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SKM

Forge Resources

Balla Balla - Underwater Noise Impact Due to Piling

- Rev 0
- 15th February 2013

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Glossary

TERM	DEFINITION
Ambient Sound Level	Sound level occurring due to natural sources in the environment eg wind, rain, biological sources
Anthropogenic Sources	Noise sources created by man eg shipping, pile drivers, seismic guns, blasting
bandwidth	The range of frequencies over which a sound is measured
Behavioural response	A response that involves any behavioural change (such as swim direction, changes or ceasing feeding behaviours, etc.)
Cetaceans	Group of animals that include the whales, dolphins, and porpoises
Decibel	A unit describing sound, equal to 20 times the logarithm (base 10) of the ratio of the measured sound pressure relative to a reference pressure
Reference pressure for Underwater Noise Level	1 µPa (micro Pascal) in water
Hz, Hertz:	Unit of frequency, expressed in cycles per second
MSP	The square root of the mean-square sound pressure level (dB re 1 µPa), which is the average of the sound level integrated over a given time. The MSP is generally calculated for time interval which contains 90% of the energy of the impact.
No dive zone	Area where divers are not allowed
Odontocetes	The toothed whales (including the dolphins and porpoises)
Permanent Threshold Shift (PTS)	A permanent loss of hearing caused by acoustic trauma from irreversible damage to the sensory hair cells of the ear
Pinnepeds	Group of animals which include the seals and sea lions

Sound attenuation	Reduction of sound pressure level with increasing range from the source
Sound exposure	The amount of sound energy an animal receives over some time frame
Sound Exposure Level (SEL)	A measure of the intensity delivered per unit time
Temporary Threshold Shift (TTS)	Temporary loss of hearing as a result of exposure to sound over time. It is assumed that exposure to high levels of sound over a relatively short time periods can cause the same amount of TTS as exposure to lower levels of sound over longer time periods.
Threshold	The threshold generally represents the lowest signal level an animal can detect, usually referred (and measured) as the threshold at which an animal will indicate detection 50% of the time.

Executive Summary

SKM has been commissioned by Forge Resources to assess the potential impact of underwater piling noise due to the construction of the trestle structure and barge loader jetty at Balla Balla.

Humpback whales do not generally approach within 500 metres of the seaward side of the Island so are not likely to be of concern. Similarly, dolphin appearances are only very sparse close in so they should also not present a problem.

For turtles, however, the safety zone would need to be of the order of 600 metres.

1. Introduction

SKM has been commissioned by Forge Resources to assess underwater noise impact due to piling associated with construction of a new barge loading jetty at Balla Balla.

This Underwater Noise Impact Assessment will:

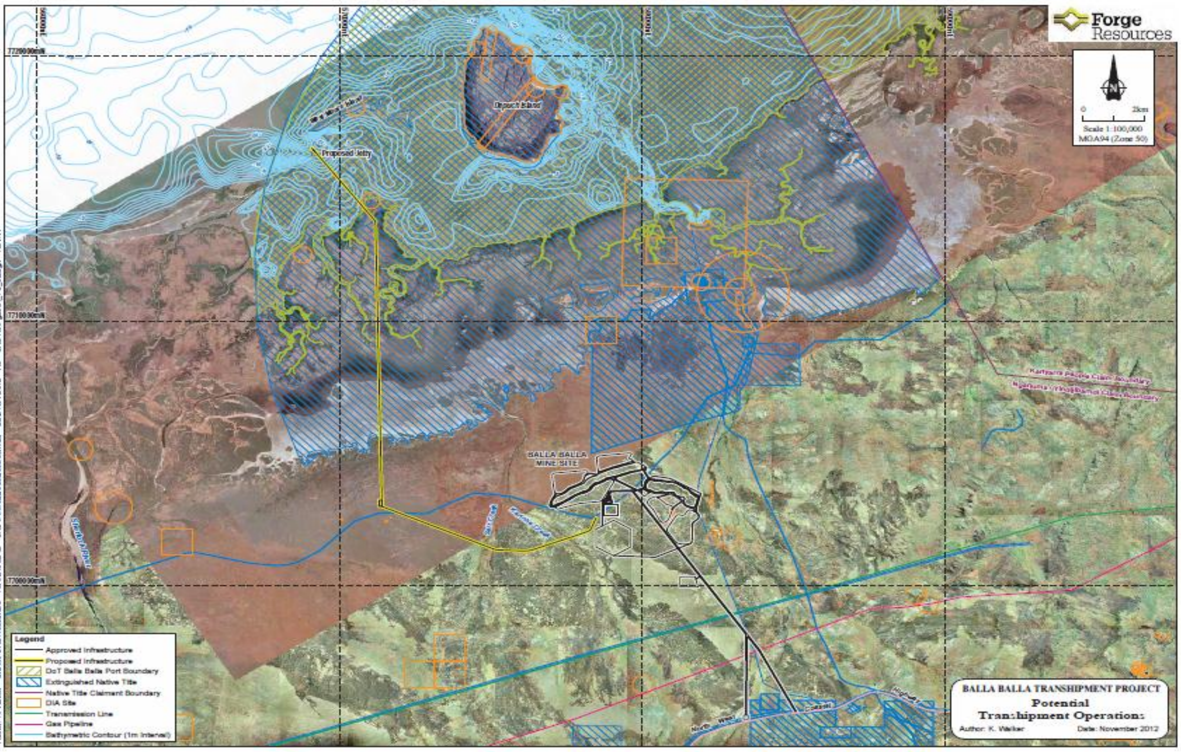
- Identify policies, legislation and standards relevant to the assessment of underwater noise effects due to the construction of the jetty
- Identify relevant noise sensitive receptors
- Identify noise levels due to piling and due to a barge
- Predict impacts due to the piling activity

2. Project Description

The proposed Forge Resources Ltd. (Forge) Balla Balla Magnetite Project involves mining and processing of magnetite ore at Balla Balla near Whim Creek in the Pilbara. It was previously intended to transport the concentrate via slurry pipeline to Port Hedland for export. However, Forge acquired this Project without obtaining port access at Port Hedland and is therefore exploring an alternate export facility.

Balla Balla is 120 kilometers (km) south west of the fully allocated Port Hedland port and 100 km east of the proposed Anketell port, for which there is no clear timeline of construction. Forge proposes to implement a low impact trans-shipment export solution on the Pilbara coast, less than 10 kilometers from the Balla Balla Project site. A small stockyard and jetty based loader operation on the coast will enable the magnetite concentrate to be loaded from the shore into a self-propelled, self-unloading barge which will sail out to a trans-shipment anchorage point for transfer to Cape-size ocean going vessels (OGV), with no requirements for dredging.

