Outer Dowsing Offshore Wind

Outline Plans

Outline Marine Mammal Mitigation Protocol for Piling Activities

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Acronyms & Terminology

Abbreviations / Acronyms

Abbreviation / Acronym	Description
ADD	Acoustic Deterrent Device
ANS	Artificial Nesting Structure
BBC	Big Bubble Curtain
dB	Decibel
DBBC	Double Big Bubble Curtain
DCO	Development Consent Order
dML	deemed Marine Licence
ECC	Export Cable Corridor
EIA	Environmental Impact Assessment
ES	Environmental Statement
HSD	Hydrosound-Damper
JNCC	Joint Nature Conservation Committee
kJ	Kilojoule
km	Kilometre
m	Meter
m^3	Meters cubed
m/s	Meters per second
MDS	Maximum Design Scenario
MMMP	Marine Mammal Mitigation Protocol
MMO	Marine Management Organisation
MMOb	Marine Mammal Observer
mins	Minutes
NAS	Noise Abatement System
NE	North East
NMS	Noise Mitigation System
ODOW	Outer Dowsing Offshore Wind (The Project)
ORBA	Offshore Restricted Build Area
ORCP	Offshore Reactive Compensation Platform
ORJIP	Offshore Renewables Joint Industry Programme
OP	Offshore Platform
OWF	Offshore Wind Farm
PAM	Passive Acoustic Monitoring
PD	Project Description
PTS	Permanent Threshold Shift
SEL	Sound Exposure Level
SEL_{cum}	Cumulative Sound Exposure Level
SPL	Sound Pressure Level
SPL_{peak}	Peak Sound Pressure Level
SNCB	Statutory Nature Conservation Body
UK	United Kingdom

Abbreviation / Acronym	Description
UWN	Underwater Noise
UXO	Unexploded Ordnance
WTG	Wind Turbine Generator
µPa	Micropascal

Terminology

Term	Definition
Array Area	The area offshore within which the generating station (including wind turbine generators (WTG) and inter array cables), offshore accommodation platforms, offshore transformer substations and associated cabling will be positioned.
Baseline	The status of the environment at the time of assessment without the development in place.
deemed Marine Licence (dML)	A marine licence set out in a Schedule to the Development Consent Order and deemed to have been granted under Part 4 (marine licensing) of the Marine and Coastal Access Act 2009.
Development Consent Order (DCO)	An order made under the Planning Act 2008 granting development consent for a Nationally Significant Infrastructure Project (NSIP).
Effect	Term used to express the consequence of an impact. The significance of an effect is determined by correlating the magnitude of an impact with the sensitivity of a receptor, in accordance with defined significance criteria.
EIA Regulations	Infrastructure Planning (Environmental Impact Assessment) Regulations 2017
Environmental Impact Assessment (EIA)	A statutory process by which certain planned projects must be assessed before a formal decision to proceed can be made. It involves the collection and consideration of environmental information, which fulfils the assessment requirements of the EIA Regulations, including the publication of an Environmental Statement (ES).
Embedded Mitigation	Mitigation that is embedded in the project design.
Impact	An impact to the receiving environment is defined as any change to its baseline condition, either adverse or beneficial.
Landfall	The location at the land-sea interface where the offshore export cable will come ashore.
Magnitude	The extent of any interaction, the likelihood, duration, frequency and reversibility of any potential impact.
Maximum Design Scenario (MDS)	The project design parameters, or a combination of project design parameters that are likely to result in the greatest potential for change in relation to each impact assessed
Mitigation	Mitigation measures, or commitments, made by the Project to reduce and/or eliminate the potential for significant effects to arise as a result of the Project. Mitigation measures can be embedded (part of the Project Design) or secondarily added to reduce impacts in the case of significant effects.
Offshore Export Cable Corridors (ECC)	The Offshore Export Cable Corridor (Offshore ECC) is the area within the Order Limits within which the export cable running from the array to landfall will be situated.

