Dogger Bank Project – PM575-PMS-054-001

Non-Material Change Application: Appendix 2 Marine Mammal Technical Report

Validity area: Dogger Bank Project / Offshore

ASSURANCE OF CONTENT

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Prepared by	The person who is regarded as the author of the document
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Approved by	The person who has the authority to accept the document and release it for implementation

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Glossary of Acronyms

µPa	Micro pascal
ADD	Acoustic Deterrent Device
BGS	British Geological Survey
CI	Confidence Interval
CODA	Cetacean Offshore Distribution and Abundance in the European Atlantic
CV	Confidence Variation
dB	Decibels
DCO	Development Consent Order
dML	deemed Marine Licence
EMODnet	European Marine Observation and Data Network
ES	Environmental Statement and associated documents (Forewind, 2013a, b, c)
GW	Gigawatts
HF	High-frequency
HRA	Habitats Regulations Assessment (undertaken by DECC, 2015)
Hz	Hertz
IAMMWG	Inter-Agency Marine Mammal Working Group
kJ	Kilojoules
km	Kilometre
km^2	Kilometre squared
LF	Low-frequency
m	meter
MAREMAP	Marine Environmental Mapping Programme
MF	Mid-frequency
MMMP	Marine Mammal Mitigation Protocol
MMO	Marine Management Organisation
MU	Management Unit
N/A	Not Applicable
NMC	Non-Material Change
NMFS	National Marine Fisheries Services
NOAA	National Oceanic and Atmospheric Administration
NPL	National Physical Laboratory
NS	North Sea
OWF	Offshore Wind Farm
PTS	Permanent Threshold Shift
SAC	Special Area of Conservation
SCANS	Small Cetaceans in the European Atlantic and North Sea
SCOS	Special Committee on Seals
SEL	Sound Exposure Level
SEL_{ss}	Sound Exposure Level for single strike
SEL_{cum}	Cumulative Sound Exposure Level
SMRU	Sea Mammal Research Unit
SPL	Sound Pressure Level
TSEG	Trilateral Seal Expert Group
TTS	Temporary Threshold Shift

Executive Summary

Dogger Bank Creyke Beck A & B are two offshore wind farms which were consented in 2015 under the Dogger Bank Creyke Beck Offshore Wind Farm Order 2015 (the DCO). In respect of both Dogger Bank Creyke Beck A & B, the DCO prescribes a number of parameters including maximum number of turbines, overall generating capacity, rotor diameter, maximum hammer energy and foundation size.

Since the DCO was granted, advancements in technology mean that larger turbines have become available which would require a limited number of changes to the consented parameters. As a result, the Project Team is seeking to make a non-material change to the DCO. In relation to potential effects on marine mammals, the key changes are an increase in the maximum hammer energy from 3,000kJ to 4,000kJ and an increase in monopile diameter from 10m to 12m.

This report considers the potential for changes to the outcomes of the assessment provided in the ES and HRA for the consented projects. The assessments are based on a like for like comparison of a maximum hammer energy of 3,000kJ and 4,000kJ and on an updated assessment based on updated modelling (as requested by Natural England, see RHDHV 2018). These assessments both consider the potential impacts on marine mammals from permanent auditory injury, temporary auditory injury and likely or possible avoidance of an area in respect of the relevant receptors (harbour porpoise, white-beaked dolphin, minke whale and grey seal (and harbour seal in the updated assessment)). This report demonstrates that in each case, the assessment outcomes would not be affected by proposed changes in hammer energy and monopile diameter.

The assessments undertaken demonstrate that there is no difference in the impact significance between the impacts as assessed under the original assessment and the updated assessment (on a like for like basis) and that there is no increase in impact significance when using the updated modelling. Therefore, the assessments demonstrate that an increase in maximum hammer energy from 3,000kJ and 4,000kJ does not affect impact significance on any of the assessed receptors.