The location of the proposed trans-shipping facility and infrastructure route is shown in Figure 1 below.



- **Figure 2.1: Proposed Balla Balla Transhippment Facility Location**

The conveyor to the barge loader (termed the over land conveyor) will have an overland section and an overwater section.

The over water section of the conveyor will be constructed on a steel piled trestle structure from a point 50 m inland of the high tide point to the barge loader located on the barge loading jetty. The over water section of the conveyor will be approximately 2,600 m in length.

The first section of the piles for the trestle conveyor will be constructed using an over hand method from the shore. The last section of the trestle structure and barge loader jetty will be constructed from a floating piling barge.

A laydown area will be constructed at the end of the overland section of the conveyor causeway.

The barge loader is a fixed point, luffing and slewing machine that sits on a steel piled structure with sealed concrete deck jetty to load the open top barges. The jetty has fenders to allow the barge to warp whilst being loaded.

The barge loading jetty is located in natural deep water with no dredging required.

The barges have a shallow draft and will transit during high tides whilst loaded. A series of navigation aids will be installed to mark the sailing channel. No dredging is required for the barge transit.

A single open top self-propelled barge with a capacity of up to 15,000 dwt will be used with a cycle time of 10-16 hours whilst loading a vessel. The barges are self-discharging with an on board mechanical reclaimer and a series of enclosed conveyors.

3. Policies, Legislation and Standards

The only "legislation/guideline" for regulating the impact of underwater noise is associated with the "Environment Protection and Biodiversity Conservation Act 1999" (EPBC. The EPBC Act Policy Statement 2.1 deals with the interactions between **offshore seismic operations** and whales (http://www.environment.gov.au/epbc/publications/seismic.html) and offers a guideline on potential impacts to be considered. The background document actually proposes a Sound Exposure Level (SEL) for a whale exclusion zone and would apply only to any humpback whales that might approach or pass the proposed jetty.

Therefore, it can be stated that there is no relevant legislation/standard that applies to the proposed jetty construction activities with respect to underwater noise impact.

4. Sensitive Receptors

The following information was provided by Ian Le Provost in relation to potential marine mammal receptors. There is no quantitative data, only qualitative information based on conversations with local fisherman.

Dugongs are rarely observed and, if seen, only occur as singles or mother calf pairs.

A pod of what was thought to be 6 **Indo Pacific dolphins** is believed to visit the bay regularly during the colder winter months but not during the summer.

Most **humpback whales** migrate south about 5 – 10 km offshore along the line of Geographe Shoals, but a few whales have been observed within 500 m of the seaward side of the island and a mother and calf was once observed inside the channel between the two islands.

Turtles are often seen both inside the bay and on the near shore platforms. No nesting occurs inside the bay or on West and East Moore Island. The nearest nesting sites are on the seaward side of the island west of West Moore Island. Flatbacks are suspected but yet to be confirmed.

Based on the above, it would appear that turtles are most likely to be the most significant marine fauna in the region.

Figures 2 and 3 below show the location of nominal sightings of the varies marine mammals in the area.

