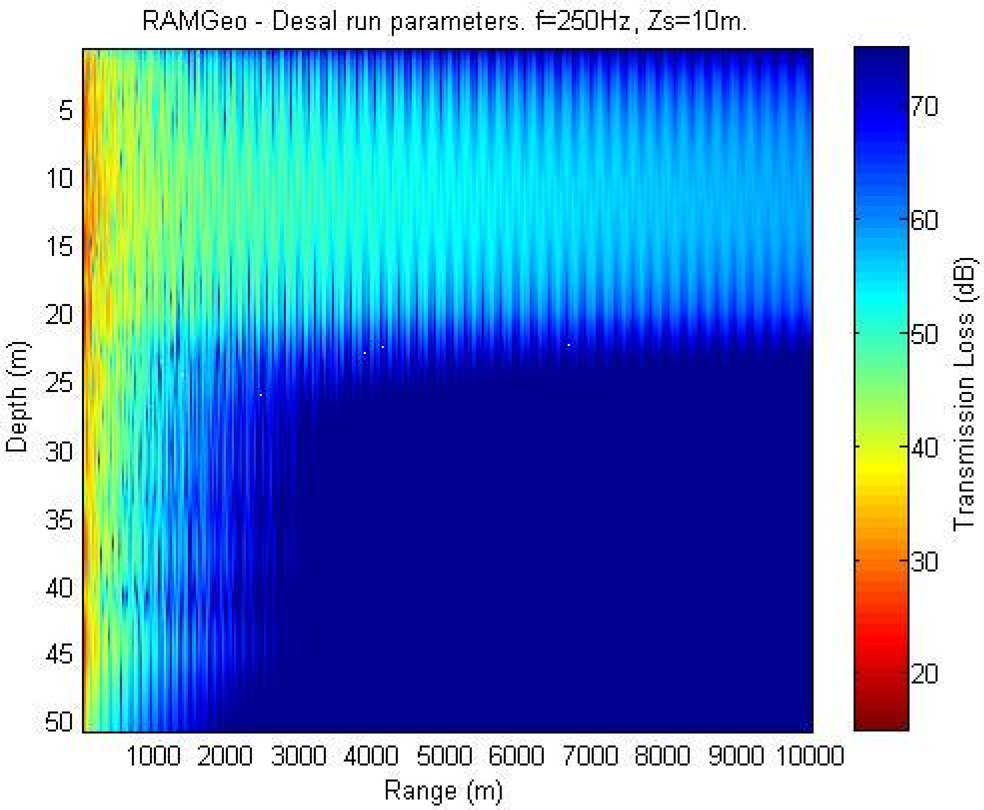

RAMGeo - Desal run parameters: f=31.5Hz, Zs=10m, Zr=10m
Transmission Loss (dB)
20
25
30
35
40
45
50
55
60
65
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Range (m)

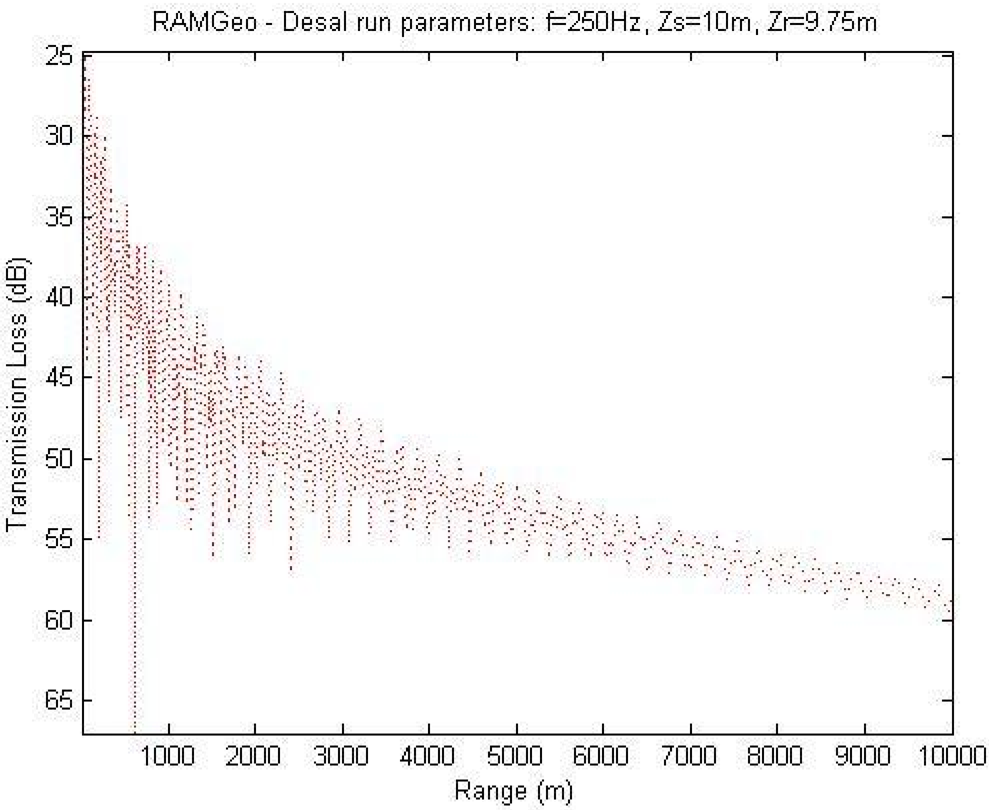

RAMGeo - Desal run parameters. f=63Hz, Zs=10m.
Depth (m)
0
5
10
15
20
25
30
35
40
45
50
1000 2000 3000 4000 5000 6000 7000 8000 9000 10000
Range (m)
Transmission Loss (dB)
70
60
50
40
30
20

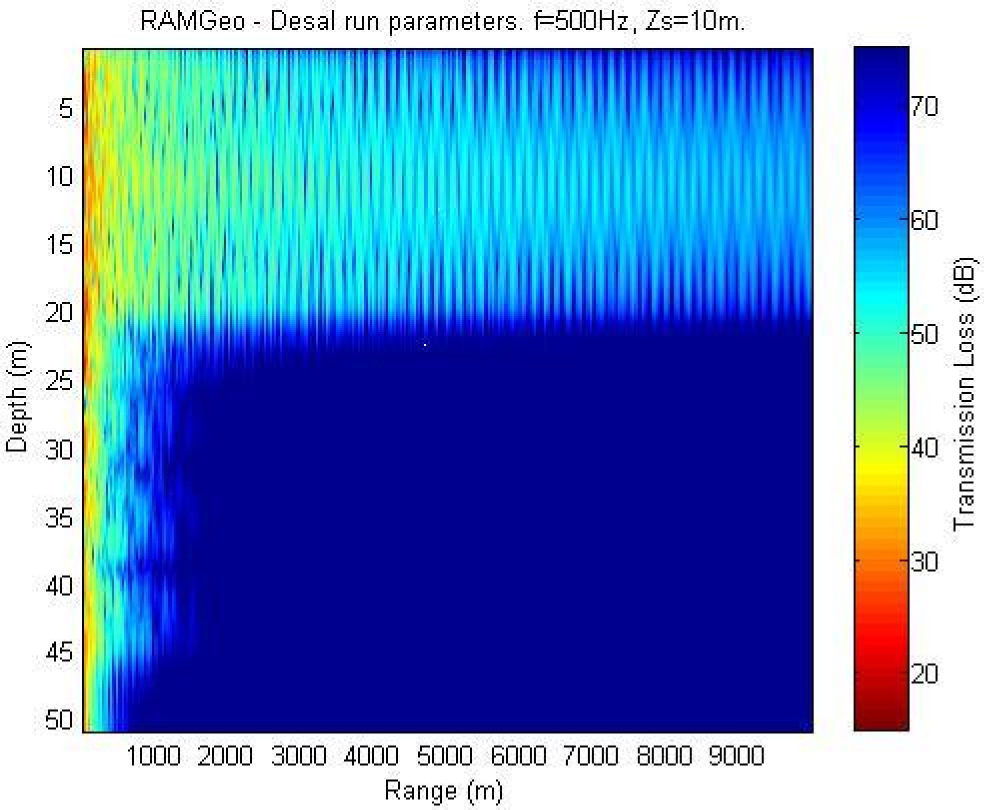

RAMGeo - Desal run parameters: f=63Hz, Zs=10m, Zr=10m
Transmission Loss (dB)
20
25
30
35
40
45
50
55
60
65
1000 2000 3000 4000 5000 6000 7000 8000 9000 10000
Range (m)