As there is no significant difference in the potential impacts on marine mammals from increasing the maximum monopile hammer energy to 4,000kJ and the monopile diameter to 12m compared to the maximum monopile hammer energy of 3,000kJ and the monopile diameter of 10m in the original assessment, there will be no significant difference to the outcome of the cumulative impact assessment in the ES assessment or to the outcome of the HRA (DECC, 2015) as a result of the proposed changes.

Therefore this report confirms that there are no new or materially different likely significant effects compared to the existing scheme. The conclusions of the existing ES, that marine mammal impacts are not significant for the project alone and cumulatively with other projects, are not affected. Similarly, the conclusions of the HRA of no adverse effect on the integrity of any European site arising from the project alone and in-combination with all other sites are not affected. The proposed changes do not have the potential to give rise to likely significant effects on any European sites (including the Southern North Sea candidate Special Area of Conservation). The worst case position remains the same and no further assessment is required for marine mammals in support of the proposed changes to the DCO.

It is concluded that the proposed changes would not give rise to any new or materially different likely significant effects on any receptor and that the conclusions of the ES and the DECC HRA are not affected and no new HRA is required. Therefore, it is appropriate for the application to amend the maximum hammer energy and monopile diameter to be consented as an NMC to the DCO.

1 Introduction

Dogger Bank Creyke Beck A and B are two consented offshore wind farms approximately 130km from shore in the North Sea (**Figure 1**). The Projects were originally developed by Forewind, a consortium comprising SSE, Equinor (formerly Statoil), Innogy (formerly RWE) and Statkraft. Following the grant of the DCO these projects were split between the parent companies.

A Joint Venture between SSE and Equinor, known as 'The Dogger Bank Offshore Wind Project' (herein referred to as the Project Team), has been set up to deliver the development of the Creyke Beck projects (herein referred to as the project).

The Creyke Beck project will comprise two offshore wind farms each with an installed capacity of up to 1.2 gigawatts (GW):

