MOTT MACDONALD

Technical Note

Project:	A494 River Dee Bridge Replacement		
Our reference:	100395318	**Date:**	1 April 2025
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Subject:	A494 River Dee Bridge Replacement Underwater Noise Assessment		

1 Introduction

This technical note provides an assessment to understand the underwater noise impacts from the construction of the A494 River Dee Bridge Replacement Scheme. This technical note establishes the distances where Auditory Injury (AUD INJ) /Permanent Threshold Shift (PTS), and Temporary Threshold Shift (TTS) are expected to arise from piling works. The results from this technical note will be used to inform the significance of effects on marine animals which are assessed in Chapter 16 of the Environmental Statement.

1.1 Policy context, legislation, and guidance

The legislation, policy, and technical guidance considered to be relevant to underwater noise and marine receptors are detailed in Table 1.1.

Table 1.1: Summary of legislation, policy and guidance relevant to underwater noise

Relevant legislation / policy / guidance	Relevance to assessment
Legislation	
The Environment (Wales) Act 2016	The Environment (Wales) Act 2016 sets out the requirement for the 'sustainable management of natural resources' together with new ways of working to achieve this. Potential underwater noise and vibration on relevant marine species and habitats of principle importance listed under Section 7 of the Environment (Wales) Act 2016 will be considered in this technical note.
The Wildlife and Countryside Act 1981	The Wildlife and Countryside Act, WCA is the principal mechanism for the legislative protection of wildlife in Great Britain. The WCA applies to the terrestrial environment and inshore waters (0 to 12 nautical miles) and concerns the protection of wild animals and the designation of protected areas, including Site of Special Scientific Interest (SSSIs). Potential underwater noise effects on relevant protected species under the WCA will be considered in this technical note.
National Policy	

Relevant legislation / policy / guidance	**Relevance to assessment**
Welsh National Marine Plan 2019	The Welsh National Marine Plan provides the planning framework to support proposals and license applications, as well as public authorities for decision making. Relevant policies include: ENV_05 Underwater Noise: Proposals should demonstrate that they have considered man-made noise impacts on the marine environment and, in order of preference to first avoid, minimise and lastly mitigate. If significant adverse impacts cannot be avoided, minimised or mitigated, proposals must present a clear and convincing case for proceeding.
UK Marine Policy Statement (MPS) 2011	The MPS is the framework for preparing Marine Plans and taking decisions affecting the marine environment. Relevant considerations include: Noise resulting from a proposed activity or development in the marine area or in coastal and estuarine waters can have adverse effects on biodiversity. For certain animals, deliberate disturbance is prohibited and can only be carried out in accordance with the terms of a license.
Local Policy	
Flintshire Local Development Plan 2015 - 2030	Relevant policies within the local development plan include: • STR14: Climate Change and Environmental Protection …(vi) Ensuring that new development has regard to the protection of the environment in terms of air, noise and light pollution, unstable and contaminated land and former landfill sites. • EN6: Sites of Biodiversity and Geodiversity Importance …(c) Any unavoidable harm is minimised by effective mitigation to ensure that there is no reduction in the overall biodiversity value of the area. Where this is not feasible compensation measures designed to create, restore and enhance biodiversity must be provided.
Guidance and Standards	
ISO 18405:2017 “Underwater acoustics – Terminology”	Provides basic terminology and quantities for underwater acoustics.
Statutory nature conservation agency protocol for minimising the risk of injury to marine mammals from piling noise, Joint Nature Conservation Committee, *JNCC 2010*	Outlines protocol for mitigation of potential underwater noise impacts arising from pile driving during offshore wind farm construction which may be useful and applicable for pile driving in other industries in the marine environment.
Guidance for assessing the significance of noise disturbance against conservation objectives of harbour porpoise Special Areas Conservation (SACs) (England, Wales & Northern Ireland), *JNCC 2020.*	Provides the recommended study area for pin piling relevant for England, Wales and Northern Ireland which may be useful and applicable for pile driving in other industries.
Sound exposure guidelines for fishes and sea turtles, *Popper et al., 2014*	Provides permanent threshold shift, temporary threshold shift, and disturbance criteria in assessing the potential adverse impact of underwater anthropogenic noise for fish, sea turtles and larvae.
2024 Revision to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing, National Oceanic and	Provides auditory injury (including permanent threshold shift) and temporary threshold shift in assessing the potential adverse impact of underwater anthropogenic noise for marine mammals of various generalised hearing groups.