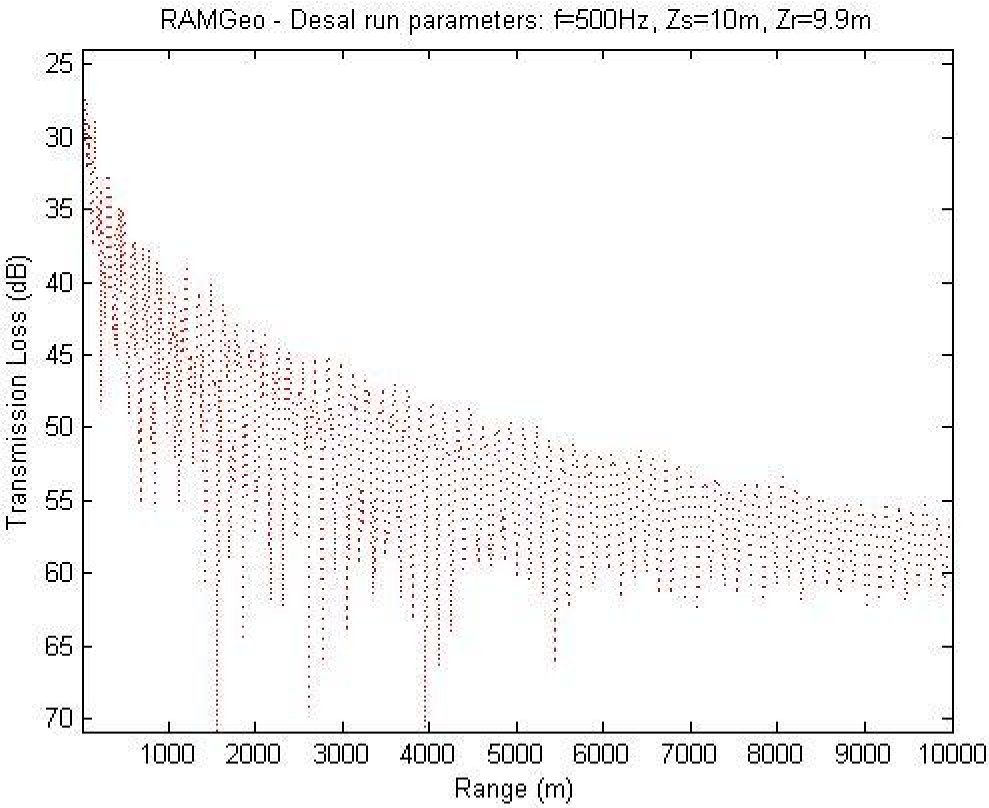

RAMGeo - Desal run parameters. f=125Hz, Zs=10m.
Depth (m)
5
10
15
20
25
30
35
40
45
50
1000 2000 3000 4000 5000 6000 7000 8000 9000 10000
Range (m)
70
60
50
40
30
20
Transmission Loss (dB)

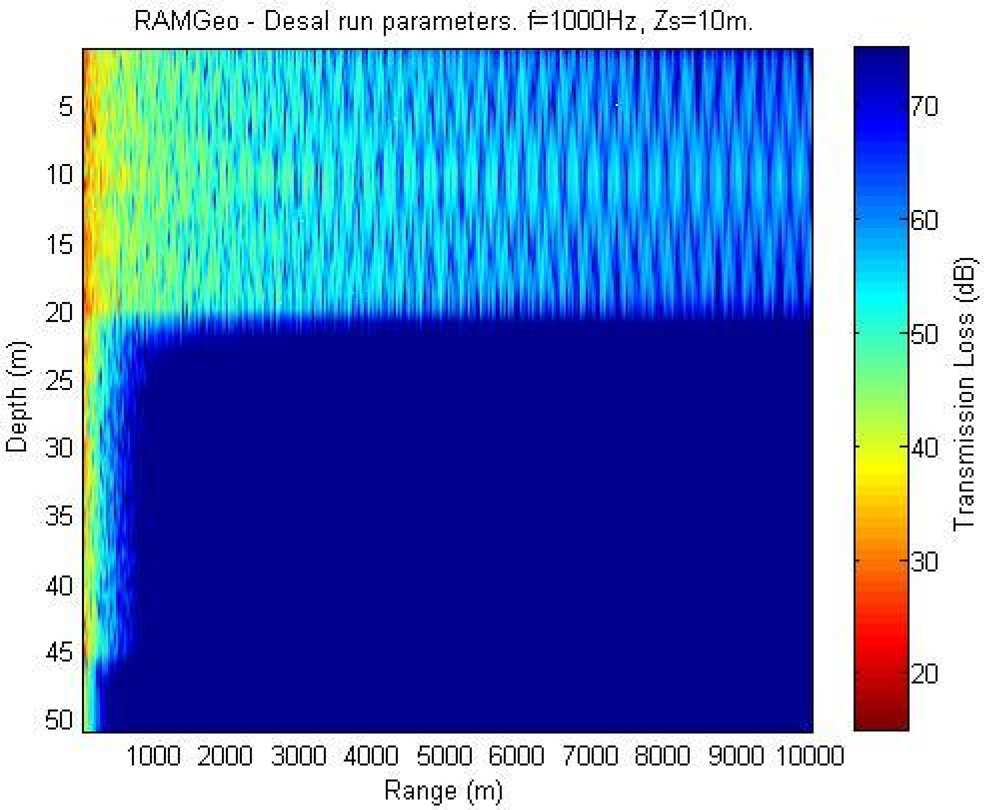

RAMGeo - Desal run parameters: f=125Hz, Zs=10m, Zr=9.5m
Transmission Loss (dB)
25
30
35
40
45
50
55
60
1000 2000 3000 4000 5000 6000 7000 8000 9000 10000
Range (m)

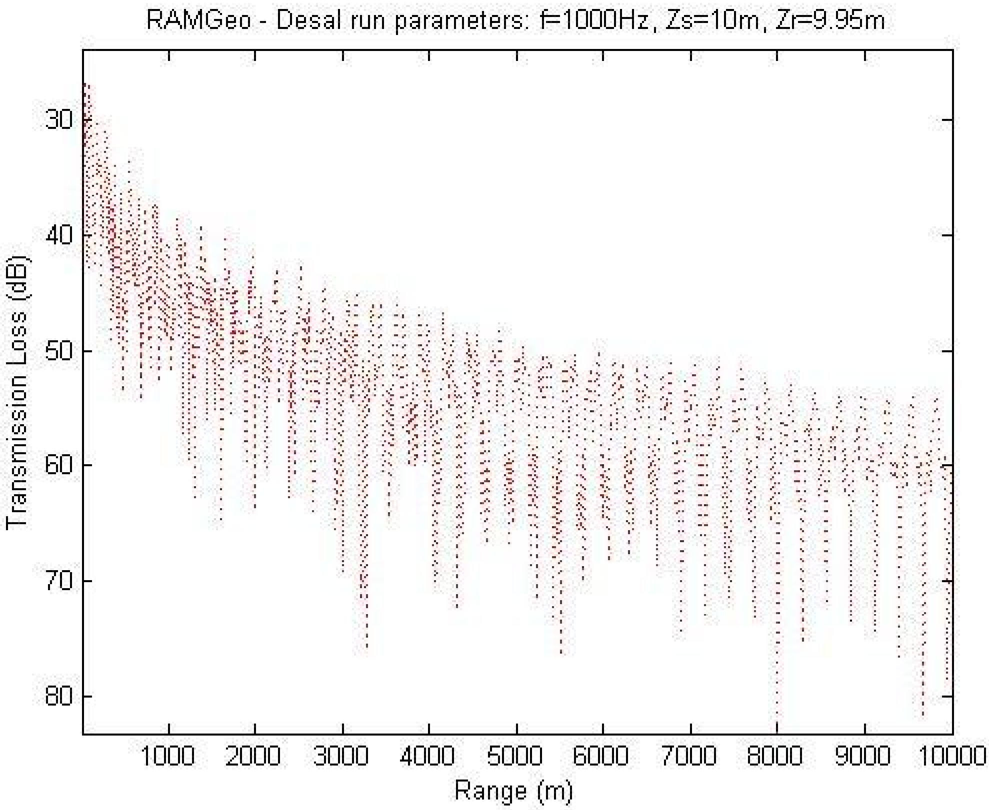

RAMGeo - Desal run parameters. f=250Hz, Zs=10m.
Depth (m)
Range (m)
Transmission Loss (dB)
5
10
15
20
25
30
35
40
45
50
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
70
60
50
40
30
20


RAMGeo - Desal run parameters: f=250Hz, Zs=10m, Zr=9.75m
Transmission Loss (dB)
Range (m)
25
30
35
40
45
50
55
60
65
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000


RAMGeo - Desal run parameters. f=500Hz, Zs=10m.
Depth (m)
5
10
15
20
25
30
35
40
45
50
1000 2000 3000 4000 5000 6000 7000 8000 9000
Range (m)
70
60
50
40
30
20
Transmission Loss (dB)