■ **Figure 4.1: Sightings of Dugongs and Dolphins in the Project Area**

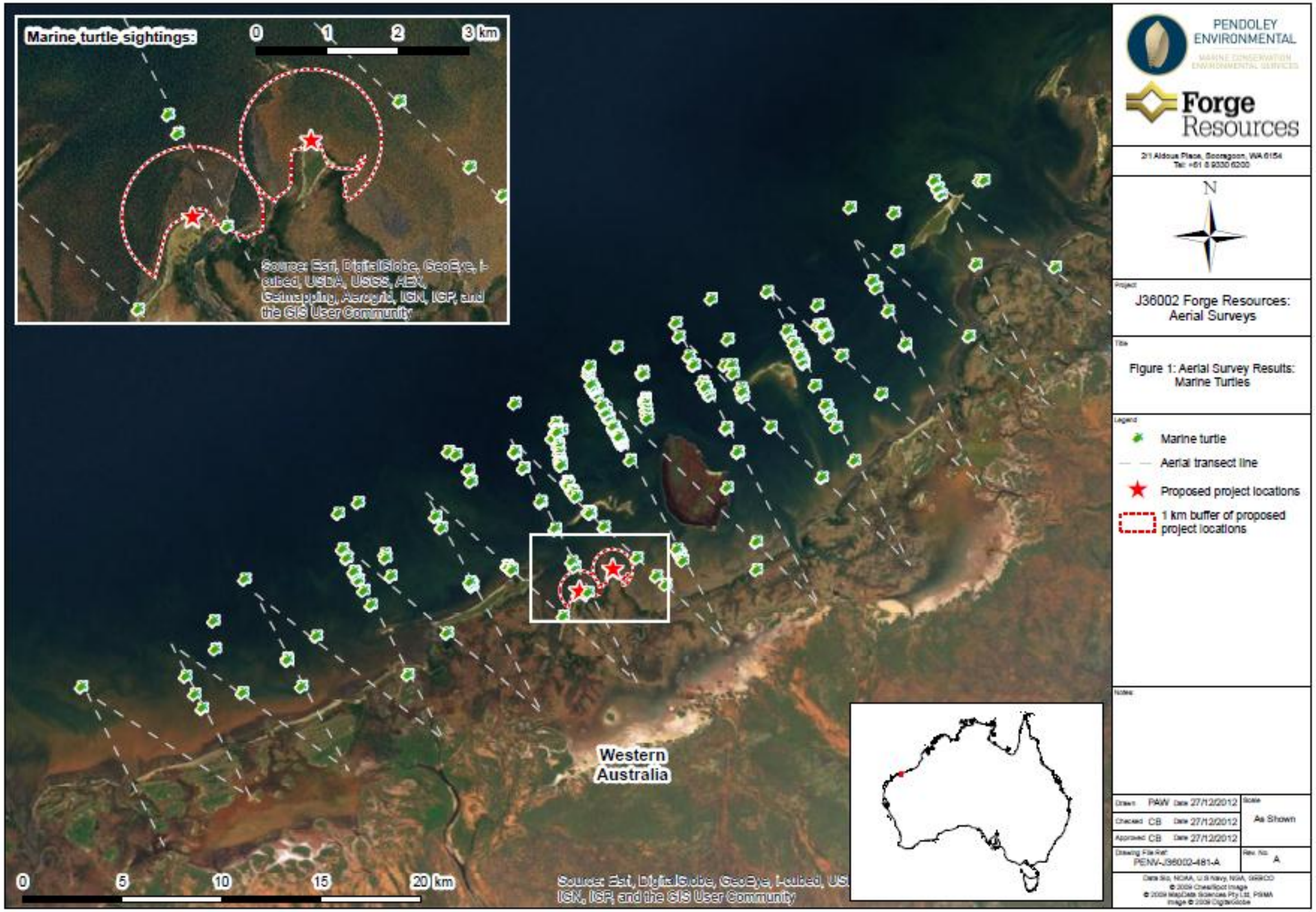


Figure 4.2: Sightings of Turtles in the Project Area

5. Noise Sources

The main underwater noise source will be the piling activity. Piling productivity will depend upon ground conditions encountered. Current information from URS is that the number of piles will be 568 based on the assumption that for the conveyor, overland piling would be at 10 m centres for 2560 m and then marine piling for 330 m.

Based on the original design for an 8 month work period, either two pile rigs will be required for 6-7 months or the piling is would need to extend over two seasons say 8 months and 4 months. As the mobilisation is a significant cost, it would be desirable to achieve the work in one season, so for the purpose of noise impact, we will assume two piling rigs operating concurrently.

The pile sizes are assumed to be generally 667 mm dia on the approach and 1117 mm at the head.

Pile hammer energy will depend upon the geotech conditions. It is expected that the geophysical survey will demonstrate Calcarenite. If conditions suit, rotor piles could then be used which will create minimal noise. However, if the piles are to be driven, then in the absence of any further geotechnical information, we have assumed a 20 t hydraulic hammer.

In terms of productivity, in favourable geotechnical conditions, there could be up to 4 piles per day driven by hydraulic hammer. If in unfavourable geotechnical conditions, then there could be up to 1 pile per day – piles would be driven to refusal, then drilled and re-driven until the design penetration was achieved (Drive – drill – drive).

No blasting is anticipated

At this time, it will most likely be a single barge.

6. Underwater Noise Level Criteria

6.1. Sound Metrics

A number of different measures, each expressed in different measurement units, can be used to characterise underwater sound. The sound metrics used in this assessment are:

Sound Pressure Level (SPL), which is the change in pressure as a sound or pressure wave passes. SPL is often expressed on a logarithmic scale in decibels (dB) relative to a standard reference pressure, calculated as[1]:

- $\mathbf{SPL = 20\log_{10}(P_t/P_{ref})}$

where P_t is the sound pressure at time t and P_{ref} is the reference pressure. In seawater the standard reference pressure is 1 µPa. Because decibels are on a logarithmic scale they are not linearly related to perceived loudness. A 3 dB increase represents a doubling of sound pressure, and a 10 dB increase represents a tenfold rise in pressure.

Peak Pressure (P_{max}), the maximum instantaneous positive SPL over the duration of the sound exposure. In the present assessment peak pressure is expressed in dB re 1 µPa.

Peak to Peak Pressure (PPP), the algebraic difference between maximum instantaneous positive and negative SPL expressed in dB re 1 µPa. This metric is 6 dB higher than the Peak Pressure.

Sound Exposure Level (SEL), the time integral of sound pressures received over the duration of exposure, which reflects the total sound energy received during exposure. This measure recognises that the effects of sound are a function of exposure duration as well as maximum instantaneous peak pressure. SEL allows comparison of short exposures to high sound pressure levels with longer exposures to lower pressure levels. SEL is referenced to both a reference pressure (1 µPa) and an exposure duration (1 s), and has units of dB re 1µPa^{2}s.

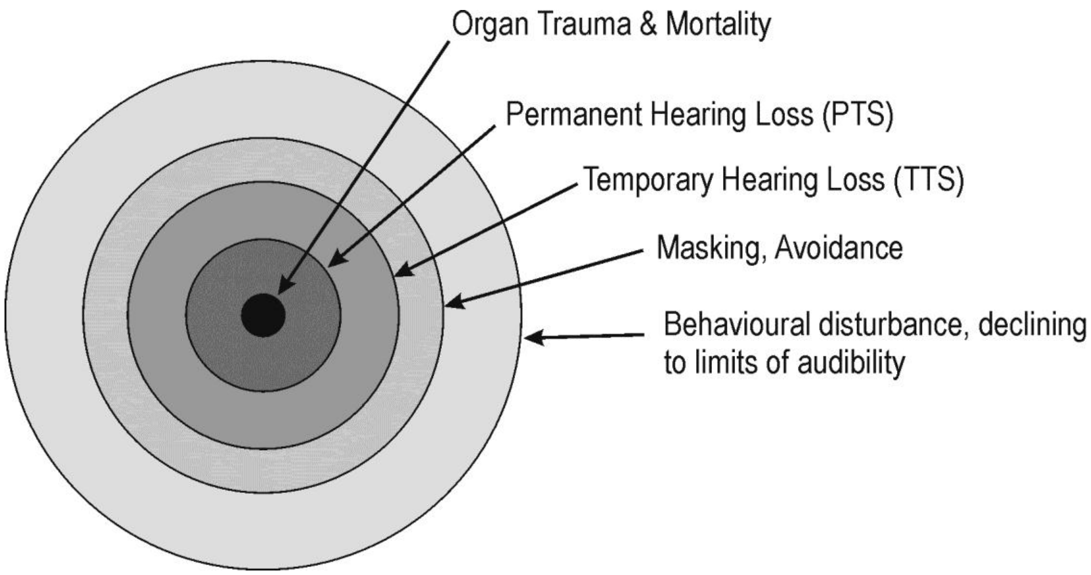
There is wide agreement that P_{max} and SEL are appropriate measures for assessment of sound impacts on marine animals (McCauley *et al.*, 2000; Southall *et al.*, 2007). Note that McCauley *et al.* (2000) refer to SEL as "equivalent energy".

6.2. Potential Effects of Piling and Dredging on Marine Animals

Piling, dredging and other anthropogenic sound sources can have a hierarchy of effects on marine animals, which depend critically on the distance from the sound source, the sound frequency and intensity, and on the hearing, vocalisation, and other biological characteristics of the organism. For a given source, the effects diminish with range depending on sound attenuation and the organism's

[1] This equation applies when the units are for pressure, as in the present case. When the units are of power or energy, the equation for decibels is $10\log_{10}(X/X_{ref})$, where X is the measured value and X_{ref} is the reference.

sensitivity (Figure 6-1). There can also be secondary effects, for example, if the sound drives away prey or attracts predators. The effects of sound have been studied mostly in cetaceans. Relatively little is known about the effects of underwater sound on fish.