Relevant legislation / policy / guidance	Relevance to assessment
Atmospheric Administration, *NOAA 2024.*	
National Marine Fisheries Service: Summary of Marine Mammal Protection Act Acoustic Thresholds, *NMFS, 2024.*	Provides a summary of the acoustic thresholds presented in the National Oceanic and Atmospheric Administration, Technical Memorandum, 2024. Also provides the disturbance criteria in assessing the potential adverse impact of underwater anthropogenic noise for marine mammals.

1.2 Glossary

The primary underwater acoustic terminology is defined in ISO 18405:2017 and summarised in Table 1.2 alongside bioacoustics terminology for marine mammals and fish defined in NOAA 2024 and Popper *et al.* 2014 respectively.

Table 1.2 Underwater noise glossary and abbreviations

Parameter		Description	Standard reference
General			
dB	Decibel	Sound and noise levels are commonly described using the decibel scale, which is logarithmic in nature.	dB
---	Source Level	Typically described as the source level 1 m from the sound source. If unavailable, this can be calculated by knowing the measured received level at another distance from the source and estimating the transmission loss or gain over that distance.	dB re 1µPa^{2}s
---	Transmission Loss	The reduction in sound pressure level due to geometrical spreading and attenuation when the distance from a sound source increases.	---
SPL, L_p or L_{rms}	Sound Pressure Level or Root-mean-square Sound Pressure	The logarithmic measure of the root-mean-square sound pressure relative to a reference sound pressure. The reference sound pressure in water is 1µPa which is equivalent to 1 µN/m^2; while in air it is 20µPa. Typically used to characterise continuous (i.e. non-impulsive) noise and vibration.	dB re 1µPa
SEL	Sound Exposure Level	The mean square value of the acoustic pressure normalised to a period of 1s and converted to a decibel quantity.	dB re 1µPa^{2}s
SEL_{cum}	Cumulative Sound Exposure Level	The cumulative measure of energy that takes into account the received level and duration of exposure of a series of sound events. Where there are N events each with the same single strike SEL of SEL_{ss} then $SEL_{cum}=SEL_{ss}+10\log(N)$	dB re 1µPa^{2}s
SEL_{ss}	Single Strike Sound Exposure Level	It is applicable only to impulsive noise such as sound from piling. It may be calculated from the SEL_{cum} knowing how many similar strikes occurred in a measurement interval.	dB re 1µPa^{2}s
Peak SPL or L_{peak}	Peak Sound Pressure Level	The highest absolute value of the instantaneous sound pressure converted to a decibel quantity.	dB re 1µPa
Particle motion	Sound Particle Acceleration Level	The acoustic particle motion caused by the oscillatory acceleration of fluid particles in a sound field (in water). The reference particle acceleration in water is 1µm/s^2. The particle acceleration level is expressed as root-mean-squared values for continuous noise and vibration.	dB re 1µm/s^2
Bioacoustics			
---	Sound	Refer to anthropogenic sources that can either be identifiable or to distant one that cannot be located or identified.	