Term	Definition
Offshore Platform (OP)	Platforms located within the array area which house electrical equipment and control and instrumentation systems. They also provide access facilities for work boats and helicopters.
Outer Dowsing Offshore Wind (ODOW)	Outer Dowsing Offshore Wind, an offshore wind generating station together with associated onshore and offshore infrastructure.
Order Limits	The area subject to the application for development consent, The limits shown on the works plans within which the Project may be carried out.
Peak Sound Pressure Level	Characterised as a transient sound from impulsive noise sources, it is the maximum change in positive pressure as the wave propagates.
Pre-construction	The phases of the Project before construction takes place.
Sound Exposure Level	Measure that considers both the received level of the sound and duration of exposure.
Sound Pressure Level	Measure of the average unweighted level of sound, usually a continuous noise source.
Receptor	A distinct part of the environment on which effects could occur and can be the subject of specific assessments. Examples of receptors include species (or groups) of animals or plants, people (often categorised further such as 'residential' or those using areas for amenity or recreation), watercourses, etc.
The Applicant	GT R4 Ltd. The Applicant making the application for a DCO. The Applicant is GT R4 Limited (a joint venture between Corio Generation, TotalEnergies and Gulf Energy Development (GULF)), trading as Outer Dowsing Offshore Wind. The project is being developed by Corio Generation (a wholly owned Green Investment Group portfolio company), TotalEnergies and GULF.
The Project	Outer Dowsing Offshore Wind, an offshore wind generating station together with associated onshore and offshore infrastructure.
Wind Turbine Generator (WTG)	A structure comprising a tower, rotor with three blades connected at the hub, nacelle and ancillary electrical and other equipment which may include J-tube(s), transition piece, access and rest platforms, access ladders, boat access systems, corrosion protection systems, fenders and maintenance equipment, helicopter landing facilities and other associated equipment, fixed to a foundation

Reference Documentation

Document Number	Title
6.1.3	Project Description
6.1.11	Marine Mammals
6.3.11.2	Underwater Noise Assessment

1 Introduction

1.1 Project Background

1. GT R4 Limited (trading as Outer Dowsing Offshore Wind) hereafter referred to as the 'Applicant', is proposing to develop the Project. The Project array area will be located approximately 54 kilometres (km) from the Lincolnshire coastline in the southern North Sea. The Project will include both offshore and onshore infrastructure including an offshore generating station (windfarm), export cables to landfall, Offshore Reactive Compensation Platforms (ORCP), onshore cables, connection to the electricity transmission network, ancillary and associated development and areas for the delivery of up to two Artificial Nesting Structures (ANS) and the recreation of a biogenic reef (if these compensation measures are deemed to be required by the Secretary of State) (see Volume 1, Chapter 3: Project Description (PD) for full details (document reference 6.1.3)).

1.2 Purpose of this document

2. The primary objective of this Outline Marine Mammal Mitigation Protocol (MMMP) for Piling is to detail the potential contingency measures which could be used by the Project to manage the risk of permanent threshold shift (PTS) auditory injury to marine mammal species arising from piling activities associated with the installation of monopile and pin-pile foundations to a negligible level. This document incorporates guidance from the Joint Nature Conservation Committee (JNCC, 2010) and integrates recommendations on the utilisation of Acoustic Deterrent Devices (ADD) as outlined by McGarry (2020), in alignment with best practices within the industry.
3. The measures outlined in this document should be considered as examples of potential mitigation measures which could be employed by the Project at the point of construction to provide confidence to stakeholders that the proposed MMMP will be sufficient to ensure the risk of injury is as low as reasonably practicable. It is not intended to identify specific mitigation measures that will be implemented during pile driving operations as this will be determined prior to construction by the Project in consultation with the regulators and their advisors. In instances where driven or partially-driven pile foundations are employed, a formal Piling MMMP will be drafted. This protocol will then be submitted to the regulatory authority, adhering to conditions specified in the deemed Marine Licence (dML) as outlined in the draft Development Consent Order (DCO). The content of this Final MMMP will be based on the best available evidence at that point in time.
4. The Project has developed commitments during the Environmental Impact Assessment (EIA) process to minimise potential impacts to marine mammals, which involves the creation and implementation of a piling MMMP (see Volume 1, Chapter 11: Marine Mammals for full details (document reference 6.1.11)).

1.3 Implementation of Outline MMMP for Piling Activities

5. In the event that a DCO is granted, and the ultimate project design affirms the use of driven or partially-driven pile foundations, a Final Piling MMMP will be prepared. This protocol will follow the principles established in this Outline MMMP for Piling Activities. Details regarding the proposed mitigation can be found in Section 4 below.