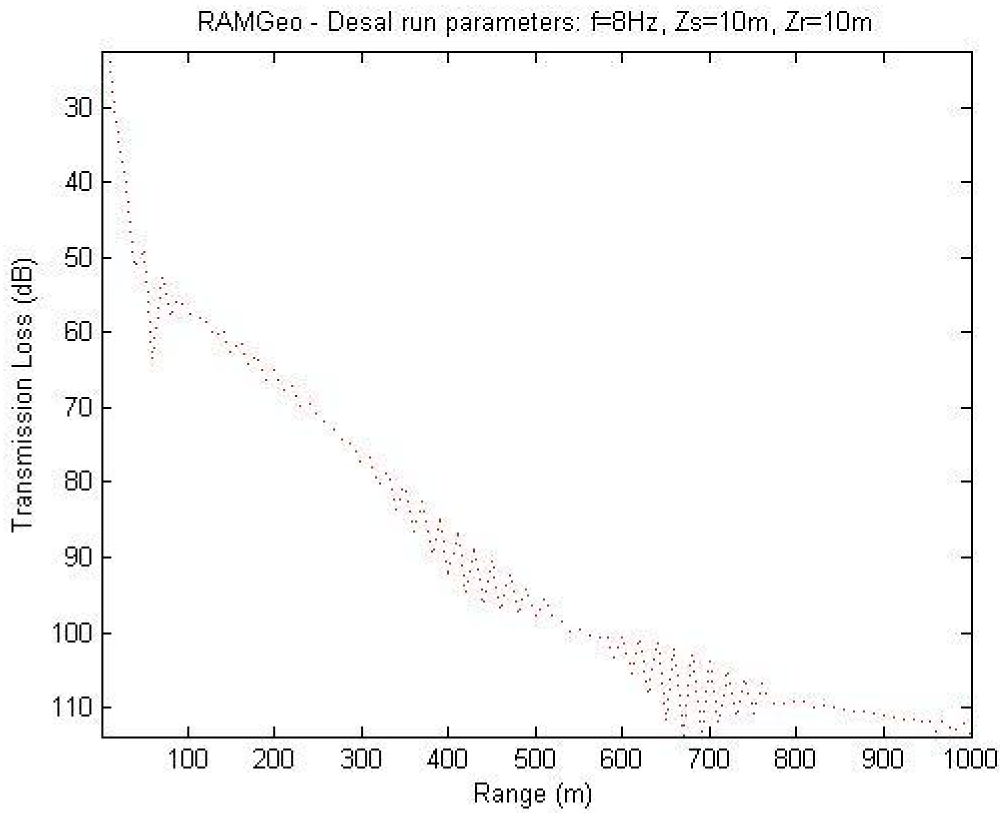

RAMGeo - Desal run parameters: f=500Hz, Zs=10m, Zr=9.9m
Transmission Loss (dB)
25
30
35
40
45
50
55
60
65
70
1000 2000 3000 4000 5000 6000 7000 8000 9000 10000
Range (m)

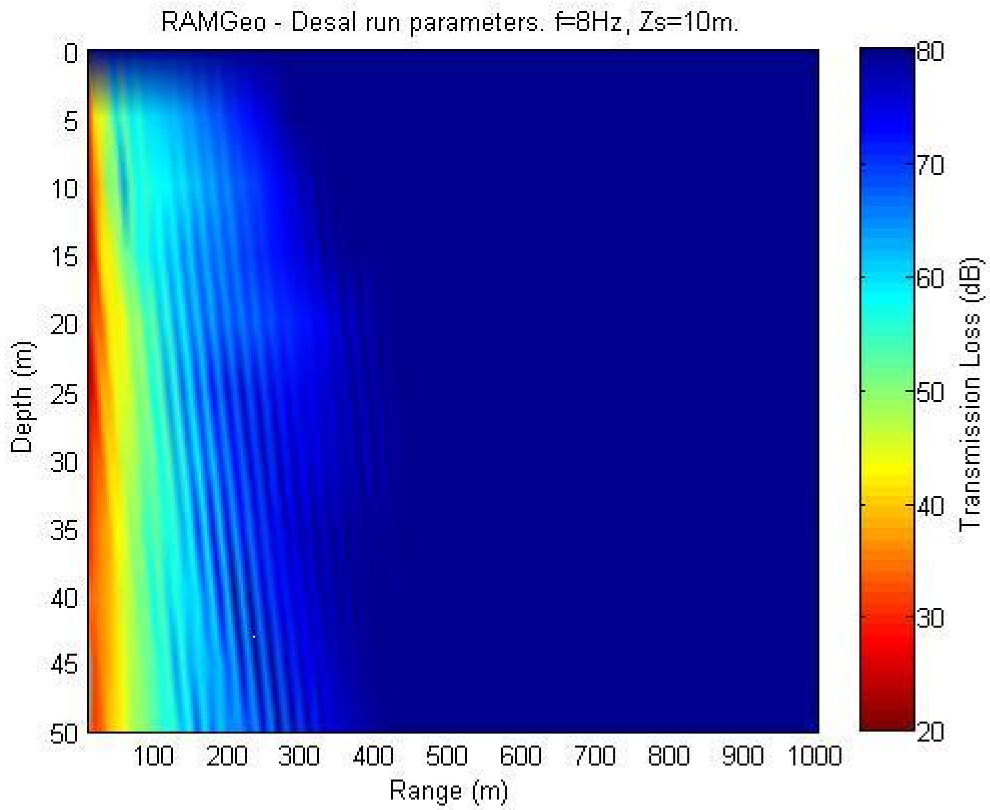

RAMGeo - Desal run parameters. f=1000Hz, Zs=10m.
Depth (m)
5
10
15
20
25
30
35
40
45
50
1000 2000 3000 4000 5000 6000 7000 8000 9000 10000
Range (m)
Transmission Loss (dB)
70
60
50
40
30
20

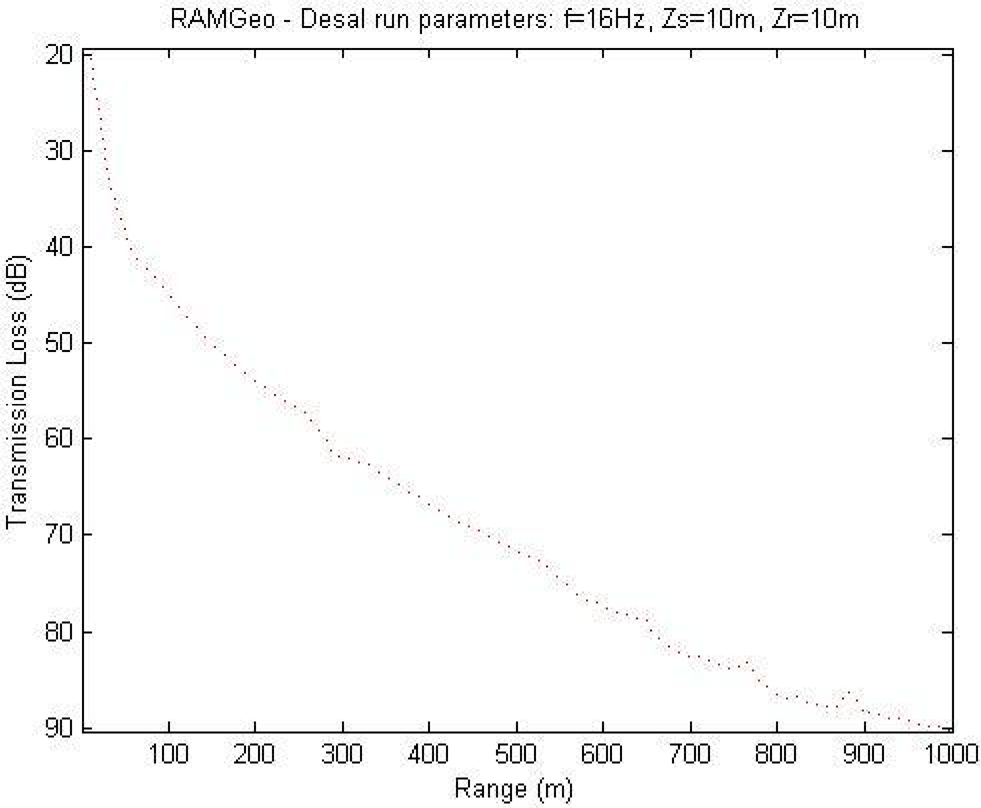

RAMGeo - Desal run parameters: f=1000Hz, Zs=10m, Zr=9.95m
Transmission Loss (dB)
30
40
50
60
70
80
1000 2000 3000 4000 5000 6000 7000 8000 9000 10000
Range (m)