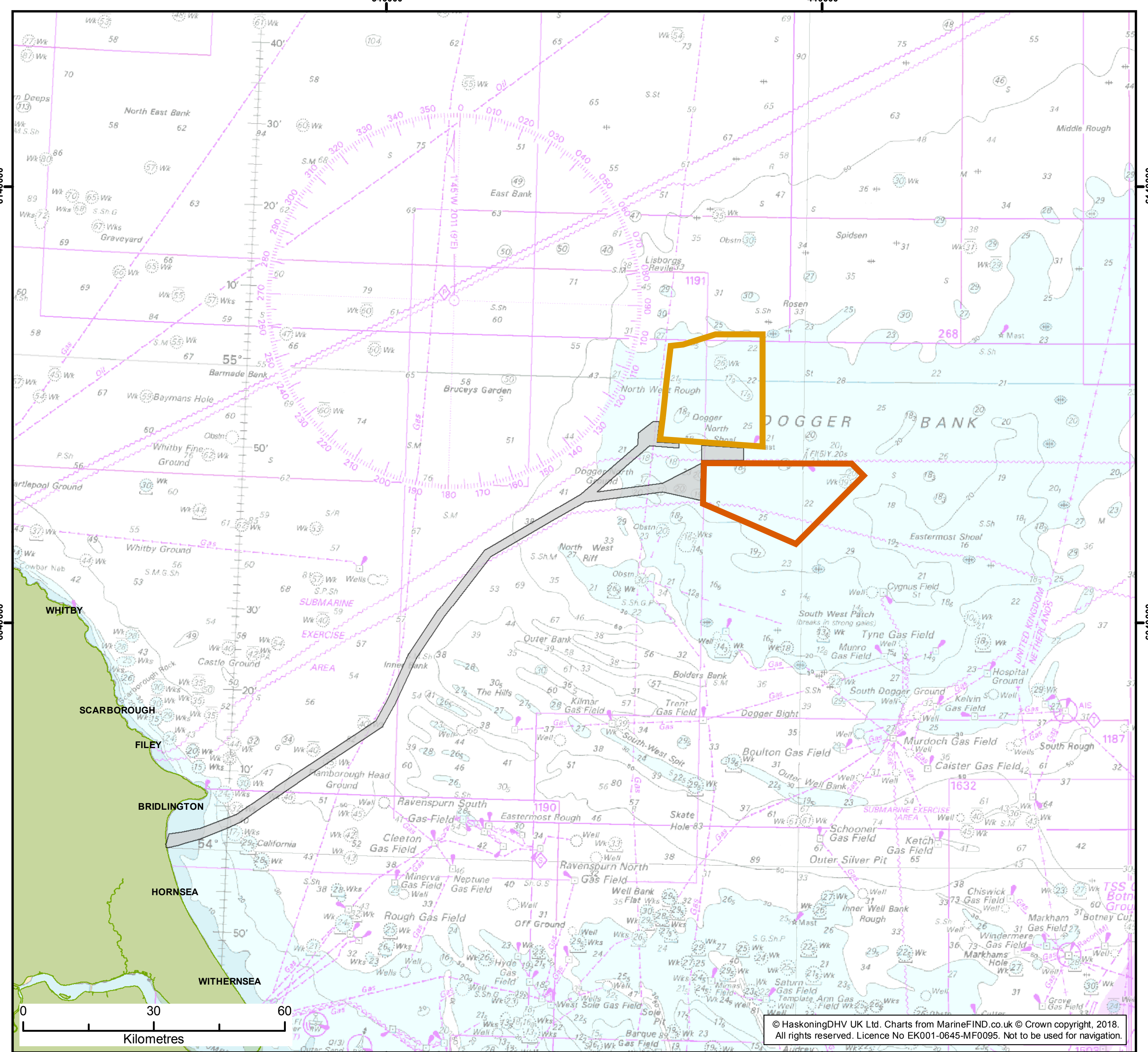
- Dogger Bank Creyke Beck A is in the southern corner of the former Dogger Bank Zone. It covers 515km^2 and is 131km from shore at its closest point.
- Dogger Bank Creyke Beck B is on the western edge of the former Dogger Bank Zone. It covers 599km^2 and is also 131km from shore at its closest point.

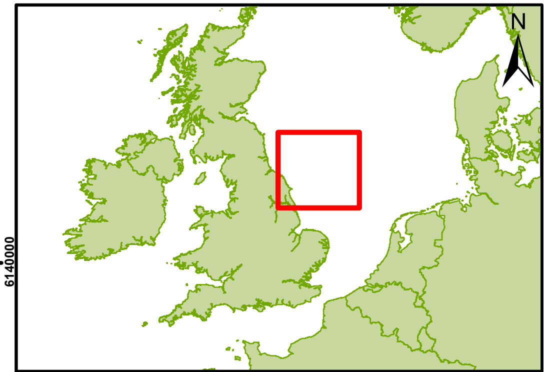
In the three years since consent was granted there have been a number of advancements in technology that would make the wind farm more efficient and cost effective. These advances are based on the size of wind turbine generators that are available, or that are likely to become available during the course of the development programme. As some of these would require a limited number of changes to the consented parameters (**Section 2**), the Project Team is looking to make a non-material change to the DCO, to enable the most efficient and cost-effective project to be constructed.

This technical report describes how the proposed amendments would affect the marine mammal assessment presented in the ES and the HRA undertaken by DECC (now Department for Business, Energy and Industrial Strategy (BEIS)).

The report is structured as follows:

- **Section 2 Proposed Amendment**;
- **Section 3 Purpose of Assessment**;
- **Section 4 Methodology for Assessment**;
- **Section 5 Outcome of Assessment**; and
- **Section 6 Conclusions**.