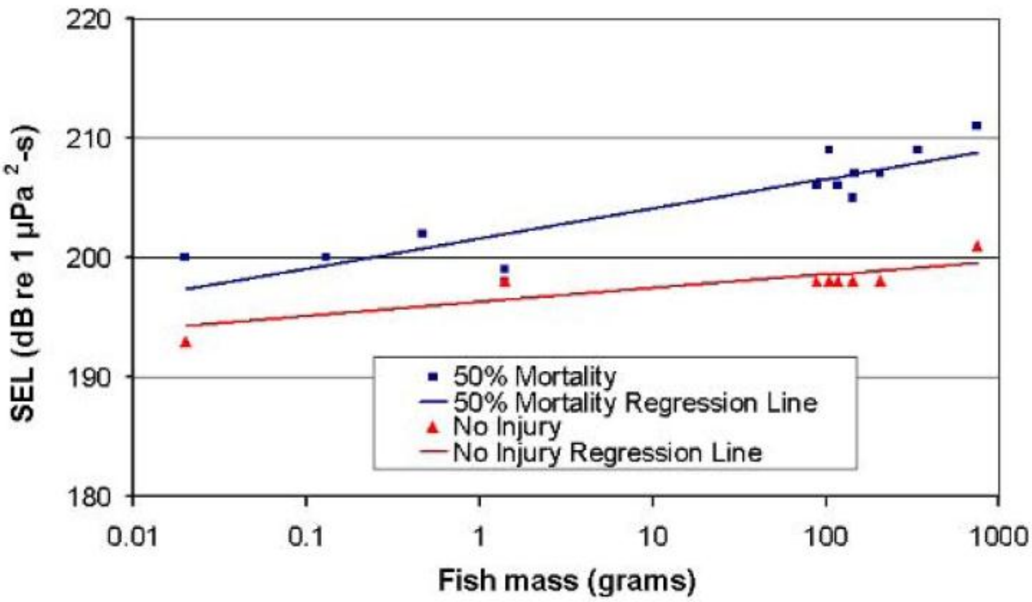


- **Figure 6-1: Potential effects of pile driving and other submarine sound sources at increasing distance from the source. The distances depend upon source intensity and the sensitivity of the organism (Modified from Richardson & Malme, 1993)**

6.2.1. Organ Trauma

The high pressure and energy levels at close range to pile driving operations can inflict lethal and acute physical injuries on marine organisms, primarily from organ haemorrhaging and ruptures of gas-filled structures such as the swim bladder, lungs, and eardrums (eg Hastings and Popper, 2005). Small animals are more vulnerable to sound-induced injury than larger ones (Yelverton *et al.*, 1975). Fishes are therefore expected to be more vulnerable to injury from piling sound than sea turtles and marine mammals.

Yelverton *et al.* (1975) developed a widely used model for acoustic mortality thresholds as a function of sound level, (expressed as impulse pressure in units of psi-ms) and fish size. Hastings & Popper (2005) adapted the model in terms to use SEL, the metric used in the present assessment (Figure 6-2).



- **Figure 6–2: Estimated sound exposure level (SEL) resulting in 50% mortality and no mortality based on the model of Yelverton *et al.* (1975), with SEL estimated from the impulse levels in the original model. (Reproduced from Hastings & Popper, 2005)**

6.2.2. Permanent Threshold Shift (PTS)

Permanent hearing loss, or more technically, permanent threshold shift (PTS) refers to a permanent increase in the threshold sound level that is audible to an organism. PTS may result from a single high-intensity exposure or from repeated exposures that produce less profound, temporary hearing loss (see reviews by Hastings & Popper, 2005; Southall *et al.*, 2007).

6.2.3. Temporary Threshold Shift (TTS)

Temporary hearing loss, or temporary threshold shift (TTS), refers to a temporary increase in the lower sound threshold of audibility, with hearing sensitivity later returning to pre-exposure levels. TTS results from fatigue of the auditory cells (Southall *et al.*, 2007). TTS varies in severity – how much louder sound needs to be for an animal to hear it – and in duration, but the severity and duration of TTS are generally correlated. They depend on the sound level, the sound frequency in relation to the animal’s hearing frequency range, and the duration, number, and timing of exposures. A threshold shift of 40 dB is likely to be permanent, at least in marine mammals (Southall *et al.*, 2007). Measured recovery times vary from minutes to days, with recovery time typically increasing with the duration of exposure as well as SPL.

Marine animals use hearing for different purposes, including predator and prey detection, communications, the detection of objects in the environment through echolocation, and possibly navigation. TTS has the potential to affect all of these functions, but is likely to be biologically significant at the population level primarily if hearing loss is prolonged (NRC, 2005).

Vulnerability to TTS depends upon the sound frequency because TTS results from the same mechanism as hearing stimulation of auditory cells. Sound frequencies significantly above or below those at which the cells respond will not fatigue the cells or induce TTS. The humpback and other baleen whales are thought to hear predominantly at low frequencies (Table 6-1). Fishes and turtles also hear best at low frequencies, though there is considerable variation among species (Nedwell *et al*., 2004). Dolphins and dugongs are thought to hear best primarily at higher frequencies above 5-10 kHz (Table 6-1). Based on their high-frequency hearing and the predominantly low-frequency spectrum of piling noise, dolphins are expected to be less vulnerable to piling-induced TTS than humpback whales and fishes.

- **Table 6-1 Hearing ranges of humpback whales, dolphins and fishes**

Species	Frequency range	Peak Sensitivity Range
Humpback whale (Megaptera novaeangliae)	Not measured, vocalisation frequency range is 25 Hz-10kHz, may be able to hear considerably higher	< 1 kHz
Bottlenose dolphin (*Tursiops truncatus*)	75 Hz – 150kHz	10-80kHz
Risso's dolphin (*Grampus griseus*)	2 – 100 kHz	8-70 kHz
Fishes	Varies, generally in 10 Hz – 2 kHz range	Generally in 10 Hz – 1 kHz range

Vulnerability to TTS depends not only on the frequency range of an animal's hearing, but also on how sensitive its hearing is within that range. Fishes have less-sensitive hearing than marine mammals (Nedwell *et al*. 2004), and therefore are expected to be less vulnerable to TTS than humpback whales. Therefore, the Southall *et al*. (2007) sound exposure criteria for marine mammals that are used in this assessment are conservative with respect to fishes.