2 Pile Driving Scenarios

2.1 Scenarios Considered

6. A full description of the Project ~~Proposed Development~~ is provided in Chapter 3 (document reference: 6.1.3).
7. Both monopiles and pin-piles may be installed at the Project therefore, both foundation types have been assessed in the Environmental Statement (ES) (see Chapter 11 (document reference: 6.1.11). A summary of the parameters assessed are presented in the sections below, with the outcome of the marine mammal assessment summarised in Section 3.2.
8. For the ES assessment, two different maximum design scenarios (MDS) have been considered:
   - A monopile foundation scenario:
     - Maximum 14m diameter, with a maximum hammer energy of 6,600 kilojoules (kJ), with up to two monopiles installed in a 24-hour period; and
   - A pin-pile foundation scenario:
     - Maximum 5m diameter, with a maximum hammer energy of 3,500kJ, with up to six piles installed in a 24-hour period.
9. These two MDS' as relevant to this Outline MMMP are presented in the sections below.

2.2 Monopile MDS

10. Table 2.1 details the piling parameters that represent the spatial MDS for monopiles. For full details of the piling parameters see Volume 3, Appendix 3.2: Underwater Noise (UWN) Assessment (document reference: 6.3.11.2).

Table 2.1: Monopile MDS parameters

Parameter	Monopiles		
	WTG	OP	ANS
Maximum number of monopiles	100	7	2
Maximum pile diameter (m)	13	14	8
Maximum hammer energy (kJ)	6,600		3,500
Maximum number of piling events per day	2		1
Maximum number of simultaneous piling events	2		1

2.3 Pin-pile MDS

11. Table 2.2 details the piling parameters that represent the temporal MDS for pin-piles. For full details of the piling parameters see the PD (document reference 6.1.3).

Table 2.2: Multi-leg pin-piled jackets MDS parameters

Parameter	Pin-piles		
	WTG	OP	ANS
Maximum number of pin-piles	400	168	8
Maximum pile diameter (m)	5		
Maximum hammer energy (kJ)	3,500		
Maximum number of piling events per day	12[1]		4
Maximum number of simultaneous piling events	2		1

[1] Maximum number of piling events in a single day is 12, assuming two piling rigs, each installing six piles. For the purposes of the underwater noise modelling to inform this MMMP, six piling events at a single location have been modelled to inform the maximum injury ranges.

3 Summary of Potential Impacts

3.1 Maximum Design Scenario

12. For full details of the piling parameters please see the Project Description and the UWN Assessment (document references 6.1.3 and 6.3.11.2, respectively). Due to the addition of the Offshore Restricted Build Area (ORBA) over a part of the array area, the underwater noise modelling location in the northeast corner of the array area (NE) presented in Chapter 11 (document reference: 6.1.11) of the ES is now situated outside of the area in which Wind Turbine Generators (WTGs) will be installed. Therefore, re-modelling was conducted for a new NE modelling location outside of the ORBA. Additionally, the removal of the northern portion of the Offshore Export Cable Corridor (ECC) means that the ORCP North modelling location presented in the ES is no longer applicable. The piling parameters remain the same as those presented in the ES. The re-modelling is presented in the Environmental Report for the Offshore Restricted Build Area and Revision to the Offshore ECC (Document reference 15.9).

3.1.1 Instantaneous and cumulative PTS-onset

13. The potential quantitative impacts from underwater noise from piling activities at the Project have been assessed for PTS on bottlenose dolphin, grey seal, harbour porpoise, harbour seal, minke whale and white-beaked dolphin making reference to the PTS-onset thresholds presented by Southall et al. (2019). Table 3.1 provides the results at the maximum hammer energy for both monopiles (6,600kJ) and pin-piles (3,500kJ). Additional detail on the piling assessment on marine mammals can be found in Chapter 11 and the UWN Assessment (document references 6.11.1 and 6.3.11.2 respectively) and the Environmental Report for the Offshore Restricted Build Area and Revision to the Offshore ECC (Document reference 15.9).

Table 3.1: Estimated worst-case locations for instantaneous and cumulative PTS-onset impact ranges (km) from piling at the Project.