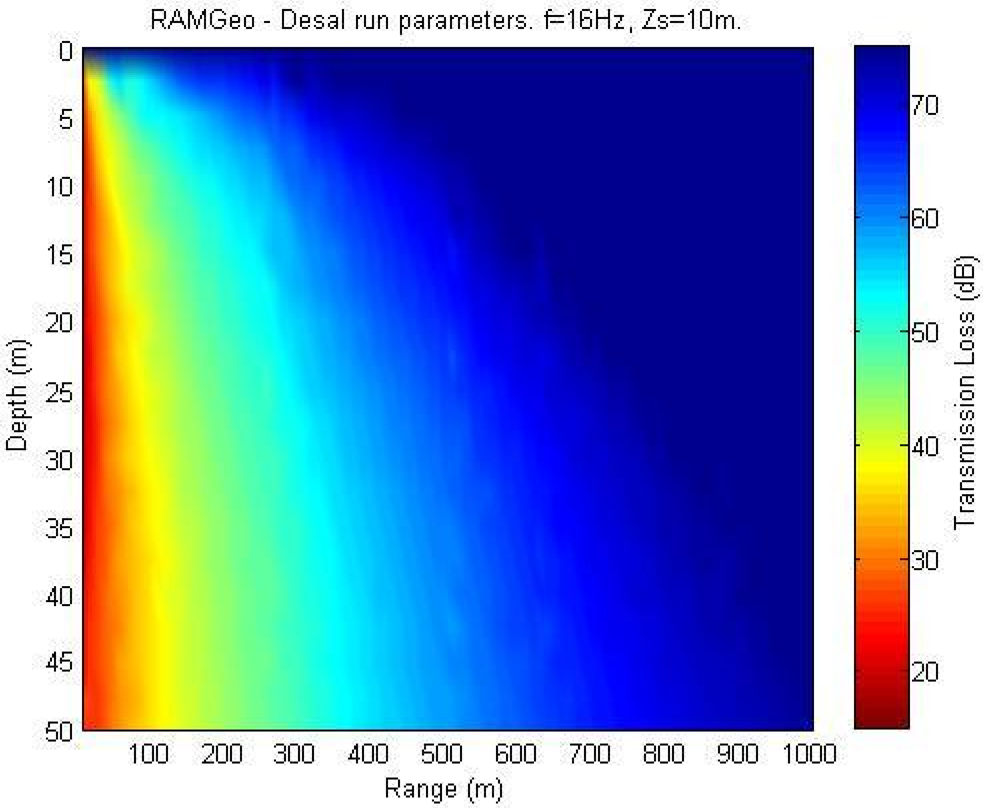
Appendix E – Transmission Loss Results : Track B

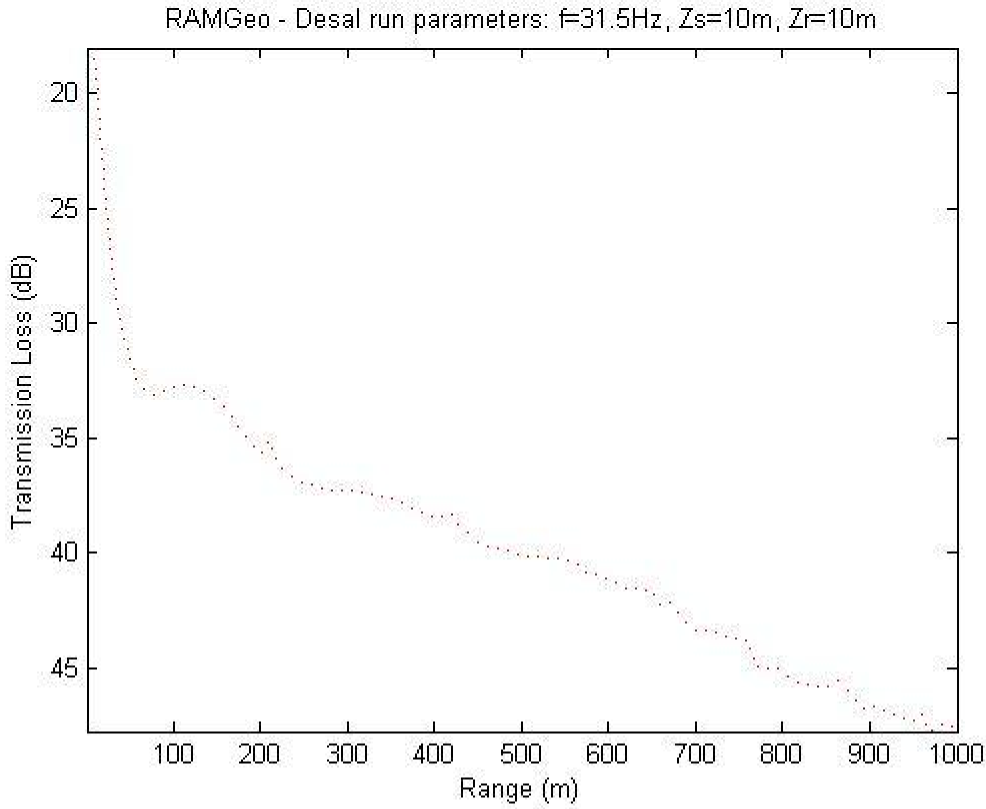
Images for each Octave Band

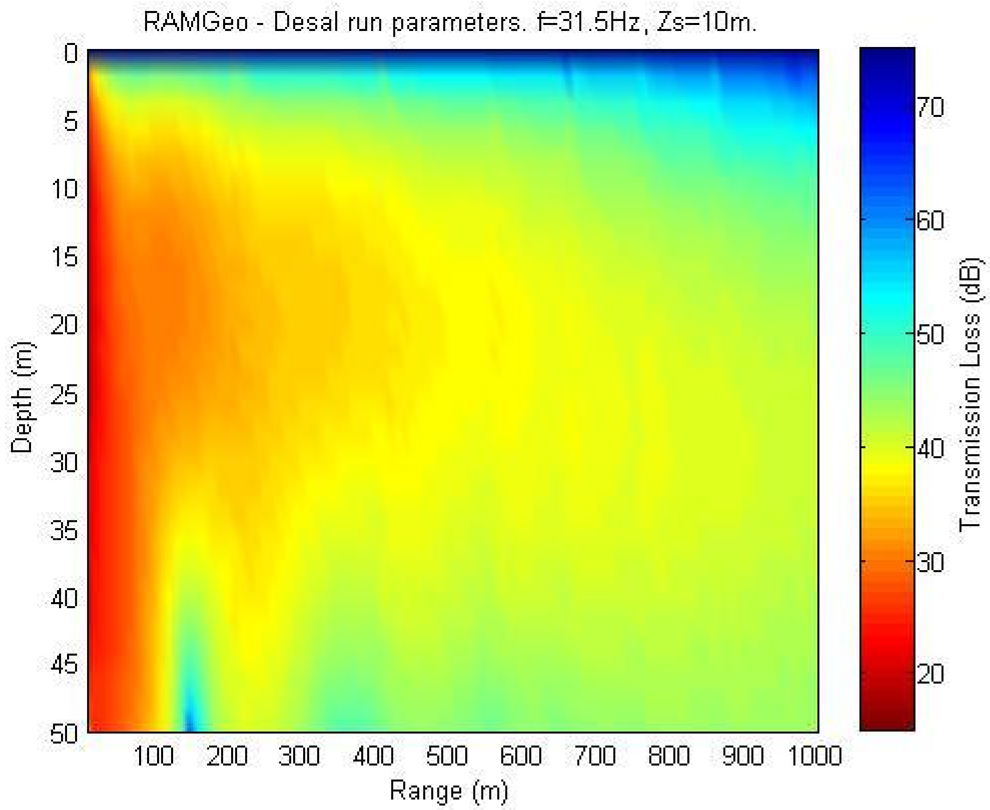

RAMGeo - Desal run parameters: f=8Hz, Zs=10m, Zr=10m
Transmission Loss (dB)
30
40
50
60
70
80
90
100
110
100
200
300
400
500
600
700
800
900
1000
Range (m)

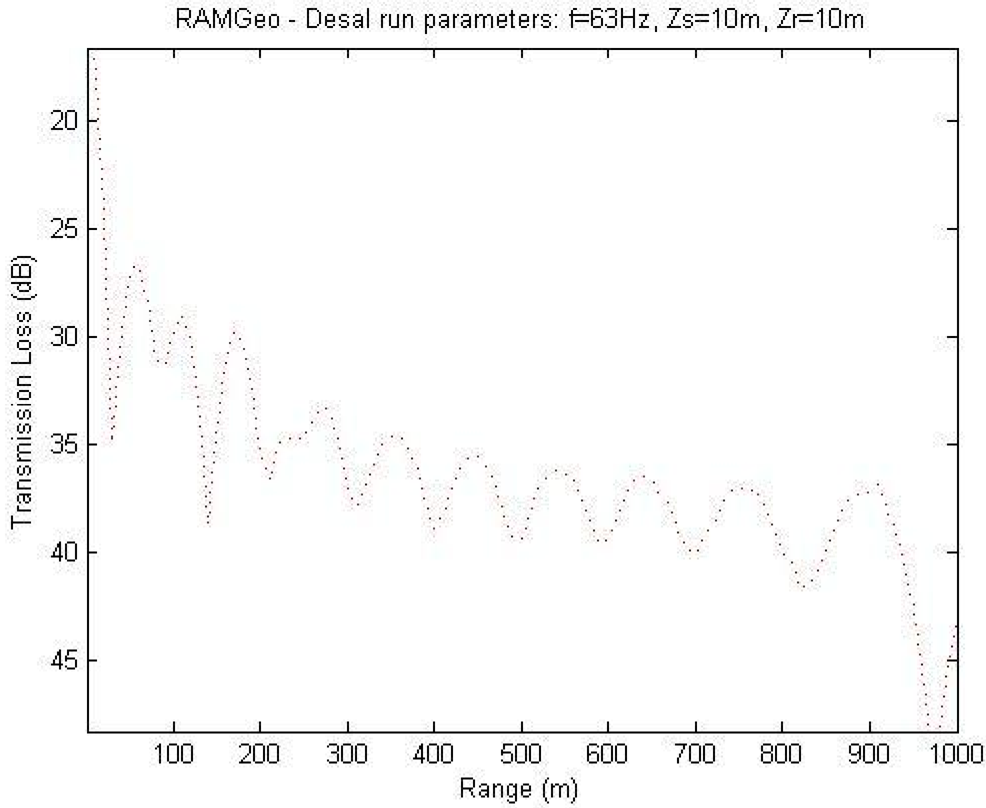

RAMGeo - Desal run parameters. f=8Hz, Zs=10m.
Depth (m)
0
5
10
15
20
25
30
35
40
45
50
100
200
300
400
500
600
700
800
900
1000
Range (m)
80
70
60
50
40
30
20
Transmission Loss (dB)