6.2.4. Behavioural Impacts

Auditory masking occurs when an animal is unable to detect a biologically relevant sound signal against background noise (Richardson *et al*., 1995). Sounds that marine animals use to detect predators and prey, communicate and echolocate are all of much longer duration than a hammer blow due to piling, or in the case of echolocation, are frequently repeated over a longer duration. But repeated impacts over a longer time can potentially interfere with marine animal behaviour.

It has been noted that piling noise has the potential to disturb marine animals' normal activities or to cause stress or behavioural disturbances (NRC 2005; Richardson *et al*., 1995). Observed responses to anthropogenic sound in marine animals include avoidance of the sound source, altered swimming direction or speed including pronounced 'startle' reactions, increased dive times, and changes in vocalisation (NRC 2005). These responses are highly variable and depend on the ecological and behavioural context as well as an animal's experience. (NRC 2005, Richardson *et al*. 1995). Anthropogenic sound can also cause physiological reactions such as changes in heart or respiratory rates, and possibly longer-term physiological changes related to stress, but the effects of stress on marine animals are poorly understood (NRC, 2005).

6.3. Impact Criteria

A number of different sound exposure criteria have been used in different contexts and jurisdictions to assess or mitigate the effects of noise on marine animals.

Probably the most authoritative noise exposure criteria are those for cetaceans and pinnipeds developed by a panel of experts in acoustics and marine mammal science (Southall *et al.*, 2007). The Southall *et al.* (2007) criteria are shown in Table 6-2. Southall *et al.* adopted a dual-criteria approach using both P_{max} and SEL thresholds for different levels of effect. This approach is meant to take into account both brief exposures to very high SPLs (eg due to piling noise) and more prolonged exposures to lower SPLs (eg due to dredging type or barge loading activities). The criteria are meant to be applied in a precautionary fashion, with whichever one is exceeded first being used as the limiting criterion.

Table 6-2 Southall *et al*. (2007) sound level criteria for injury (PTS), TTS, and behavioural disturbance in cetaceans

Source type	Effect	Threshold criteria	
		Humpback whale (low frequency cetacean)	Dolphins (medium-frequency cetacean)
Single pulse	PTS	P_{max}: 230 dB SEL: 198 dB MSP 180 dB	P_{max}: 230 dB SEL: 198 dB MSP 180 dB
	TTS	P_{max}: 224 dB SEL: 183 dB	P_{max}: 224 dB SEL: 183 dB
	Behavioural disturbance	P_{max}: 224 dB SEL: 183 dB MSP 160 dB	P_{max}: 224 dB SEL: 183 dB MSP 160 dB
Multiple Pulse	PTS	P_{max}: 230 dB SEL: 198 dB MSP 180 dB	P_{max}: 230 dB SEL: 198 dB MSP 180 dB
	TTS	P_{max}: 224 dB SEL: 183 dB	P_{max}: 224 dB SEL: 183 dB
	Behavioural disturbance	Not applicable,	Not applicable

P_{max} values are expressed in dB re 1 µPa, MSP in dB re 1 µPa , SEL's are expressed in dB re µPa^2-s.
Values for P_{max} refer to unweighted measurement, SEL values refer to M-weighted measurements

The exposure criteria for low- and mid-frequency cetaceans are numerically identical despite the differences in hearing range between the two groups. For P_{max}, this is because the criteria relate to physical effects of rapid pressure change, which may not be directly related to the frequency of hearing.

The Southall *et al*. (2007) criteria do not address the onset of organ trauma and mortality. Vulnerability to noise-induced trauma is inversely related to body size, so marine mammals are less likely to suffer organ trauma at a given sound exposure than fishes. In the present assessment, the Southall *et al*. (2007) criteria for PTS onset are also applied to organ trauma in marine mammals but this is very conservative ie compliance with these criteria should not result in any injury. Note that the SEL criterion of 198 dB re 1 µPa^2-s is the same as that for a 100 g fish, and actually lower than the criterion for a 1 kg fish.

Although little is known about the potential impacts on marine turtles from increased noise exposure, McCauley et al. (2000) suggested that marine turtles may begin to show behavioural responses at 155 dB re 1 µPa2-s but will not show actual avoidance behaviours until 164 dB re 1 µPa2-s. Cumulative exposure is likely to cause a gradual desensitisation to the noise with individuals becoming less likely to be startled or impacted.

The sound exposure criteria used in the present assessment are summarised in Table 6-3.

- **Table 6-3 Summary of sound exposure criteria used in this assessment**

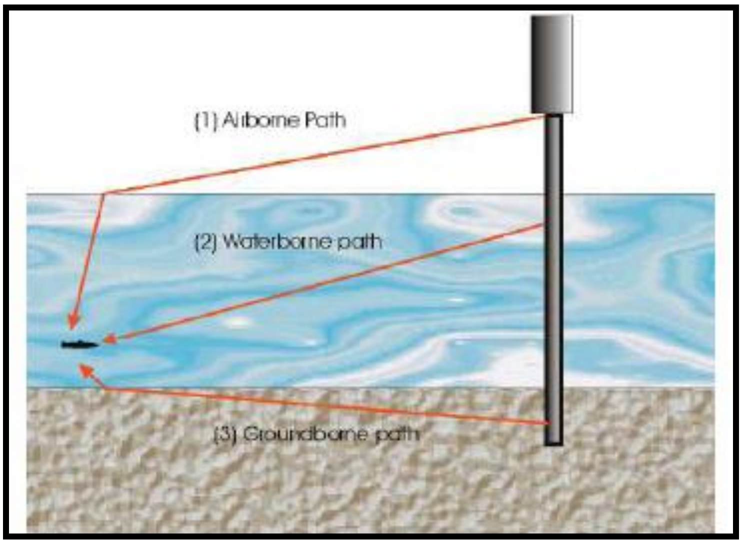
Criterion	Effect/Application	Source	Comments
Peak Pressure criteria			
224 dB re 1 µPa	Onset of TTS and behavioural disturbance in cetaceans. Also applied here to dugongs and turtles.	Southall *et al*., 2007	Application to turtles is conservative.
230 dB re 1 µPa	Onset of PTS and organ trauma in cetaceans. Also applied here to dugongs and turtles.	Southall *et al*., 2007	Application to organ trauma is conservative; Application to turtles is conservative.
SEL Criteria			
198 dB re 1 µPa^2-s	Onset of PTS and organ trauma in cetaceans. Also applied here to dugongs and turtles.	Southall *et al*., 2007	Application to turtles is conservative
183 dB re 1 µPa^2-s	TTS and behavioural disturbance in cetaceans. Also applied here to dugongs and turtles.	Southall *et al*., 2007	Application to turtles is conservative due to their poor hearing relative to cetaceans.
RMS Pressure criteria			
166 dB re 1 µPa	Behavioural response in Turtles	McCauley et al 2000	
175 dB re 1 µPa	Avoidance behaviours by Turtles	McCauley et al 2000	