Species	Threshold	Monopile (6,600 kJ)			Pin pile (3,500 kJ)		
		Array Area	ORCP	ANS	Array Area	ORCP	ANS
Instantaneous PTS (SPL_{peak})							
Harbour porpoise (*Phocoena phocoena*)	Unweighted SPL_{peak} 202 dB re 1µPa	0.58	0.39	0.50	0.49	0.34	0.54
Bottlenose dolphin (*Tursiops truncatus*) & white-beaked dolphin (*Lagenorhynchus albirostris*)	Unweighted SPL_{peak} 230 dB re 1µPa	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Minke whale (*Balaenoptera acutorostrata*)	Unweighted SPL_{peak} 219 dB re 1µPa	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Harbour seal (*Phoca vitulina*) & grey seal (*Halichoerus grypus*)	Unweighted SPL_{peak} 218 dB re 1µPa	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Cumulative PTS (SEL_{cum})							
Harbour porpoise	Weighted SEL_{cum} 155 dB re 1µPa²s	3.0	1.3	2.6	2.0	0.65	2.6
Bottlenose dolphin & white-beaked dolphin	Weighted SEL_{cum} 185 dB re 1µPa²s	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Minke whale	Weighted SEL_{cum} 183 dB re 1µPa²s	5.0	1.2	5.0	3.3	0.30	5.0
Harbour seal & grey seal	Weighted SEL_{cum} 185 dB re 1µPa²s	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10

3.2 Summary of Impacts Assessed for Marine Mammals in Relation to PTS for Piling Noise

14. Chapter 11 (document reference 6.1.11) and the Environmental Report for the Offshore Restricted Build Area and Revision to the Offshore ECC (Document reference 15.9) present the full assessment of the impacts of PTS-onset for piling noise of marine mammals. In summary, the assessment concluded that, with the use of a MMMP (and the specific measures that will be contained within that the final MMMP that will be submitted to the Marine Management Organisation (MMO) under the dMLs), examples of the potential measures are outlined within this document), it is expected that the risk of PTS will be negligible under the MDS for both monopiles and pin-piles and is not therefore considered to have a significant effect on any marine mammal species considered in the assessment.

4 Mitigation Methodology

4.1 Introduction

15. In order to minimise the risk of any auditory injury to marine mammals from underwater noise during pile driving, there are a suite of mitigation measures that the Applicant could implement for the Project piling activities. These mitigation measures may include (but are not limited to) the following:
    - Pre-piling deployment of ADDs;
    - Marine Mammal Observer (MMOb);
    - Passive Acoustic Monitoring (PAM) system; and
    - Piling soft start procedure.
16. The specific mitigation measure (or suite of measures) that will be implemented during the construction of the Project will be determined, in consultation with relevant Statutory Nature Conservation Bodies (SNCBs), following the appointment of the installation contractors (and therefore, confirmation of final hammer energies and foundation types), collection of additional survey data (further geophysical and/or geotechnical data) and/or information on maturation of emerging technologies. This additional data and information will allow the noise modelling to be updated and feed into discussions on the appropriate mitigation measure(s) in the Final Piling MMMP (if required).
17. The following sections provide a high-level methodology for each of these elements. If necessary, a Final Piling MMMP will be produced prior to the relevant stage of construction for approval by the MMO.

4.2 Mitigation Zone

18. The mitigation zone is defined as the maximum potential PTS-onset impact range. The Applicant will update the noise modelling prior to construction once the final project details are known. The JNCC (2010) guidelines recommend a mitigation zone of at least 500m during piling activities. The actual mitigation zone for the Project piling will be confirmed in the Final Piling MMMP as this will be determined based on the final noise modelling data. If the final noise modelling estimates a PTS-onset impact range larger than the 500m suggested by JNCC, the mitigation zone will be increased to cover the PTS-onset impact.

4.3 Pre-Piling

4.3.1 Marine Mammal Observers ~~(MMOb)~~

19. ~~The~~ JNCC (2010) recommends a 30-minute visual pre-piling search by a qualified and experienced MMOb for both monopiles and pin-piles within the mitigation zone prior to ADD activation[2]. ~~If this mitigation measure is adopted, the~~ A ~~q~~qualified MMOb would record monitoring periods, environmental conditions, and marine mammal sightings as per JNCC guidelines. Identified behavioural responses to ADD activation (if used) would also be documented.
20. If a marine mammal is detected during the pre-piling search, the soft start would be delayed until the MMOb confirms its departure from the mitigation zone and ensures a safe distance (defined as the PTS-onset range for the Project). If a marine mammal is not observed leaving the mitigation zone, a delay of 20 minutes will be implemented from last recorded sighting before the commencement of a soft-start. The ADD's operation would be checked concurrently, and the MMOb would continue to monitor for sightings and animal behaviour during the soft start.
21. The JNCC guidelines have stipulated fully-trained~~complete~~ MMOb roles in piling for minimising piling noise-related risks to marine mammals (JNCC, 2010). Specific details on confirming MMObs and methods will be updated in the Final Piling MMMP, considering any available guidance at that time.