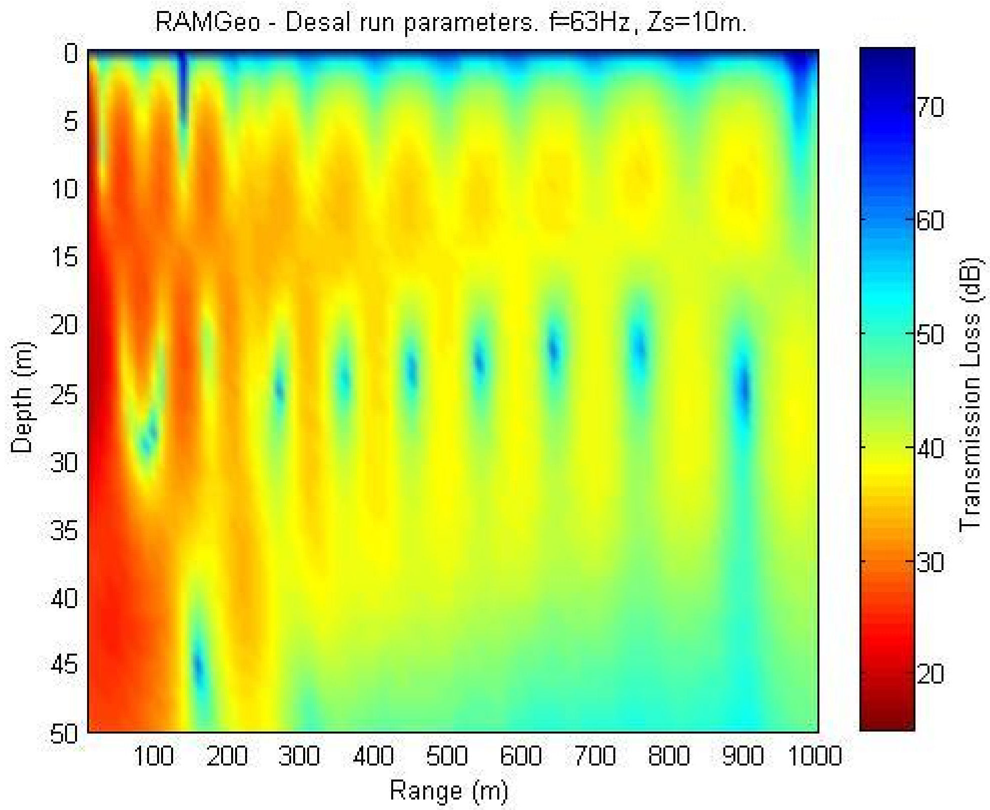

RAMGeo - Desal run parameters: f=16Hz, Zs=10m, Zr=10m
Transmission Loss (dB)
20
30
40
50
60
70
80
90
100
200
300
400
500
600
700
800
900
1000
Range (m)

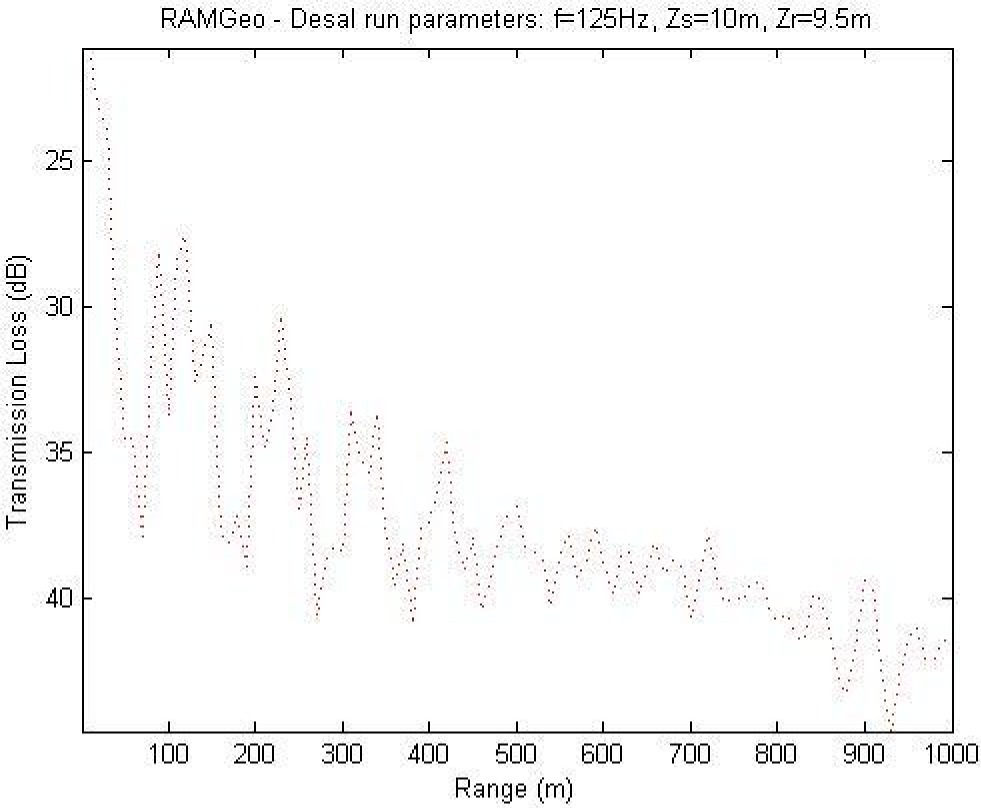

RAMGeo - Desal run parameters. f=16Hz, Zs=10m.
Depth (m)
0
5
10
15
20
25
30
35
40
45
50
100
200
300
400
500
600
700
800
900
1000
Range (m)
70
60
50
40
30
20
Transmission Loss (dB)

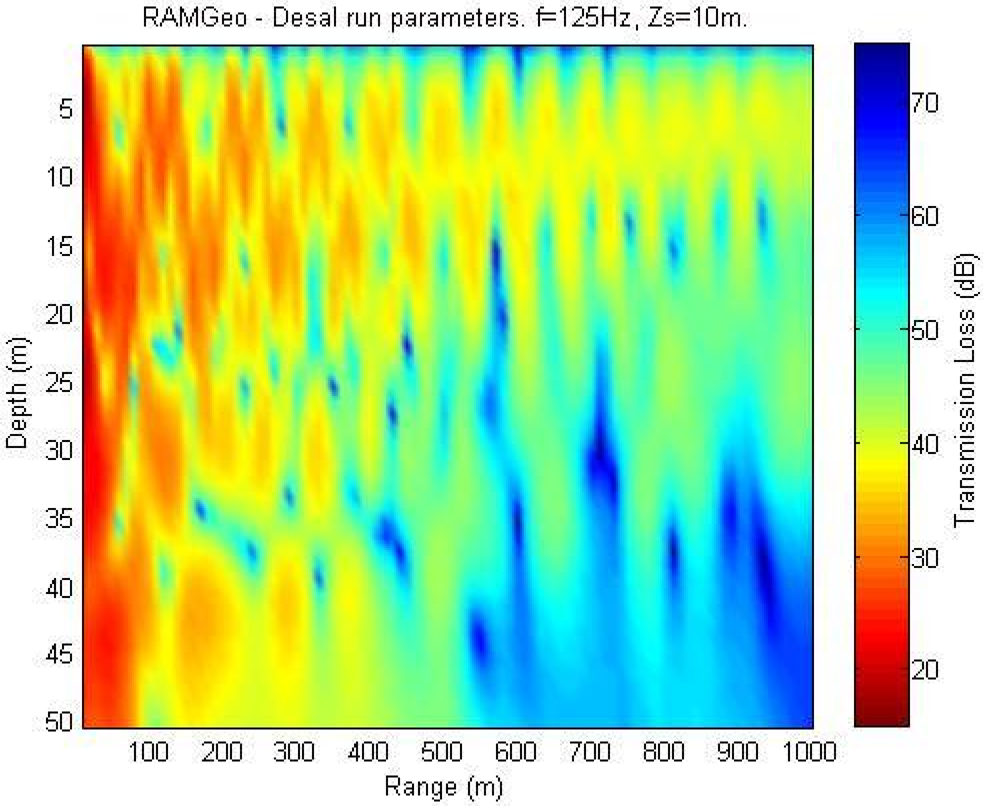

RAMGeo - Desal run parameters: f=31.5Hz, Zs=10m, Zr=10m
Transmission Loss (dB)
20
25
30
35
40
45
100
200
300
400
500
600
700
800
900
1000
Range (m)