Parameter		Description	Standard reference
---	Behavioural hearing threshold	Threshold at which changes arise in the behaviour of animals exposed to a sound. This may include long-term changes in behaviour and distribution (e.g. moving from preferred sites for feeding and reproduction or alteration of migration patterns). It does not include effects on single animals, or where animals become habituated to the stimuli, or small changes in behaviour (e.g. startle response or small movements).	
---	Hearing threshold shift	Change in hearing threshold.	
AUD INJ	Auditory Injury	Damage to inner ear that can result in destruction of tissue, such as the loss of cochlear neuron synapses or auditory neuropathy which may or may not result in a permanent threshold shift.	
PTS	Permanent Threshold Shift	Level at which hearing loss arises in marine fauna and is permanent. Reduced hearing fidelity may impact the ability to communicate and ability to detect predators and prey.	
TTS	Temporary Threshold Shift	Short or long term changes in hearing sensitivity that may or may not reduce fitness. Within Popper A.N. *et al.* (2014) is also defined as any change in hearing of 6dB or greater that persists.	
---	Barotrauma	Result of rapid pressure changes that produce tissue injury.	
---	Recoverable injury	Injuries, including hair cell damage, minor internal or external hematoma (etc.). None of these injuries are likely to result in mortality.	
M&PMI	Mortality and potential mortal injury	Immediate or delayed death.	

Source: modified from ISO 18405:2017, NOAA 2024 and Popper *et al.* 2014.

2 Methodology

2.1 Supporting literature overview

Popper et al. 2014 establishes broadly applicable sound exposure guidelines for fish subject to anthropogenic noise. The guidelines consider noise impacts on behavioural changes, injuries, and mortality of various categories of fish.

NOAA 2024 provides the noise exposure criteria for marine mammals. The technical guidance assigns marine mammals to different generalised hearing groups based upon their hearing range and sensitivity and provides acoustic thresholds to assess auditory impacts. A summary of these acoustic thresholds are also found in *NMFS 2024* which also provides the disturbance criteria in assessing the potential adverse impact of underwater anthropogenic noise for marine mammals.

These references lay out the acoustic thresholds for marine species subjected to anthropogenic noise. The acoustic thresholds introduced are Temporary Threshold Shift (TTS), Permanent Threshold Shift (PTS), Auditory Injury (AUD INJ) and behavioural disturbance.

TTS is a temporary, reversible increase in the threshold of audibility at a specified frequency or portion of an individual's hearing range above an established reference level while PTS results in a permanent, irreversible increase in the threshold of audibility.

AUD INJ is the damage to the inner ear of a marine animal which can result in destruction of tissue, such as the loss of cochlear neuron synapses or auditory neuropathy. Hence, AUD INJ includes but is not limited to PTS as AUD INJ may or may not result PTS.

Behavioural disturbance relates to substantial change in behaviour for animals exposed to a sound. This may include long-term changes in behaviour and distribution, such as moving from preferred sites for feeding and reproduction, or alteration of migration patterns.

2.2 Non-impulsive and impulsive noise source

Underwater noise sources are typically categorised into two types: non-impulsive and impulsive noise sources. Non-impulsive noise sources are characterised by prolonged, continuous or intermittent noise sources that do not have rapid rise and decay of sound pressure levels (i.e., dredging, shipping noise) while impulsive noise sources are characterised by transient, brief and rapid rise and decay of sound pressure levels (i.e., impact piling, explosives).

For non-impulsive noise sources, the acoustic pressure of underwater noise over a specified duration can be expressed as the square root of the average of the square of it. This is known as the root-mean-square (rms) pressure which when converted to sound pressure level is the L_{rms} with a reference pressure of 1µPa.

Criteria also involve the sound exposure level, SEL, that is used to characterise the PTS and TTS thresholds for marine mammals and fish. The SEL is the mean square value of the acoustic pressure normalised to a period of 1 second, converted to dB re 1µPa^{2}s.

For impulsive noise sources, the sound exposure level from a single impulse is defined as the single strike sound exposure level SEL_{SS}. The combined energy of multiple impulses over a specified duration is known as the cumulative sound exposure level, SEL_{cum}. (National Oceanic and Atmospheric Administration, 2024) recommends assessing SEL_{cum} over 24-hour duration. Hence, the SEL_{cum} of an impact piling activity will be the combined energy of the total number of pile strikes over a 24-hour period.