7. Sound from Underwater Piling

7.1. Acoustic Characteristics of Underwater Piling

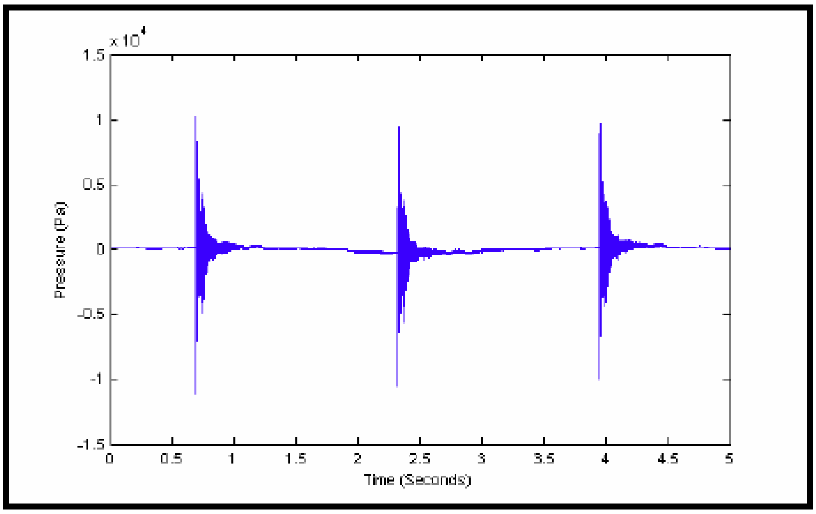
Pile driving techniques include impact pile driving where a pile is hammered into the ground or vibratory driving, where a rotating eccentric weight vibrates the pile into the ground. At the worst, piling for this development will utilise both types of pile driving.

The noise paths during a typical piling operation are shown in Figure 7-1. Pile driving sound is transmitted into the water column directly, and, to a relatively minimal extent, via an air-borne path (see Figure 7-1). At the lower end of the pile, energy is transmitted into the seabed and as the resultant waves travel outward, sound will leak into the water column. As the speed of sound is generally greater in consolidated sediments than in water, these waves usually arrive before the waterborne wave (Nedwell and Howell, 2004). The level of noise received in the water therefore depends on the pile size, shape, length and energy of the hammer, on the water depth (localised bathymetry), the seabed sediment type and thickness and the localised water temperature and salinity.



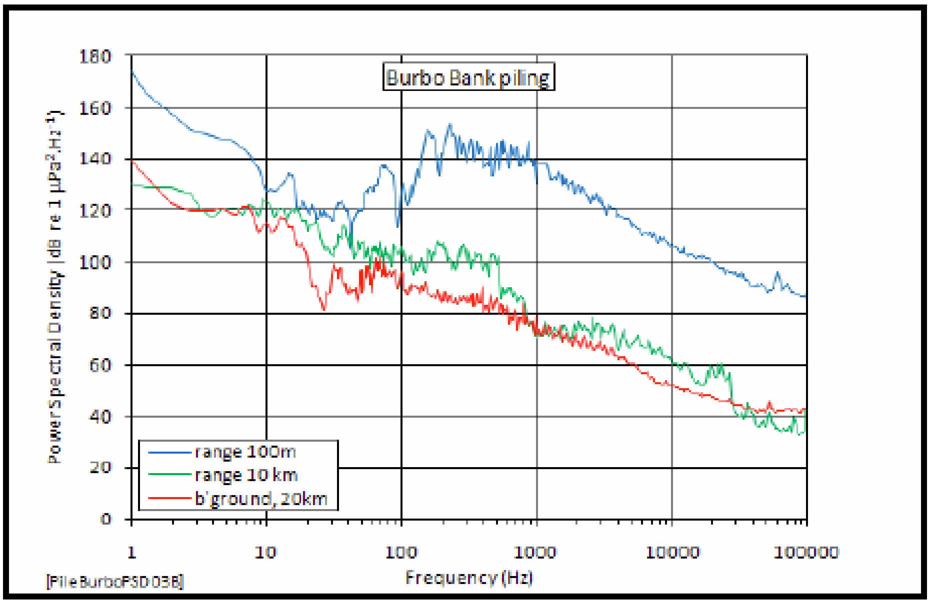
- **Figure 7-1 Noise Paths During Impact Piling (After Nedwell *et al.* 2007)**

A typical pressure time history is shown in Figure 7-2. The individual pile strikes can be seen with the duration of each strike being of the order of 0.5 second. The peak-to-peak pressure level (difference between highest and lowest SPL) for this wave is of the order of 206 dB re 1 µPa.



- **Figure 7-2 Typical Pressure Time History over 5 seconds for a Piling Operation (After Nedwell *et al.* 2007)**

Figure 7-3 shows the spectra for piling noise measured at 100 metres and 10 km from the pile driving source (background ambient noise is also shown for comparison). The dominant frequency range for piling can be seen to be in the range 100 – 2000 Hz (excluding the very low frequency energy below 20 Hz which is generally well below the hearing range of marine mammals).



- **Figure 7-3 Spectra for Impact Piling Noise at 100 m and 10 km as Compared to Ambient Background Noise (After Nedwell *et al.* 2007)**

7.2. Underwater Piling Noise Levels

Salgato and McCauley (2006) summarize measured underwater sound levels from Hastings and Popper (2005) and these are indicated in Table 7-1 below. The seafloor bottom types were not described.