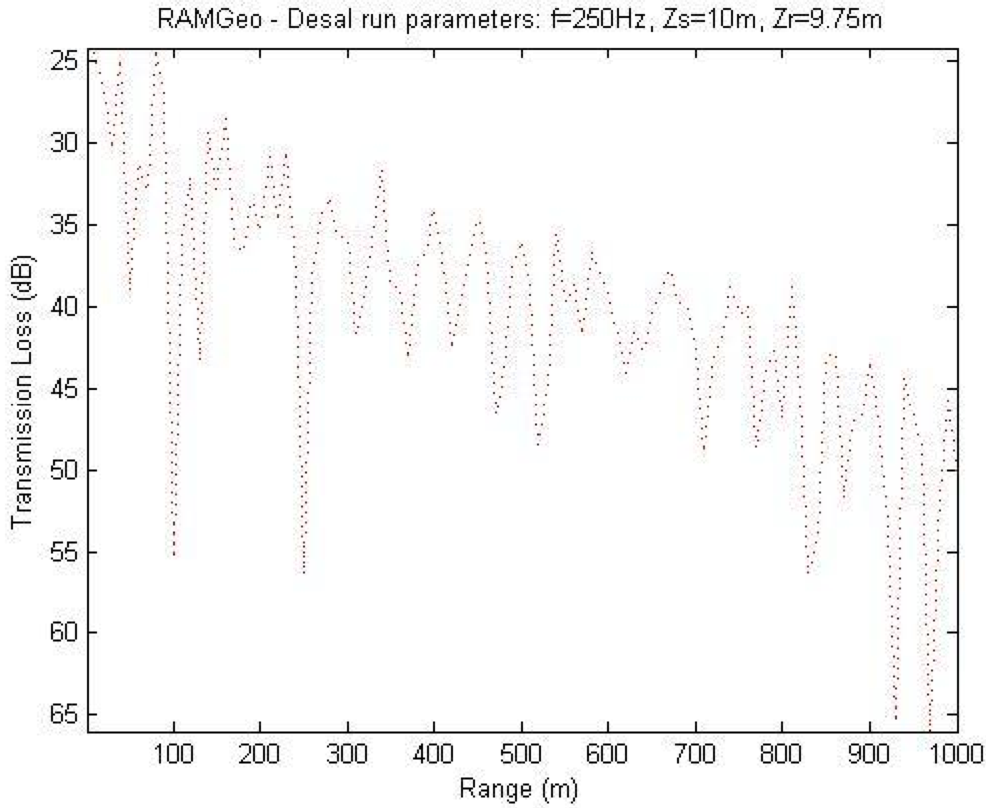

RAMGeo - Desal run parameters. f=31.5Hz, Zs=10m.
Depth (m)
0
5
10
15
20
25
30
35
40
45
50
100
200
300
400
500
600
700
800
900
1000
Range (m)
Transmission Loss (dB)
70
60
50
40
30
20

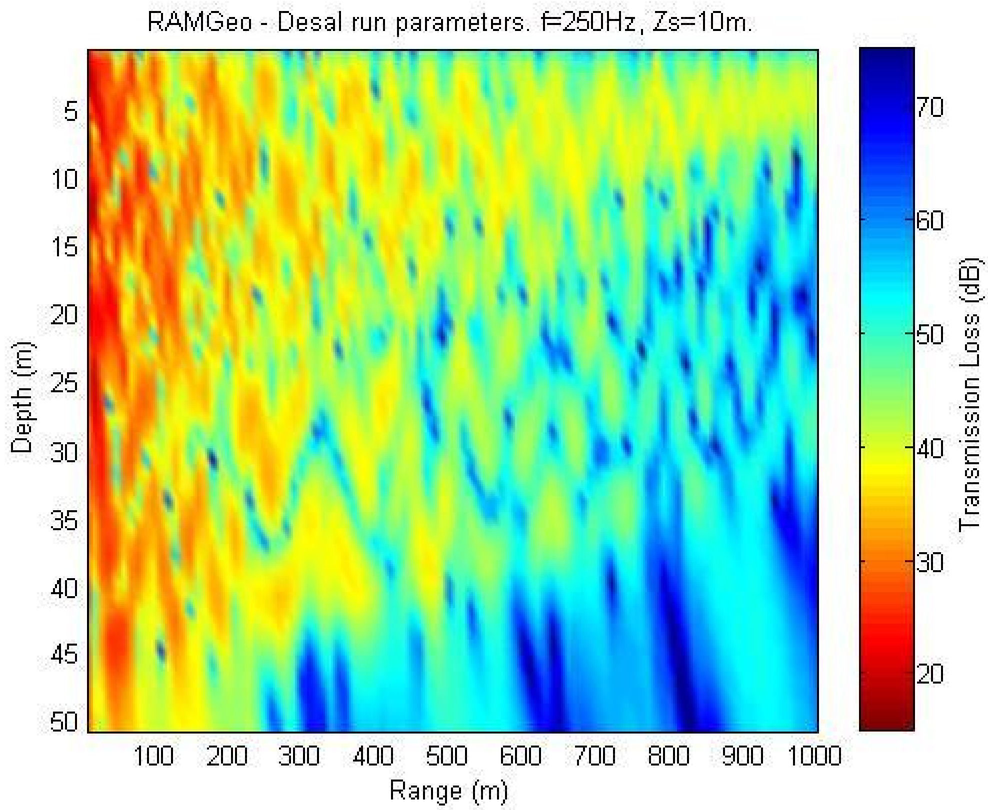

RAMGeo - Desal run parameters: f=63Hz, Zs=10m, Zr=10m
Transmission Loss (dB)
20
25
30
35
40
45
100
200
300
400
500
600
700
800
900
1000
Range (m)

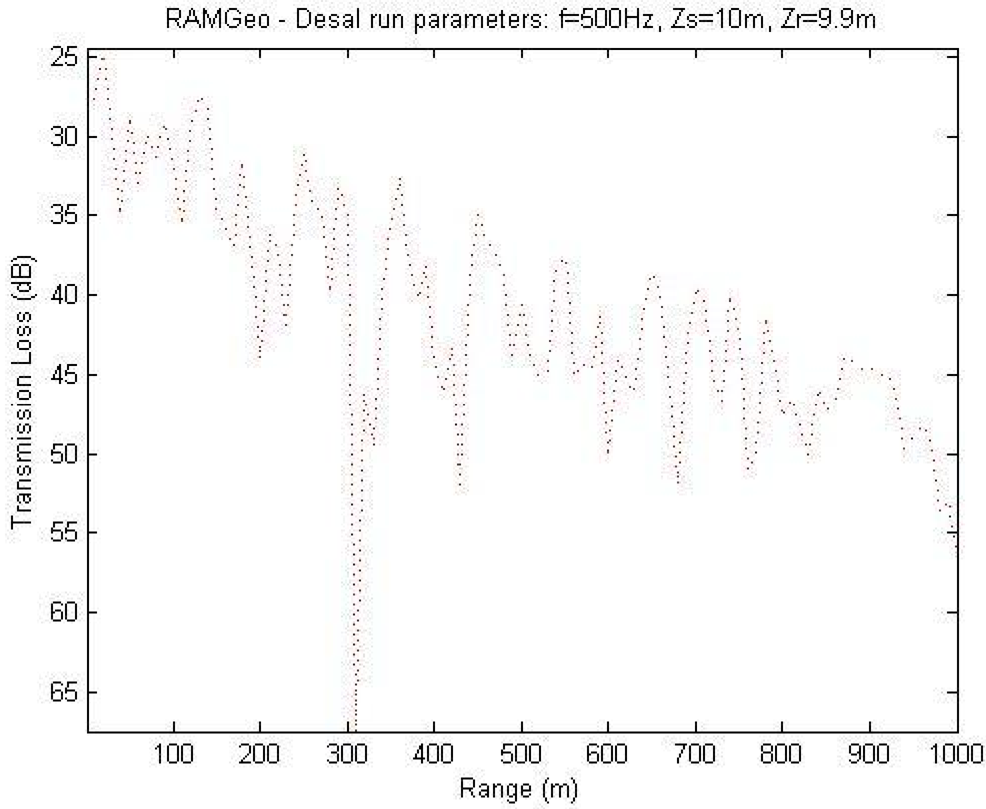

RAMGeo - Desal run parameters. f=63Hz, Zs=10m.
Depth (m)
0
5
10
15
20
25
30
35
40
45
50
100
200
300
400
500
600
700
800
900
1000
Range (m)
70
60
50
40
30
20
Transmission Loss (dB)