The peak sound pressure level, L_{Peak} is defined as the instantaneous peak sound pressure level of an impulse and is associated with the risk of harm due a high instantaneous sound pressure level even if the duration is short. Hence, the dual metrics, SEL_{cum} and L_{Peak} are used when assessing noise exposure in comparison with the PTS and TTS criteria for impulsive noise.

Noise sources from concurrent works should be assessed depending on the type of source (impulsive or non-impulsive) as criteria and units for impulsive and non-impulsive noise sources are not interchangeable. This means impulsive noise sources can only be cumulatively assessed with other impulsive noise and vice versa.

2.3 Summary of marine acoustic thresholds

Different marine mammal species have different frequency-specific hearing sensitivity, and this influences how each species perceive underwater noise. However, broad marine mammal hearing groups, each containing many species that still have some expected differences among them have been established to predict the effects of noise exposure. Within these groupings, group-specific weighting functions were developed, with the shape of the weighting function acting as a band pass filter that attenuates low and high frequency components depending on the hearing range of the marine mammal species.

The acoustic criteria specified may be weighted or unweighted. A weighted acoustic threshold level has been adjusted against the weighting function of each hearing group where appropriate.

Table 2.1 summarises the AUD INJ/PTS, TTS and behaviour disturbance acoustic thresholds to be used for the underwater noise assessment. The SEL levels expressed in Table 2.1 are unweighted levels for fish and weighted for marine mammals to account for the marine mammal auditory function. High peak sound pressure levels do not strictly reflect the hearing sensitivity and frequency range of each hearing groups. Hence, the L_{Peak} criteria is considered unweighted within the generalised hearing range of the marine mammals and fish.

As existing research on fish are limited, literature recommends a subjective approach for non-impulsive sound in which relative risk of effect is placed in order of rank at three distances from source – near (N, for tens of metres), intermediate (I, for hundreds of metres) and far (F, for thousands of metres). The relative risk of effect is then rated as ‘high’, ‘moderate’, and ‘low’ with respect to source distance and fish hearing type (Popper, et al., 2014).

Table 2.1: Summary of marine acoustic thresholds from NOAA 2024 and Popper et al., 2014

		Continuous sound			**Impulsive sound**				
		SEL (dB re 1µPa²s)		**rms (dB re 1µPa)**	**SEL_{cum} (dB re 1µPa²s)**			**Peak SPL (dB re 1µPa)**	
Hearing group/ Animal types	**Weighting**	**PTS**	**TTS**	**Behavioural Disturbance**	**PTS**	**TTS**	**Behavioural Disturbance**	**PTS**	**TTS**
Fish									
No swim bladder (particle motion detection)	None	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Moderate (F) Low	>219	>>186	(N) High (I) Moderate (F) Low	>213	---
Swim bladder is not involved in hearing (particle motion detection)	None	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Moderate (F) Low	210	>186	(N) High (I) Moderate (F) Low	>207	---
Swim bladder is involved in hearing (primarily pressure detection)	None	(N) Low (I) Low (F) Low	L_{rms} 158 dB re 1µPa, for 12h	(N) High (I) Moderate (F) Low	207	186	(N) High (I) High (F) Moderate	>207	---
Eggs and larvae	None	(N) Low	(N) Low	(N) Moderate	>210	(N) Moderate	(N) Moderate	>207	---