- **Table 7-1 Summary of Measured Underwater Sound levels near Marine Pile Driving (Salgato and McCauley, 2006)**

Pile Type	Distance from Pile (m)	Peak Pressure (dB re 1µPa)	rmsp (impulse) Pressure (dB re 1µPa)	SEL (dB re 1µPa2-s)
--Various Projects				
Timber (12-in) Drop	10	177	165	157
CISS (12-in) Drop	10	177	165	152
Concrete (24-in) Impact (diesel)	10	188	176	166
Steel H-Type Impact (diesel)	10	190	175	--
CISS (12-in) Impact (diesel)	10	190	180	165
CISS (24-in) Impact (diesel)	10	203	190	178
CISS (30-in) Impact (diesel)	10	208	192	180
--Richmond-San Rafael Bridge				
CISS (66-in) Impact (diesel)	4	219	202	--
CISS (66-in) Impact (diesel)	10	210	195	--
CISS (66-in) Impact (diesel)	20	204	189	--
--Benicia-Martinez Bridge				
CISS (96-in) Impact (Hydraulic)	5	227	215	201
CISS (96-in) Impact (Hydraulic)	10	220	205	194
CISS (96-in) Impact (Hydraulic)	20	214	203	190
--SFOBB East Span				
CISS (96-in) Impact (Hydraulic)	25	212	198	188
CISS (96-in) Impact (Hydraulic)	50	212	197	188
CISS (96-in) Impact (Hydraulic)	100	204	192	180

This data suggests a maximum Peak Pressure of **240** dB re 1µPa@ 1m and a maximum SEL of the order of **215** dB re 1µPa^2.s @ 1m for one pulse.

SVT (2011) measured similar results. Figure 7-4 below shows the piling pressure wave versus time and SVT estimated the Source Level for a single pile impulse as:

$SL_{PEAK:}$ **240** dB re 1µPa@ 1m

SEL for one pulse: **220** dB re 1µPa^2.s @ 1m

It can be seen that during this measurement, there were 26 impulses over the 60 second measurement period. Generally, the pulse rate could be expected to be of the order of 30 impulses per minute. Thus a single pile might be driven in 60–70 minutes i.e. if all goes well, a pile may be driven in just over one hour.

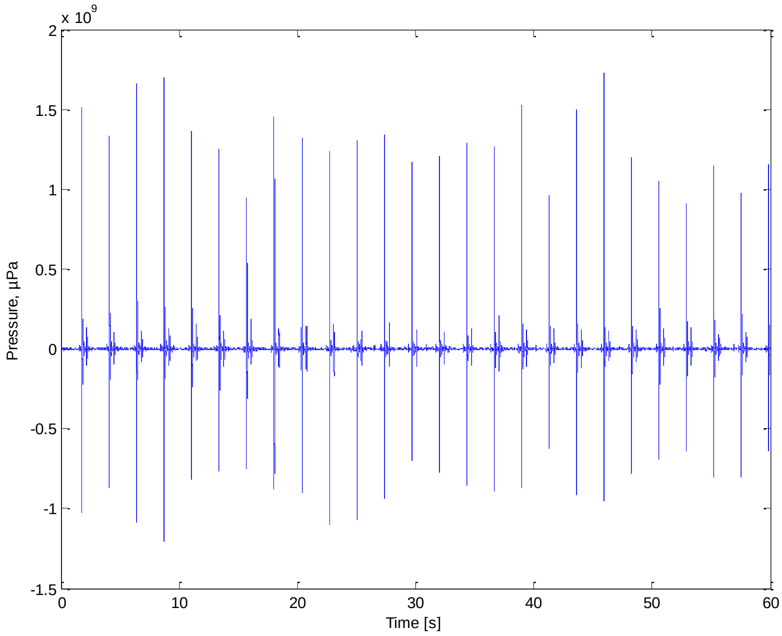


Figure 7-4 Sound Pressure Waveform Versus Time Measured by SVT (2011) During Piling

The currently proposed piling schedule calls for the use of up to two piling barges per day. If each rig completes two piles per day, then the number of piling impulses could be in range 6000 – 8000. Thus it is possible that in the worst case scenario, to have up to 8000 piling noise impulses per day.

Because the SEL is an energy based noise measure, the total energy over a one day period will be the SEL for the single impulse integrated over the total number of impulses. This is simply calculated in terms of the logarithm of the number of impulses as follows:

TOTAL SEL = $SEL_{single\ impulse}$ + 10 LOG_{10}(total number of impulses)

So at 1 m distance, in this instance, the TOTAL SEL = 220 + 10 LOG_{10} (N) dB re 1µPa^2.s

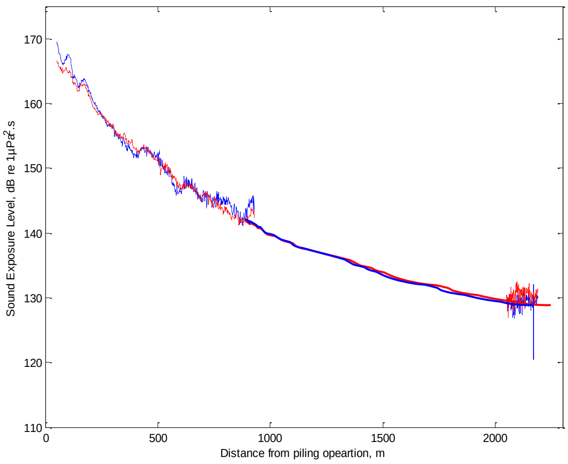
Table 7-2 below shows the relationship between the total number of piling impulses and the increase in total SEL over that for the single pile impulse SEL.

- **Table 7-2 Total SEL at 1 m Due to N Piling Impulses**

Number of Piling Impulses	10 LOG_{10}(N)	Total SEL dB re 1µPa2.s @ 1m
500	27	247
1000	30	250
2000	33	253
4000	36	256
6000	38	258
8000	39	259

SVT directly measured the SEL for single piling impulses at various distances from a piling operation in July 2011. A Junttan HHK 25S – 400 kNm pile hammer was used during the model validation measurements. The hammer's 25,000 kg ram is hydraulically powered and capable of effecting 30 to 100 blows per minute

Figure 7-5 below shows the SEL versus distance results obtained.



- **Figure 7-5 SEL versus distance for a single pile impulse measured by SVT (2011) recorded at two water depths (2 m below sea surface (blue) and 2 m above seabed (red))**

Using this data, the allowable exposure times for a given distance for two piling barges operating concurrently are shown in Table 7-3 below.