Legend:

- Dogger Bank Creyke Beck A
- Dogger Bank Creyke Beck B
- Export cable corridor

Client:	Project:
SSE and Equinor	Dogger Bank Creyke Beck

Title:

Location of Dogger Bank Creyke Beck A and B

Figure:	Drawing No:
1	PB6994-100-201

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
01	05/06/2018	GC	GC	A4	1:1,250,000

Co-ordinate system: WGS84 UTM 31N

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2 Proposed Amendment

The proposed amendment requires an increase to the consented parameters for rotor diameter, monopile diameter and hammer energy, whilst leaving all other DCO parameters unchanged, including the site boundary and total generating capacity (**Table 1**). In effect, the amendments mean that it is possible for fewer, larger turbines to be installed.

Of these, the monopile diameter and hammer energy have the potential to affect the marine mammal assessment. Review and reassessment has been undertaken using the updated parameters shown in **Table 1**.

There are no proposed changes to the maximum hammer energy or pile diameter in relation to pin-piles.

Table 1 Proposed consent amendments relevant to marine mammals

Parameter	Consented Envelope	Proposed Amendment
Maximum hammer energy – monopile	3,000kJ	Up to 4,000kJ
Maximum hammer energy – pin pile	2,300kJ	No change
Monopile diameter	Up to 10m	Up to 12m
Pin-pile diameter	3.5m	No change
Soft-start	300kJ for 30 minutes	No change
Active piling time per pile	Up to 5 hours plus 30 minutes soft-start	No change
Capacity	Up to 1.2GW per project	No change
Number of turbines	Up to 200 turbines per project	No change

3 Purpose of Assessment

As set out in **Section 2**, the proposed changes are:

- An increase in the maximum hammer energy for single monopile structures from 3,000kJ to up to 4,000kJ; and
- An increase in the maximum monopile diameter from 10m to 12m.

The purpose of this assessment is to determine the potential impacts on marine mammals associated with the proposed increase in hammer energy and increased pile diameter. This report provides a comparison of the assessment for the ES and the HRA with the updated assessment for the increased hammer energy and pile diameter. The assessment referred to throughout this report is the assessment conducted for the ES, HRA and everything that led to consent, including examination.

Underwater noise propagation modelling for the original assessment was carried out by the National Physical Laboratory (NPL) (Theobald *et al*., 2012) to assess the effects of noise from the construction of the Dogger Bank Creyke Beck offshore wind farms.

Since the NPL modelling was completed for the ES, NPL no longer conduct noise modelling for individual projects. In addition, new noise thresholds and criteria have been developed by the US National Marine Fisheries Service (NMFS, 2016) for both permanent threshold shift (PTS) where unrecoverable hearing damage may occur, as well as temporary threshold shift (TTS) where a temporary reduction in hearing sensitivity may occur in marine mammals.

Therefore, for the proposed increase in hammer energy, underwater noise modelling has been undertaken by Subacoustech to:

(i) Compare the NPL model used in the original assessment and Subacoustech INSPIRE model used in this assessment to ensure the models are comparable. This is presented in **Annex A**.

(ii) Replicate underwater noise modelling undertaken for the original assessment, for equivalent inputs and scenarios to enable a like for like comparison to be made between the consented hammer energy of 3,000kJ and the proposed increase of 4,000kJ.

(iii) Update the underwater noise modelling based on the latest inputs and scenarios for increased pile diameter and hammer energy using the latest (NMFS, 2016) thresholds and criteria for PTS and TTS. This was requested by Natural England (see RHDHV 2018).

This aim of the assessment is to determine whether there is are any new or materially different likely significant effects in relation to marine mammals between using the proposed maximum hammer energy of 4,000kJ compared to the currently consented maximum hammer energy of 3,000kJ. The updated underwater noise modelling has been undertaken based on the increase in monopile diameter to 12m.