4.3.2 Passive Acoustic Monitoring ~~(PAM)~~

22. A PAM system, used by a trained operator, may be used to supplement visual monitoring, especially in conditions of limited visibility such as during the night, fog, or high sea states, as specified by the JNCC (2023) prior to the commencement of piling at a foundation. If an animal is acoustically detected within the mitigation zone, the soft start would be delayed until the PAM operator (or MMObs if used) confirms its departure from the mitigation zone and ensures a safe distance (defined as the PTS-onset range for the Project).

[2] This may require the total visual watch time to be longer than 1 hour when the ADD activation time is longer than 30 minutes, as the watch will continue during ADD deployment

4.3.3 ADD Choice and Specification

23. The standard ADD used in UK waters for current construction phase projects is the Lofitech AS seal scarer. This ADD has demonstrated consistent effectiveness in deterring harbour seals, grey seals, harbour porpoises and minke whales, especially in conditions similar to offshore windfarm (OWF) construction sites (Sparling *et al*., 2015, McGarry *et al*., 2017). It has a successful track record in marine mammal mitigation at various European OWF projects, including C-Power Thornton Bank OWF in Belgium (Haelters *et al.,* 2012), Horns Rev II, Nysted and Dan Tysk OWFs in Denmark (Carstensen *et al.,* 2006; Brandt *et al.,* 2016), and has been widely used for UK projects including Hornsea Project One, Hornsea Project Two, Dogger Bank A and the Sofia Offshore WindFarm Unexplored Ordnance (UXO) campaign amongst others.

24. The evidence available suggests that the Lofitech ADD can be highly effective in deterring harbour porpoise to at least 7.5 km with deterrence observed to 15 km range (Brandt *et al.,* 2013a; Brandt *et al.,* 2013b). Furthermore, a recent study also showed that after a 15 minute ADD exposure, in a 3-hour period after exposure there was a 50% probability of a significant behavioural response in harbour porpoise out to a range of 21.7 km (Thompson *et al*., 2020).

25. The ORJIP review suggested that for grey and harbour seals, ADDs could be effective at a range of approximately 1,000m (e.g. Götz and Janik, 2010; Götz, 2008). In addition, field trials have been carried out in the Moray Firth (Gordon *et al*., 2015), the results of which demonstrate that harbour seals exhibited aversive responses to the Lofitech seal scarer ADD signals in all trials at initial ranges of 1,000m or less. It is worth noting that the Offshore Renewables Joint Industry Programme (ORJIP) review (Sparling *et al.,* 2015) concluded that given detection probabilities of traditional passive methods of mitigation (visual observers and passive acoustic monitoring) would be significantly less than 100% for harbour porpoise and seals, ADDs were likely better than traditional passive methods at reducing risk of injury.

26. A recent study of the effects of the Lofitech ADD on minke whales demonstrated significant deterrent reactions, including directed movement away from the ADD and a significant increase in swim speed (McGarry *et al.*, 2017). Exposures were carried out at 500 m and 1,000 m from the device and significant responses were seen at both ranges. In this study, whales responding to the ADD were tracked to beyond the limit of the visible range, which was approximately 4,000 m, therefore deterrence behaviour is likely to extend beyond this range for minke whales.

~~24.~~27. Currently, there is no available published evidence demonstrating the effectiveness of ADDs on white-beaked dolphins (*Lagenorhynchus albirostris*) or bottlenose dolphins (*Tursiops truncatus*). However, it is important to note that these deterrents only need to be effective within a very limited range (<100m based on the conservative modelling parameters used for the ES) for white-beaked and bottlenose dolphins to mitigate the risk of instantaneous or cumulative auditory injury. Additionally, considering the lower densities of these species in the area compared to harbour porpoises, the likelihood of encountering white-beaked or bottlenose dolphins at the site is significantly reduced.

~~25.~~28. It is important to note that there may be additional ADD models identified in the pre-construction phase for the Project that are available and suitable for use at that point in time. As such, if an ADD is identified as a mitigation measure within the Final Piling MMMP, the final ADD choice and specification would follow current best practice as advised by the relevant SNCB and would be approved by the MMO.

4.3.4 ADD Deployment Procedure

~~26.~~29. If an ADD is used during piling activities, one ADD would be deployed from the platform/vessel deck, with the control unit and power supply on board. Verification of ADD operations would be required before piling commences. The deployment procedure would be determined with the foundation installation contractor and would adhere to safe, standard practices, using experienced/trained staff to ensure proper ADD equipment use within varying vessel layouts.