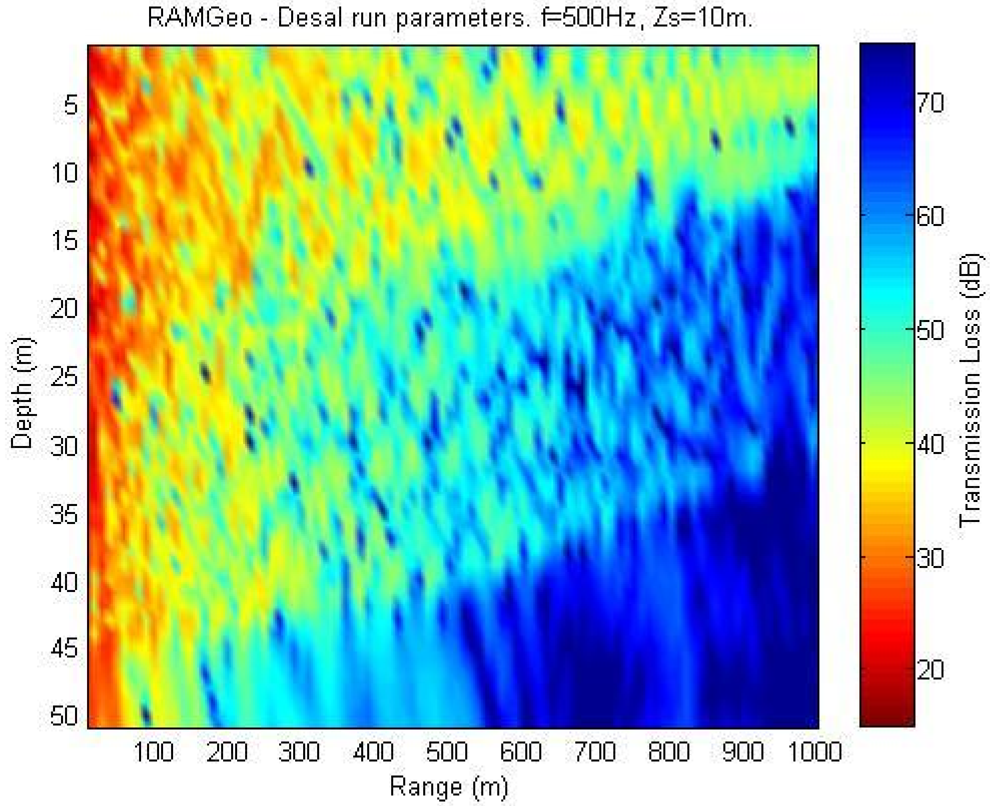

RAMGeo - Desal run parameters: f=125Hz, Zs=10m, Zr=9.5m
Transmission Loss (dB)
25
30
35
40
100
200
300
400
500
600
700
800
900
1000
Range (m)

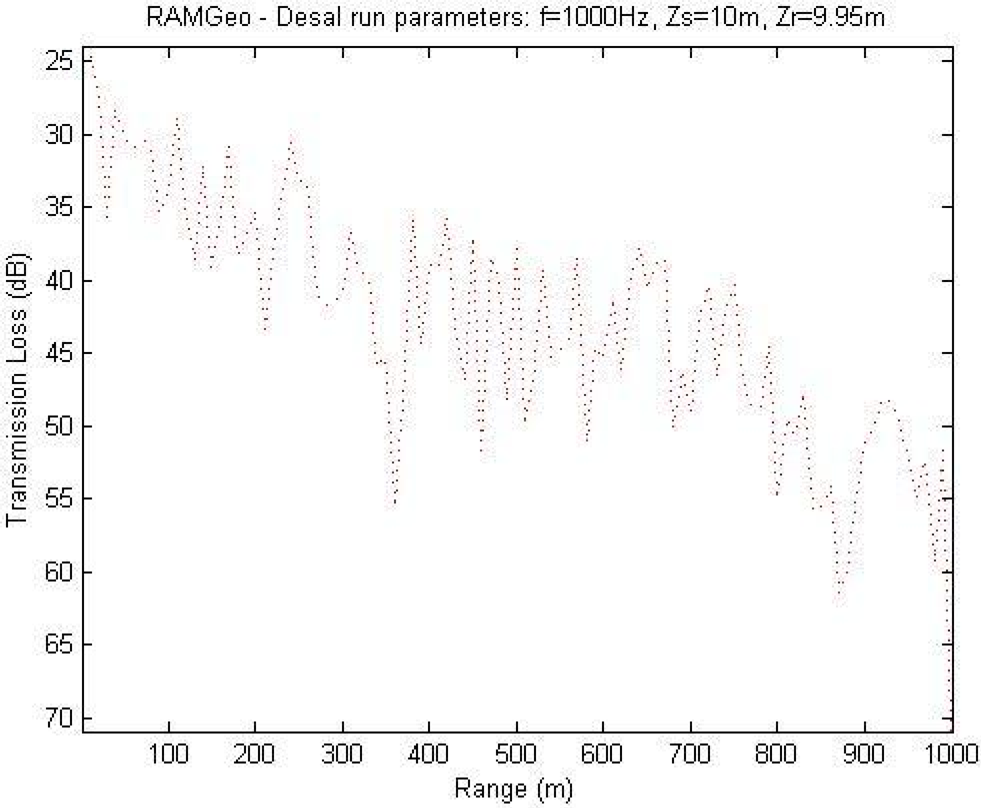

RAMGeo - Desal run parameters. f=125Hz, Zs=10m.
Depth (m)
5
10
15
20
25
30
35
40
45
50
100
200
300
400
500
600
700
800
900
1000
Range (m)
70
60
50
40
30
20
Transmission Loss (dB)

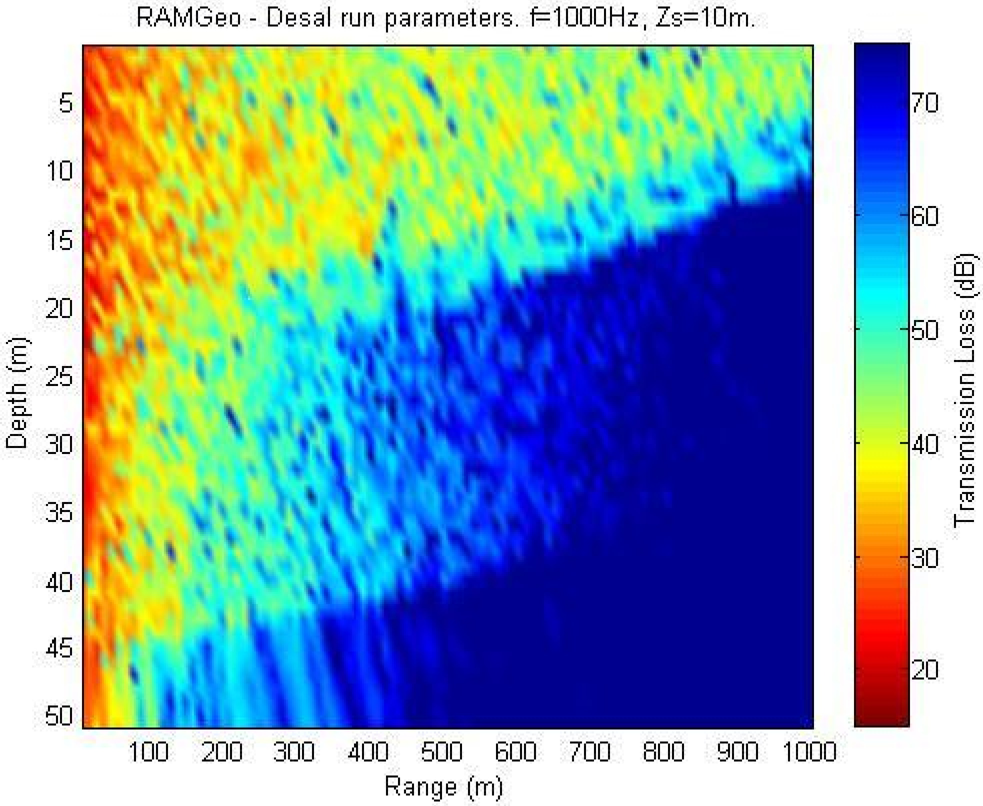

RAMGeo - Desal run parameters: f=250Hz, Zs=10m, Zr=9.75m
Transmission Loss (dB)
25
30
35
40
45
50
55
60
65
100
200
300
400
500
600
700
800
900
1000
Range (m)


RAMGeo - Desal run parameters. f=250Hz, Zs=10m.
Depth (m)
5
10
15
20
25
30
35
40
45
50
100
200
300
400
500
600
700
800
900
1000
Range (m)
Transmission Loss (dB)
70
60
50
40
30
20


RAMGeo - Desal run parameters: f=500Hz, Zs=10m, Zr=9.9m
Transmission Loss (dB)
25
30
35
40
45
50
55
60
65
100 200 300 400 500 600 700 800 900 1000
Range (m)


RAMGeo - Desal run parameters. f=500Hz, Zs=10m.
Depth (m)
5
10
15
20
25
30
35
40
45
50
100 200 300 400 500 600 700 800 900 1000
Range (m)
Transmission Loss (dB)
70
60
50
40
30
20


RAMGeo - Desal run parameters: f=1000Hz, Zs=10m, Zr=9.95m
Transmission Loss (dB)
25
30
35
40
45
50
55
60
65
70
100
200
300
400
500
600
700
800
900
1000
Range (m)


RAMGeo - Desal run parameters. f=1000Hz, Zs=10m.
Depth (m)
5
10
15
20
25
30
35
40
45
50
100
200
300
400
500
600
700
800
900
1000
Range (m)
Transmission Loss (dB)
70
60
50
40
30
20

Appendix F – Risk Analysis Criteria

Risk Analysis Criteria

Environmental Risk Assessment

A risk assessment process was completed to identify hazards, causes and likelihood/consequence of risks and to identify potential environmental impacts associated with the construction of the ADP. Using the likelihood/consequence severity criteria (outlined below) a matrix was developed to assess the qualitative risk to the environment from potential impacts.
Risks include:

- Extreme – Intolerable environmental risks with significant and urgent actions required to reduce the risk;
- High and Moderate – Implement actions necessary to reduce risk to as low a reasonably practical within the EMP; and
- Low – Monitor and manage risk to extent necessary

Determine Potential Consequence

Concentrating on the environmental impact, the potential consequence of each impact is considered under the following four broad categories:

- The effect or impact on people (safety);
- The effect or impact on the environment and licensing requirements;
- The effect or impact on the plant or business, usually in dollars; and
- The effect or impact on reputation due to stakeholder concern

The consequence rankings were established.