- **Table 7-3 Allowable Exposure Time Per Day to Piling Impulses Versus Range from the Piling Location for Different Criteria Assuming 2 Piling Rigs are Operational**

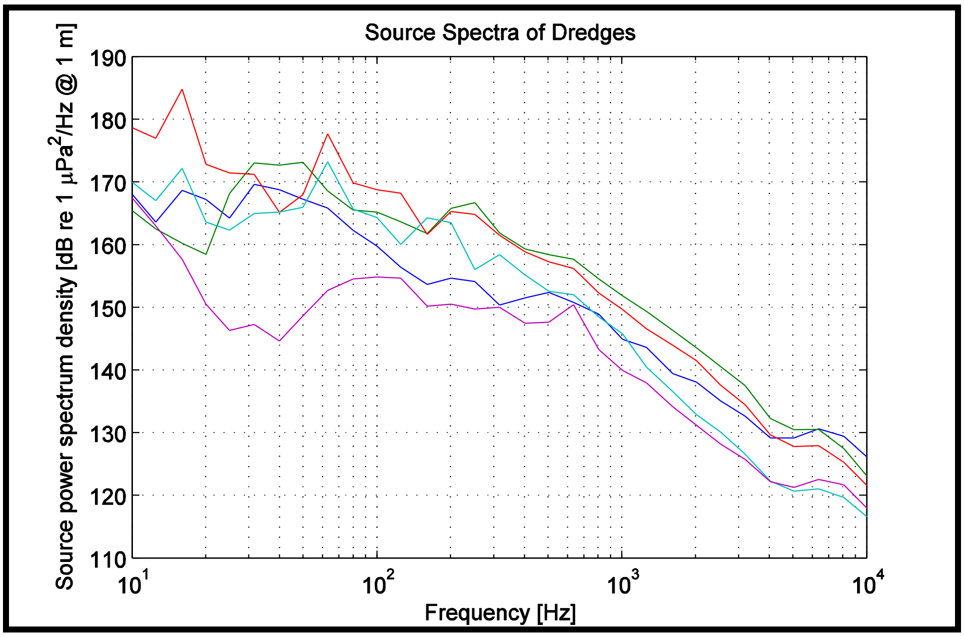
Distance (m)	160 dB re 1 µPa2.s EPBC Act Spec at 1 km Whales	183 dB re 1 µPa2.s TTS for Whales/Dolphins and Turtles
100		10 sec
200		2 mins
500	8 sec	20 mins
1000	100 secs	5.4 hrs
2000	18 mins	> 24 hrs

Given the location of these piling noise measurements and the relative bathymetry and seabed properties, these underwater piling noise levels would be considered a worst case scenario for what could be expected due to piling works at Balla Balla.

7.3. Underwater Loading Barge Noise Level

The principal sound sources from all types of power vessel include propeller cavitation, hull noises and machinery noises. For example, the source levels associated with container ships lie in the range 180-190 dB re 1 µPa at 1m, while dredging operations predominantly generate low frequency noise of similar magnitude (Richardson et al., 1995). We expect that the loading barge would generate similar noise levels.

Figure 7-6 shows source spectra for various dredges (details not provided on the types but indicated as typical of the range of noise levels to be expected from all types of dredges) recorded by JASCO elsewhere (2011). A broadband source level of over 190 dB re 1 µPa @ 1 m has been measured and, as stated above, it could be expected that the barge noise level would be of this order.



- **Figure 7-6: Source spectra of various types of dredges recorded by JASCO (2011)**

8. Assessment of Impact

It can be seen from the above that the predicted underwater noise level in Balla Balla due to piling for the jetty would result in compliance with the impact criteria for cetaceans (whales and dolphins) assuming that their closest approach is of the order of 500 meters. Generally, behavioural impacts are more likely, if at all, than either TTS or PTS.

Humpback whales do not generally approach within 500 metres of the seaward side of the island so are not likely to be of concern. Dolphin appearances are only very sparse close in so they should also not present a problem.

For turtles, however, the safety zone would need to be of the order of 600 metres. This is potentially a problem as the closest sightings of turtles are in the order of 250 – 500 metres from the proposed jetty. As the nearest nesting sites identified are outside this area, it is expected any passage of turtles in the proposed piling safety zone can be suitably managed with the protocol outlined in Section 9 below.

The barge noise level is significantly less than the piling noise level and while it is continuous rather than impulsive, the zone of significant influence is likely to be of the order of only 50 – 100 metres, if that.

9. Management Controls

We recommend the following management controls:

1. **Hours of operation**

- Marine-based pile driving operations to take place during daylight only (daylight is defined as where there is adequate light to see a minimum distance of 600 m).

2. **Start procedure**

- The start procedure for the pile driving unit should comprise of a soft start approach with increasing noise level over a ten minute period. Alternatively, a noise producing device that is capable of gradually increasing the level of acoustic energy for 10 minutes could be used prior to commencement of piling. The noise producing device shall provide an initial noise level that is no greater than 140 dB re 1µPa@ 1m (this noise level is less than that known to produce a Temporary Threshold Shift for cetaceans). This is to enable mobile fauna to move away.

3. **Marine-based pile driving – noise assessment**

- An initial check of marine-based pile driving equipment, confirming actual noise emissions to validate the safety zone.

4. **Marine-based pile driving – cetaceans**

- 'All clear' for cetaceans and turtles within a 600 m radius of the pile driving unit to be confirmed before the commencement of pile driving operations.
- If a cetacean or turtle is spotted within 600 m of the pile rig, then the following actions will be required:
  - Pile driving unit to suspend operations immediately.
  - If cetaceans and turtles are not seen to move beyond 600 m, operations cannot restart until no cetacean has been sighted for at least 15 minutes.
- If cetaceans and turtles are seen to move beyond 600 m, operations can recommence immediately.

10. Mitigation and Management

Given the information above, and on the assumption that similar piling equipment is used, it is recommended that the proposed piling program should incorporate the following mitigation measures to reduce the potential for adverse impacts on marine fauna from piling noise:

- Piling noise should be attenuated by appropriate engineering measures where practicable;
- Correct specifications of piles and the pile driver for the proposed constructions works should be used to avoid excessive energy requirements to achieve pile penetration;
- A 600 m safety exclusion zone should be established around piling works;
- Observations should be conducted during piling works, and piling should cease in the event that marine mammals or turtles are seen to enter the 600 m safety exclusion zone, and shall not recommence until the mammals move out of the exclusion zone; and
- All impact and vibratory piling works should adopt a soft start approach. In the first instance, this should incorporate piling commencing at low energy levels, say at 25% power, and then building up progressively to full impact force. If this is not possible, then a single pile impact should be conducted followed by another single pile impact after say 5 minutes. Then normal piling can then begin after another 10 minutes, so as to allow any marine mammals who may be approaching to leave the area. If either of the soft start approaches described is not practically feasible for operational reasons, then an acoustic deterrence device should be used to allow marine mammals to leave the area prior to commencement of full piling.

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