4 Methodology for Assessment

The ES identified the following species as requiring assessment:

- Harbour porpoise *Phocoena phocoena*
- White-beaked dolphin *Lagenorhynchus albirostris*
- Minke whale *Balaenoptera acutorostrata*
- Grey seal *Halichoerus grypus*
- Harbour seal *Phoca vitulina*

4.1 Underwater noise modelling

The original model used by NPL is not openly available. As such, Subacoustech have used the INSPIRE model to produce comparable modelling methodology.

As outlined in **Annex A**, on a like for like basis the Subacoustech modelling using the INSPIRE model provides comparable results to the previous NPL modelling used in the ES and is therefore considered to be suitable to conduct the updated noise modelling and to allow a comparison with the original assessment.

4.1.1.1 Modelling locations and environmental conditions

The same modelling locations and environmental conditions that were used in the original assessment were also used in the updated assessment as outlined in **Annex A**.

The results from location ID6 at Creyke Beck B was chosen as a representative modelling location due to its location in the deeper water to the north and west of the site (location shown on Figure 1-1 in **Annex A**).

4.1.2 Increased hammer energy and pile diameter

The maximum hammer energies and pile diameters for monopiles in the original assessment and updated assessment for the increased hammer energy and pile diameter are presented in **Table 2**.

The size of the pile being installed has been applied to the modelling to estimate the frequency content of the noise. Frequency data was not given in the NPL report. As such, frequency data has been derived using Subacoustech's noise measurement database. Representative third-octave noise levels dependent on the size of the monopiles and pin-piles have been used for this modelling.

Table 2 Maximum hammer energies and pile diameters assessed in the original assessment and updated assessment

Assessment	Maximum pile diameter	Maximum hammer energy
Original assessment	10m	3,000kJ
Updated assessment	12m	4,000kJ

4.1.3 Source levels

The unweighted source level for maximum hammer energies of 3,000kJ and 4,000kJ for monopiles used in the original assessment and updated assessment are presented in **Table 3**, these are in line with those seen at other, similar scale offshore wind farm (OWF) projects.

It is important to note that the source level value is theoretical and does not necessarily, nor is intended to, represent the actual noise level at 1m from the piling operation, which is highly complex close to a large distributed source. Its purpose is for the accurate calculation of noise levels at greater distances from the source, to correspond with relevant thresholds, and crucially in this case, to agree with the original NPL modelling (see **Annex A** for further details).

Table 3 Unweighted, single strike, source levels used for modelling in the assessment

Source level	SPLpeak source level	SEL_{ss} source level
Monopile 3,000kJ (maximum)	245.2 dB re 1 µPa @ 1 m	219.2 dB re 1 µPa²s @ 1 m
Monopile 4,000kJ (maximum)	247.5 dB re 1 µPa @ 1 m	220.4 dB re 1 µPa²s @ 1 m

4.1.4 Soft-start, strike rate, piling duration and swim speeds

The scenarios used in the cumulative Sound Exposure Level (SEL) modelling in the original assessment and for increased hammer energies for monopiles used in the updated assessment are presented in **Table 4**.

Assessments have been based on the worst-case scenario for piling duration, sequence 3 (as referred to in the original assessment (Forewind, 2013a)), which assumes 12,600 strikes over 330 minutes.

The soft-start, or the use of lower hammer energy for an initial period, takes place over the first half-hour of piling, with a starting hammer energy of 10% of the maximum energy, then for the remaining number of strikes the hammer energy is 100%. This is a worst-case scenario, as it is likely that the hammer energy will ramp-up gradually from 10% to 100% after the soft-start and for engineering reasons piling would not be at 100% for this extended period (and may not operate at 100%). However, information on a ramp-up was unavailable in the NPL report and ES, and thus these worst-case assumptions have been made and have informed the basis for this assessment.