		Continuous sound			**Impulsive sound**				
		SEL (dB re 1μPa²s)		**rms (dB re 1μPa)**	**SEL_{cum} (dB re 1μPa²s)**			**Peak SPL (dB re 1μPa)**	
Hearing group/ Animal types	**Weighting**	**PTS**	**TTS**	**Behavioural Disturbance**	**PTS**	**TTS**	**Behavioural Disturbance**	**PTS**	**TTS**
		(I) Low (F) Low	(I) Low (F) Low	(I) Moderate (F) Low		(I) Low (F) Low	(I) Low (F) Low		
Marine mammals									
Low-frequency cetaceans (LF)	LF	197	177	120	183	168	163	222	216
High-frequency cetaceans (HF)	HF	201	181	120	193	178	173	230	224
Very high-frequency cetaceans (VHF)	VHF	181	161	120	159	144	139	202	196
Sirenians (SI)	SI	200	180	120	186	171	---	225	219
Phocid carnivores in water (PCW)	PCW	195	175	120	183	168	163	223	217
Other marine carnivores in water (OCW)	OCW	199	179	120	185	170	165	230	224

2.4 Sound propagation in water

Conventionally levels are expressed as SL-TL where SL is the source level which is the level that would be obtained at 1m from the (conceptual) acoustic centre of the source and TL is the transmission loss associated with the reduction in noise level from the nominal 1m to the measurement or prediction location. The TL model is potentially very complex with dependency on many factors such as water depth, bottom type, surface roughness, water temperature (and particularly variation as a function of depth), salinity etc. All of these factors are potentially also frequency dependent.

The simplified model of TL=βlog(r)+ αr is widely used for underwater noise assessments where the coefficient of the log term, β corresponds to attenuation by spreading while the α term corresponds to saltwater absorption. The β term has a value of 10 for cylindrical spreading, which is most applicable in shallow/confined waters where sound is reflected, and 20 for spherical spreading, which is most applicable in deep/unconfined waters where sound can propagate unobstructed. An intermediate “practical spreading” value of 15 is applicable where the environment contains elements of both, is widely used for intermediate or spatially varying conditions when actual values for transmission loss are unknown and is recommended by the NOAA.

As site specific information on transmission loss is not available, this assessment assumes a transmission loss coefficient, β, of 15 to account for the shallow water conditions of a riverbed for a conservative approach.

3 Baseline conditions

3.1 Study area

The construction activity likely to have the greatest impact on underwater noise and vibration is anticipated to be rotary bored piling during construction phase. The study area will comprise of a 15 km buffer distance from the site boundary based on the effective deterrent ranges for pin piling laid out in Guidance for assessing the significance of noise disturbance against Conservation Objectives of harbour porpoise SACs (JNCC, 2020). It is anticipated that no underwater noise and vibration adverse effects will arise at distances greater than 15 km from the Site Boundary.

3.2 Marine receptors

The identified marine receptors present within the study area is summarised in Table 3.1 according to their respective hearing groups.

Table 3.1: Marine species identified in the study area

Hearing group	Species
Fish	
No swim bladder (particle motion detection)	Sea lamprey (*Petromyzon marinus)* River lamprey (*Lampetra fluviatilis*)
Swim bladder is not involved in hearing (particle motion detection)	Allis shad (*Alosa alosa*) Herring (*Clupea harengus*)
Swim bladder is involved in hearing (primarily pressure detection)	Atlantic salmon (*Salmo salar*) Brown / sea trout (*Salmo trutta*) European smelt (*Osmeridae*) Bullhead (*Cottus gobio*)[1] European eel (*Anguilla anguilla*) Juvenile flounder (*Pleuronectes flesus)*[2] Flatfish (*Pleuronectidae*)

Hearing group	Species
Eggs and larvae	
Marine mammals	
Phocid carnivores in water (PCW)	Grey seal (*Halichoerus grypus*)

[1] Located above the tidal limit at Chester weir 11km upstream of the Scheme.
[2] Located in Queensferry drain.

4 Assessment

4.1 Construction work overview

During mobilisation, a temporary crane platform and pier will be built at the eastern river bank to enable jack-up barge to be mobilized. The temporary pier will also allow cranes and plat to transfer from land to the jack-up barge. The temporary pier will have up to 6 x 600mm diameter steel tubes vibrated into the riverbank to support a structural steel deck above.