4.3.5 ADD Duration of Deployment

~~27.~~30. The duration of ADD deployment would be calculated based on assumed swimming speeds to ensure that marine mammals are safely outside the mitigation zone when piling begins. An assumed swim speed of 1.5m/s would be applicable to all marine mammals except minke whales, for which a speed of 3.25m/s, would be assumed. These selected swim speeds are considered precautionary, as evidence suggests that animals often flee at much higher initial speeds. For instance, studies indicate that minke whales can flee ADDs at an average speed of 4.2m/s (McGarry *et al.*, 2017).

~~28.~~31. A study by Kastelein *et al.* (2018) demonstrated that captive harbour porpoises responded to pile driving sounds by swimming at significantly higher speeds than their baseline, reaching speeds of up to 1.97m/s sustained for a 30-minute test period. Another study by van Beest *et al.* (2018) showed that a harbour porpoise responded to airgun noise exposure with a fleeing speed of 2m/s.

~~29.~~32. During the soft start and ramp-up, marine mammals are expected to continue moving away from the noise source. Additionally, the presence of other construction vessel activity on-site would be likely to induce animals to move away from the piling location and out of the mitigation zone prior to piling commencement, as indicated by studies (Brandt *et al.,* 2018; Graham *et al.,* 2019; Benhemma-Le Gall *et al.,* 2021).

4.3.6 ADD Operator Training and Responsibilities

~~30.~~33. A trained and dedicated ADD operator would be responsible for ADD maintenance, operation, and reporting. Their duties would include deploying the ADD, verifying its operation, maintaining charged batteries and spare equipment, recording and reporting ADD activities. Before the MMOb's and/or PAM operator's pre-piling watch, the ADD operator would test and deploy the ADD to the agreed depth and distance. When the ADD is activated, the MMOb and/or PAM operator would ensure the mitigation zone is clear before commencing piling soft start operations, at which point the ADD is turned off.

4.3.7 Soft Start Procedure

~~31.~~34. After pre-piling deployment of the ADDs and pre-piling watch by the MMOb and/or PAM operator, the foundation installation process would commence. Initially, a maximum of up to 10~~5~~% of the full hammer energy would be applied before the hammer energy would gradually increase until it reaches the level necessary for pile installation, or the maximum hammer energy capacity. This gradual initiation process, known as the 'soft start', would cover the ~~entire~~ piling operation from the initial strike until the maximum hammer energy is attained, and in line with the JNCC (2010) guidance would last for no less than 20 minutes.

~~32.~~35. If a marine mammal enters the mitigation zone during the soft start, then, whenever possible, the piling operation at that mitigation zone would cease, or at the least the power would not be further increased until the marine mammal exits the mitigation zone. The ADD activation will also ensure that animals are beyond the injury zone based on instantaneous sound levels from the initial hammer strikes.

~~33.~~36. It is important to note that the hammer energy would not be raised beyond what is required to drive the pile to the target depth. If ground conditions permit the use of less than the maximum hammer energy for a complete installation, the energy will not be needlessly increased to its maximum level.

4.4 Noise Abatement

~~34.~~37. Technologies are available which reduce the amount of noise emitted at source (noise abatement). Such technologies are being routinely deployed in other parts of the North Sea to reduce the risk of impact on marine life, particularly marine mammals (Merchant and Robinson, 2019).

~~35.~~38. Various noise abatement technologies have distinct constraints dictated by water depth and prevailing oceanographic conditions (Weilgart, 2023; Bellmann *et al.*, 2020; Merchant and Robinson, 2019). Practical technological remedies exist for the entire range of water depths found within the proposed area for offshore windfarm construction in the UK.

- *Percussive pile-driving:* Barrier type noise abatement systems, such as bubble curtains, have been extensively proven to be effective in waters up to 45m. For bubble curtains in particular, their effectiveness diminishes with increasing water depth due to bubble dispersion. Systems relying on casings (such as the IHC Noise Mitigation Screen) have demonstrated efficacy up to 45m, contingent upon the availability of sufficiently large systems for the given water depth. Encapsulated resonator systems (*e.g.,* the Hydrosound damper (HSD) and AdBm noise abatement system (NAS)) are theoretically unrestricted by water depth (Verfuss *et al.*, 2019; Weilgart, 2023). However, adverse water conditions, such as high current speeds and wave heights, may pose challenges at specific times and locations (Koschinski and Lüdemann, 2020; Merchant and Robinson, 2019). It should be noted that many of these systems must be designed and built to match the specific conditions found at each project location and would require extensive maintenance throughout the piling phase.