Table 4 Summary of the multiple pulse scenarios used for cumulative SEL modelling used in the original assessment and updated assessment

Soft-start, strike rate and piling duration scenarios for SEL_{cum}	Percentage of maximum hammer energy	
	10% (soft-start)	100%
3,000kJ (monopile)	300kJ	3,000kJ
4,000kJ (monopile)	400kJ	4,000kJ
Strike rate	1 strike every 3 seconds	1 strike every 1.5 seconds
Duration	30 minutes	35 minutes (sequence 1) 110 minutes (sequence 2) 300 minutes (sequence 3)
Number of strikes	600 strikes	1,400 strikes (sequence 1) 4,400 strikes (sequence 2) 12,000 strikes (sequence 3)

The cumulative SEL modelling uses a fleeing animal model. This assumes that the animal exposed to the noise levels will swim away from the source as it occurs. For this assessment, a constant speed of 3.25 m/s has been assumed for minke whale (Blix and Folkow, 1995). All other receptors are assumed to swim at a constant speed of 1.5 m/s (Otani *et al*. 2000; Hirata, 1999). These are considered worst-case (i.e.

relatively slow, leading to greater calculated exposures) as marine mammals are expected to swim much faster under stress conditions. These are the same swim speeds used in the original assessment.

4.1.5 Thresholds and criteria

4.1.5.1 Original assessment

The following criteria were used in the NPL Report for the original assessment and have been used to give a 'like for like' comparison between the results of the original assessment and the increase in hammer energy in the updated assessment:

- Lucke *et al*. (2009) for harbour porpoise (e.g. high-frequency cetaceans); and
- Southall *et al*. (2007) for mid-frequency cetaceans (e.g. dolphin species); low-frequency cetaceans (e.g. minke whale) and pinnipeds in water (e.g. grey and harbour seal).

The criteria used in the original assessment are summarised in **Table 5** to **Table 8**. It should be noted that the Southall *et al*. (2007) and Lucke *et al*. (2007) criteria presented in the NPL Report, and here as a comparison, are only for single strike SEL (SEL_{ss}).

Table 5 Criteria for assessing impacts on harbour porpoise in the original assessment and modelled by NPL, based on Lucke et al. (2009)

Potential Impact	Criteria
Instantaneous injury / PTS	SPL_{peak} 200 dB re 1 µPa
	Unweighted SEL_{ss} 179 dB re 1 µPa^{2}s
TTS / fleeing response	SPL_{peak} 194 dB re 1 µPa
	Unweighted SEL_{ss} 164 dB re 1 µPa^{2}s
Possible avoidance	SPL_{peak} 168 dB re 1 µPa
	Unweighted SEL_{ss} 145 dB re 1 µPa^{2}s

Table 6 Criteria for assessing impacts on mid-frequency (MF) cetaceans (e.g. dolphin species) in the original assessment and modelled by NPL, based on Southall et al. (2007)

Potential Impact	Criteria
Instantaneous injury / PTS	SPL_{peak} 230 dB re 1 µPa
	M_{mf} weighted SEL_{ss} 198 dB re 1 µPa^{2}s
TTS / fleeing response	SPL_{peak} 224 dB re 1 µPa
	M_{mf} weighted SEL_{ss} 183 dB re 1 µPa^{2}s
Likely avoidance from area	Unweighted SEL_{ss} 170 dB re 1 µPa^{2}s
Possible avoidance from area	Unweighted SEL_{ss} 160 dB re 1 µPa^{2}s

Table 7 Criteria for assessing impacts on low-frequency (LF) cetaceans (e.g. minke whale) in the original assessment and modelled by NPL, based on Southall et al. (2007)

Potential Impact	Criteria
Instantaneous injury / PTS	SPL_{peak} 230 dB re 1 µPa
	M_{lf} weighted SEL_{ss} 198 dB re 1 µPa^2s
TTS / fleeing response	SPL_{peak} 224 dB re 1 µPa
	M_{lf} weighted SEL_{ss} 183 dB re 1 µPa^2s
Likely avoidance from area	Unweighted SEL_{ss} 152 dB re 1 µPa^2s
Possible avoidance from area	Unweighted SEL_{ss} 142 dB re 1 µPa^2s