The replacement bridge will be supported by two river piers, each constructed with 12 foundation piles, totalling to 24 x 1.5m diameter piles. After the jack-up barge is mobilised to the bridge pier location, steel casing tubes will be inserted to a depth of approximately 13m below the riverbed. The tubes will be lifted from a floating support barge by crane, lowered vertically into position and then driven in with a vibratory hammer. A rotary bore mounted on the piling rig will be used to remove riverbed silt and underlying glacial till deposits from inside the steel casing tubes. The arisings from the rotary bore will be captured and removed to land to minimise any loss of material into the river. Drilling fluid such as polymer or bentonite will be used to stabilise the ground. The steel casing tubes will then be filled with concrete to form piles, pumping off the displaced drilling fluid for recycling. It is anticipated that the piles will be installed in groups of four, and the jack-up barge will be moved slightly for each group to maintain an even spread of load from cranes on the deck of the barge. Temporary form-work or precast concrete caisson will be installed at the top of piles above riverbed level to construct a continuous pile cap and piers.

As the tubular casing will be driven through a vibratory hammer for the temporary pier and river pier installation, the noise source is non-impulsive and continuous in nature. Underwater noise levels produced through piling should therefore be assessed against the PTS/AUD INJ, TTS, and behavioural disturbance acoustic thresholds for continuous noise in Table 2.1.

The rotary bored piling also requires extraction of sediments within the steel casing tubes through a rotary bore mounted on the piling rig. This noise source is non-impulsive and continuous in nature and should be assessed with the same acoustic thresholds as the vibropiling.

The construction hours are anticipated to be from h07:30 to h19:30 and last up to 12 months. Given the piling methodology requires some downtime to reposition jack-up barge, pumping of concrete and repositioning of steel casing tubes, a conservative estimate on-time for noise produced through piling is anticipated to be 60%. This equates to 7.2 hours over a 12 hour construction day.

4.2 Source levels

The source levels used for vibropiling are based on Mott MacDonald's in-house underwater noise measurements. These measurements were taken during vibratory piling at a riverbed, with measurement locations ranging from 25 to 150 m upstream and downstream of the piling location. It is expected that the noise levels derived from these in-house measurements will provide an appropriate estimate of the underwater noise levels generated by the Scheme, due to the similar construction conditions.

The source levels for the rotary bored is taken from geotechnical drilling[1]. The noise source is similar to geotechnical drilling where a core is drilled and extracted from the seafloor for examination.

Table 4.1: Construction information and predicted source levels

Construction Activity	Working hours	% on-time	Plant and pile type	Source type	L_{rms} at 1m (dB re 1µPa)*	SEL_{24hr} at 1m (dB re 1µPa^{2}s)*
Tubular piling for steel casing installation (for temporary pier and river pier construction)	h0730 to h1930	60% (7.2h/day)	Vibratory hammer, 600mm and 1.5m diameter steel casing tubes	Continuous	152	196
Rotary bored piling for sediment removal	h0730 to h1930	60% (7.2h/day)	Rotary bore attachment installed on piling rig	Continuous	145	189

*L_{rms} and SEL_{24hr} at 1m were calculated with transmission loss value of $\beta = 15$

4.3 Results

The source levels in Table 4.1 are used to assess against the acoustic thresholds for continuous noise in Table 2.1 for identified species in Table 3.1. The subsequent distances where PTS/AUD INJ, TTS, and behavioural disturbance may arise for each relevant hearing groups are summarised in Table 4.2.

Table 4.2: Predicted impact distances for relevant hearing groups

		Tubular Piling			**Rotary Bored Piling**		
Hearing group/ Animal types	**Weighting**	**PTS/AUD INJ impact distances**	**TTS impact distances**	**Behavioural Disturbance impact distances**	**PTS/AUD INJ impact distances**	**TTS impact distances**	**Behavioural Disturbance impact distances**
Fish							
No swim bladder (particle motion detection)	None	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Moderate (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Moderate (F) Low
Swim bladder is not involved in hearing (particle motion detection)	None	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Moderate (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Moderate (F) Low
Swim bladder is involved in hearing (primarily pressure detection)	None	(N) Low (I) Low (F) Low	<1m	(N) High (I) Moderate (F) Low	(N) Low (I) Low (F) Low	<1m	(N) High (I) Moderate (F) Low

[1] Erbe, Christine & Mcpherson, Craig. (2017). Underwater noise from geotechnical drilling and standard penetration testing. The Journal of the Acoustical Society of America. 142. 10.1121/1.5003328.