Table 13 Consequence Ranking Scores

	Critical (5)	Major (4)	Moderate (3)	Minor (2)	Low (1)
Occupational Health & Safety	**Multiple fatality** and/or significant irreversible exposure to a health risk that effects greater than 10 people	**Single fatality** and /or Severe permanent injury, paralysis, brain damage, life threatening exposure to a health risk	**Serious injury**. Moderate permanent effects from injury or exposure. Eg, serious burns, serious internal and/or head injuries, gassings that require hospitalisation	**Significant injury**. Medically Treated Injuries from which recovery is likely. Eg, burns, broken bones, severe bruises, cuts	**Minor injury**. No medical treatment Eg, cuts, bruises, no measurable physical effects
Legal	**Investigation by authority** with significant prosecution and fines. Very serious civil action, including class actions.	**Major regulatory breach** with investigation and prosecution, and potential mayor fine. Major civil action possible	**Serious regulatory breach** with expected prosecution and/or moderate fine. Civil action possible	**Minor legal issue**. Non-compliances to regulations. Minor prosecution, eg., on the spot fine	**Low-level legal** issue. Technical non-compliance. Prosecution unlikely
Financial Efficiency (excludes Legal Costs)	Cost Risks associated with the site would be **severe** (>$1.0m). These include management of the site, remediation now and in the future and loss of capability.	Cost Risks associated with the site would be **major** ($100,000 up to 1 m). These include management of the site, remediation now and in the future and loss of capability.	Cost Risks associated with the site would be **moderate** ($50,000 - $100,000) These include management of the site, remediation now and in the future and loss of capability.	Cost Risks associated with the site would be **minor** ($10,000 up to $50,000). These include management of the site, remediation now and in the future and loss of capability.	Cost Risks associated with the site would be **negligible** (<$10,000). Including management of the site, remediation now and in the future and loss of capability.
Reputation	Detrimental international media reports Subject of international government attention	Sustained detrimental national or state media reports Subject of a number of parliamentary question and Ministerials Sustained community outrage	Limited detrimental national or state media reports Subject of a parliamentary question or ministerial Organised community concerns/complaints	High profile detrimental local media reports Subject of local government action Random substantiated complains from the community	Low profile detrimental local media reports Trivial substantiated complains from the community

Environment Pollution	**Extreme Event**. Detectable effects on plants, animals or community. Contamination levels may result in acute toxicity to receptors (users and the environment)	**Major Release**. Detectable effects on plants, animals or community. Contamination levels may result in perceived major impacts on receptors	**Moderate Pollution**. Detectable effects on plants, animals or community. Contamination levels may result in perceived moderate impact on receptors	**Minor Pollution**. Detectable effects on plants, animals or community including noise, odour. Water contamination levels may result in perceived minor impacts on receptors	**Low Pollution**. Negligible damage contained on-site. No detectable effect to animals or community on or off-site. Emission or discharges as a result of being outside normal operating procedure.
Environment and Heritage	**Irreversible and extensive damage** caused to a Heritage Listed Area Irreversible and extensive damage is caused to a Matter of National Environmental Significance to the environment under the EPBC Act Causing material and serious harm potentially leading to prosecution under the SA EPA Act	**Irreversible and extensive damage** is caused to a non Heritage listed non environmentally significant area or asset Significant damage is caused to a Heritage Listed area, asset or to the environment (as defined by s528 of the EPBC Act) from which it will take up to 10 years to recover Causing environmental nuisance potentially leading to an environmental protection order under the SA EPA Act being imposed	**Moderate damage** to the environment (as defined by s528 of the EPBC Act) or a heritage listed asset, which is repairable. The resource will take up to 5 years to recover Causing environmental nuisance potentially leading to a complaint and investigation by the EPA	**Minor damage** to the environment (as defined by s528 of the EPBC Act) or heritage asset that is immediately contained on-site. It will take less than 2 years for the asset to fully recover Causing minor but evident damage to the environment on site	**Negligible damage** that is fully recoverable with no permanent effect on the environment or the asset, it will take less then 6 month for the resource to fully recover
Social & Cultural	**Very Serious widespread social impacts**. Irreparable damage to highly value structures, items or locations of cultural significance. Highly offensive infringements of cultural heritage.	**On-going serious social issues**. Significant damage to structures or items of cultural significance, or significant infringement and disregard of cultural heritage	**Ongoing social issues**. Permanent damage to structures or items of cultural significance, or significant infringement on cultural heritage / sacred locations	**Minor medium-term** social impacts on local population. Minor damage to structures or items of significance. Minor infringement of cultural heritage. Mostly repairable	**Low-level** social or cultural impacts. Low-level repairable damage to commonplace structures

Determine Likelihood

The risk assessment must include an assessment to the likelihood of the event occurring leading to the potential consequences identified in Appendix G. The likelihood is determined and given a rating.

Table 14 Likelihood Ranking Scores

Description	Rating
Almost Certain - Event expected to occur in most circumstances OR has a >90% chance of occurring in within 24 months if the risk is not mitigated	5
Likely - Event will probably occur in most circumstances OR has a 60-90% chance of occurring in within 24 months if the risk is not mitigated	4
Possible - Event should occur at some time OR has a 40-60% chance of occurring within 24 months if the risk is not mitigated	3
Unlikely - Event could occur at some time OR has a 10-30% chance of occurring in the future if the risk is not mitigated	2
Rare - Event may occur but only under exceptional circumstances OR has a less than 10% chance of occurring within 24 months if the risk is not mitigated	1

Assign risk

The risk level for each risk is determined by mapping the consequence and likelihood rating in accordance with the following risk assessment matrix. The risk score for each risk is determined by adding the consequence and likelihood rating numerical value in accordance with Table 15. This risk assessment model has been determined with guidance from the Australian Standard AS/NZS 4360.

Risk (R) = Consequence (C) + Likelihood (L)

Table 15 Risk Ranking Matrix

		Consequence				
		Severe (5)	**Major (4)**	**Moderate (3)**	**Minor (2)**	**Low (1)**
Likelihood	**Almost Certain (5)**	Critical	Critical	High	Medium	Low
	Likely (4)	Critical	High	Medium	Medium	Low
	Possible (3)	Critical	High	Medium	Medium	Low
	Unlikely (2)	High	Medium	Medium	Low	Low
	Rare (1)	High	Medium	Low	Low	Low

For example – A risk assessed as “Major” Consequence with a “Possible” likelihood is allocated a Risk Level of **HIGH**.

Appendix G – Underwater Noise and Vibration Impact Assessment

Table 15 Construction Impacts and Mitigation Measures

Table 16 Operational Impacts and Mitigation Measures

Table 16 Construction Impacts and Mitigation Measures

Project Activity	Specific Impact	Receptor	Regulatory Controls	Consequence	Likelihood	Risk Rank	Mitigation & Management
Blasting	Noise from explosions	Marine Fauna	EPBC Guideline	Major	Unlikely	High	Surveillance. Warnings. Not within migrating/breeding seasons
Seismic Survey	Noise from airguns	Marine Fauna	EPBC Guideline	Moderate	Possible	Medium	Surveillance. Warnings. Modify Practice
Dredging	Noise from ships/pumps	Marine Fauna	None	Minor	Possible	Medium	Surveillance. Warnings. Monitor
Support Vessels	Noise from ships	Marine Fauna	None	Minor	Possible	Medium	Surveillance. Warnings. Monitor
Drilling	Noise from drilling	Marine Fauna	None	Minor	Possible	Medium	Surveillance. Warnings. Monitor
Tunnelling	Noise from TBM	Marine Fauna	None	Minor	Unlikely	Medium	Monitor

Table 17 Operational Impacts and Mitigation Measures

Project Activity	Specific Impact	Receptor	Regulatory Controls	Consequence	Likelihood	Risk Rank	Mitigation & Management
Pump Intake & Outfall	Noise from Pump intake and outfall	Marine Fauna	None	Minor	Unlikely	Low	Monitor.
Maintenance	Noise from support vessel movements	Marine Fauna	None	Minor	Possible	Medium	Surveillance. Warnings. Monitor