- *Alternative piling methods:* this involves the modification of the noise source, which could be achieved by altering the pile-driving procedure. This adjustment may encompass changes in the force applied by the impact hammer, for instance, adopting technologies like BLUE piling. This not currently included in the Project design parameters in Chapter 3 (document reference 6.3.1). Alternatively, the Project could explore other pile-driving methods which do not generate high-amplitude shock waves within the pile, such as vibro-piling or employing gentle driving of piles techniques (Keene, 2021; Bellmann *et al.,* 2020) as detailed in the Project design envelope in Chapter 3 (document reference 6.3.1).

~~36.~~39. The approximate level of noise reduction, which can be achieved by some these different methods, either alone or -combined, is outlined in Table 4.1 and Plate 1 based on the review of NAS and their limitations provided by Verfuss *et al*. (2019), and Koschinski and Lüdemann (2020).

Table 4.1: Minimum and maximum noise reduction efficacy. Data obtained from Verfuss *et al.,* (2019) and Koschinski and Lüdemann (2020)

Noise abatement system	Water depth (m)	Noise reduction SELss (dB) range
BBC (> 0.3m³/min*m)	~ 40	7-11
DBBC (> 0.3m³/min*m)	~ 40	8-13
DBBC (> 0.4m³/min*m)	~ 40	12-18
DBBC (> 0.5m³/min*m)	> 40	~ 15-16 (based on one pile)
NMS	Up to 40	13-16
HSD	Up to 40	10-12
NMS + optimised BBC (>0.4m³/(min*m)	~ 40	17-18
NMS + optimised BBC (>0.5m³/(min*m)	~ 40	18-20
HSD + optimised BBC (>0.4m³/(min*m)	~ 30	15-20
HSD + optimised DBBC (0.48m³/(min*m)	20-40	15-28
HSD + optimised DBBC (>0.5m³/(min*m)	< 45	18-19
BLUE Hammer	30	19-24

BBC = Big Bubble Curtain, DBBC = Double Big Bubble Curtain, NMS = IHC Noise Mitigation Screen, HSD = Hydrosound Damper

Bubble curtain air volume flow given in m³/(min*m)

Water depth = the depth of the OWF project where noise reduction was used and where noise measurements were obtained