		Tubular Piling			**Rotary Bored Piling**		
Eggs and larvae	None	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Moderate (F) Low	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Moderate (F) Low
Marine mammals							
Phocid carnivores in water (PCW)	PCW	<1m	<15m	<140m	<1m	<5m	<50m

In line with *Popper et al*., 2014 the relative risk classification for continuous noise in the absence of a numerical threshold, the risk of PTS arising is described as *low* across all distances in all fish groups for both tubular and rotary bored piling.

The relative risk classification for TTS is *moderate* for tens of metres, and *low* at greater distances for fish with no swim bladders and fish with swim bladders that are not involved in hearing. The relative risk classification for TTS is *low* for eggs and larvae across all distances. For fish with swim bladders involved in hearing, the TTS impact is expected to arise at distances <1m.

The relative risk classification for behavioural disturbance is *moderate* across tens and hundreds of metres and *low* at thousands of metres for all hearing groups except for fish with swim bladders involved in hearing. Fish with swim bladders involved in hearing have a *high* risk of behavioural disturbance at tens of metres compared to other fish hearing groups.

Only one species of marine mammal was identified within the study area - grey seal (*Halichoerus grypus*) which falls under the Phocid Carnivores in Water hearing group (PCW).

For tubular piling, it is anticipated that PTS/AUD INJ may arise at distances <1m, TTS at <15m and Behavioural Disturbance at <140m. For rotary bored piling, it is anticipated that PTS/AUD INJ may arise at distances <1m, TTS at <5m and Behavioural Disturbance at <50m.

From Table 4.2, potential adverse impacts are confined to within hundreds of metres from piling location, with the least stringent threshold being behavioural disturbance for tubular piling, which carries a *moderate* risk at hundreds of metres for all fish hearing groups and <140m for grey seals.

5 Mitigation

The following site specific measures is recommended for the benefit of underwater receptors in line with JNCC 2010:

- Careful planning of the sequence of work in order to minimise the transfer of noise/vibration in the water environment and limit the use of machines in contact with it.
- A mitigation zone should be established of a pre-agreed radius around the piling site prior to any piling. This is an area in which the Marine Mammal Observer (MMO) / Passive Acoustic Monitoring (PAM) operative will monitor either visually and/or acoustically for marine mammals before piling commences. JNCC recommends that the radius of the mitigation zone should not be less than 500m from piling location.
- The mitigation zone should be monitored by MMO/PAM for an agreed period prior to the commencement of piling. JNCC 2010 recommends this monitoring duration should be a minimum of 30 minutes.
- Piling should not be commenced during periods of darkness and poor visibility as there is a greater risk of failing to detect the presence of marine mammals. Piling should not be commenced if marine mammals are detected within the mitigation zone or until 20 minutes after the last visual or acoustic detection.

- Where possible equipment shall be soft started over a period of 20 minutes duration, to avoid sudden noise.

6 Conclusion

This technical note has presented the underwater noise assessment associated with rotary bored piling for the construction of the A494 Dee Bridge replacement. It is anticipated that the risk behavioural disturbance for fish groups will be *moderate* at hundreds of metres for all fish groups and falls to *low* at greater distances. The risk of TTS is *moderate* at tens of meters for all fish groups and falls to *low* at greater distances. For grey seals that fall under the hearing group PCW, behavioural disturbance may arise at distances less than 140 m and TTS may arise at distances less than 15 m. For all marine animals, the risk for AUD INJ/PTS is *low* across all distances.