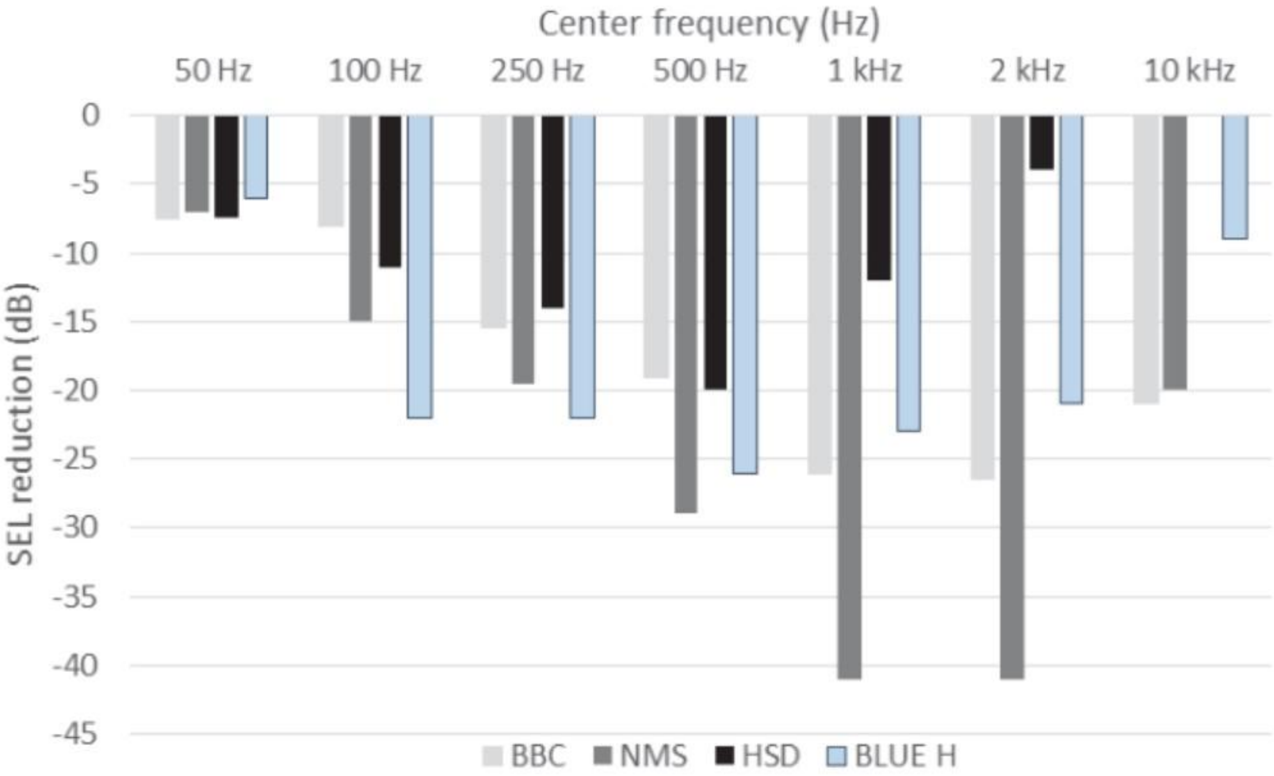

Plate 1: Reduction in SEL at frequencies 10Hz, 250Hz, 500Hz, 1kHz and 2kHz in the 1/3rd octave and frequency spectrum of a pile strike when comparing mitigated and unmitigated piling from Verfuss et al., (2019).

~~37.~~40. It is worth noting that the techniques discussed here may not be exhaustive, as new technologies continue to emerge over time.

4.5 Breaks in Piling

~~38.~~41. Breaks in piling could result in marine mammals re-entering the mitigation zone. According to JNCC (2010) guidelines, if there is a pause in piling operations exceeding 10 minutes, the pre-piling search and soft start procedures should be repeated (where possible) before resuming piling activities. If MMOb/PAM watch has been continuous the pre-watch starts from the end of piling.

~~39.~~42. However, the feasibility of resuming with a soft start depends on the stage of piling and pile/seabed conditions. If a soft start is not possible, the pre-piling ADD deployment and pre-piling search would be redone before continuing piling operations. The specific protocol for handling piling breaks would be determined in collaboration with the piling contractor (once contracted) and SNCBs and documented in the Final Piling MMMP.

4.6 Delays in Commencement of Piling

~~40.~~43. If the commencement of piling is delayed, there would be a risk of animals re-entering the mitigation zone when ADDs are switched off. However, turning on ADDs for extended periods may lead to habituation. Therefore, ADDs would be promptly turned off during delays and reactivated when piling is ready to commence. The break in ADD would be for greater than 20 minutes to ensure a startle and flee response once the ADD is reactivated. ADDs would be used for the minimum duration necessary to ensure animals vacate the mitigation zone, accompanied by continuous visual and/or acoustic monitoring (if employed).

4.7 Communications

~~41.~~44. The Final Piling MMMP will specify a communication protocol for implementing marine mammal mitigation measures, including any delays in commencing piling due to marine mammal presence. It will also outline the roles and responsibilities of key personnel to ensure these mitigation measures are effectively carried out. This will be developed based on the mitigation measures and personnel required with the titles and responsibilities being refined depending on the contractual agreement

4.8 Reporting

~~42.~~45. Reports on piling activities and mitigation measures would be prepared, including, but not limited to:

- Outline of the marine mammal monitoring methodology and procedures employed;
- Record of piling operations detailing date, soft-start duration, piling duration, hammer energy during soft-start and piling as well as any operational issues for each pile;
- Record of ADD deployment, including the start and end times of all ADD activation periods and any problems with ADD deployment;
- Record of marine mammal observations and/or PAM detections including the duration of the ~~marine mammal observer~~MMOb pre-piling search;
- Environmental conditions during the pre-piling search, description of any marine mammal sightings and/or PAM detections and any actions taken, and a record of any incidental sightings made;
- Details of any problems encountered during the piling process including instances of noncompliance with the agreed piling protocol; and
- Any recommendations for amendment of protocols.

~~43.~~46. Following the completion of piling, a final report, covering piling events, mitigation methods, issues, sightings, behavioural observations, and potential protocol improvements, would be submitted to the regulator.

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