Table 8 Criteria for assessing impacts on pinnipeds in water (e.g. grey and harbour seal) in the original assessment and modelled by NPL, based on Southall et al. (2007)

Potential Impact	Criteria
Instantaneous injury / PTS	SPL_{peak} 218 dB re 1 µPa
	M_{pw} weighted SEL_{ss} 186 dB re 1 µPa^2s
TTS / fleeing response	SPL_{peak} 212 dB re 1 µPa
	M_{pw} weighted SEL_{ss} 171 dB re 1 µPa^2s

4.1.5.2 New criteria

The latest criteria from NOAA (NFMS, 2016) for single strike, unweighted peak criteria (SPL_{peak}) and cumulative (i.e. more than a single impulsive sound) weighted sound exposure criteria (SEL_{cum}) for PTS and TTS were used in the updated assessment (**Table 9**).

It should be noted that these cannot be compared like-for-like with criteria in the original assessment as cumulative SELs were not considered for marine mammals (cumulative SELs are the risk of PTS or TTS during the duration of the pile installation including the soft-start and ramp-up and the total maximum duration, as opposed to risk from a single strike).

Table 9 PTS and TTS thresholds for marine mammals from NMFS (2016) criteria for impulsive noise

Marine Mammal hearing group	PTS threshold		TTS threshold	
	SPL_{peak} (unweighted) dB re 1 µPa	SEL_{cum} (weighted) dB re 1 µPa^2s	SPL_{peak} (unweighted) dB re 1 µPa	SEL_{cum} (weighted) dB re 1 µPa^2s
Low-frequency cetaceans (e.g. minke whale)	219	183	213	168

Marine Mammal hearing group	PTS threshold		TTS threshold	
	SPL_{peak} (unweighted) dB re 1 µPa	SEL_{cum} (weighted) dB re 1 µPa^{2}s	SPL_{peak} (unweighted) dB re 1 µPa	SEL_{cum} (weighted) dB re 1 µPa^{2}s
Mid-frequency cetaceans (e.g. dolphin species)	230	185	224	170
High-frequency cetaceans (e.g. harbour porpoise)	202	155	196	140
Pinnipeds in water (e.g. grey and harbour seal)	218	185	212	170

4.1.5.3 Possible behavioural response

The Lucke *et al*. (2009) criteria for possible avoidance of harbour porpoise (**Table 5**), the Southall *et al*. (2007) criteria for the likely and possible avoidance of dolphin species (**Table 6**) and minke whale (**Table 7**) were also used in the updated assessment.

4.2 Density estimates and reference populations

Since the ES was completed, updated information on the density estimates and reference populations for marine mammals in the Dogger Bank area has become available. Table 10 and Table 11 provide the density estimates and reference populations, respectively, used in the original assessment and the updated assessment.

The same density estimates and reference populations used in the original assessment have been used in the like for like comparison (**Section 5.1**).

The most recent density estimates have been based on the SCANS-III survey for cetaceans (Hammond *et al*., 2017) and the latest Sea Mammal Research Unit (SMRU) seal at-sea usage maps (Russell *et al*., 2017) have been used for the updated assessment (**Section 5.2**).

Since the original assessment, the density estimate for:

1. Harbour porpoise has increased by 0.2344 harbour porpoise per km^2 (increase of approximately 36%), based on the latest SCANS-III survey. This increased density estimate has been used as a worst-case scenario, e.g. highest density estimate, in the updated assessment.

2. White-beaked dolphin has lowered slightly by 0.0051 individuals per km^2 (decrease of approximately 72%), based on the latest SCANS-III survey. However, for the wider area of likely or possible avoidance the SCANS-III density estimate was more appropriate to use.

3. Minke whale has increased by 0.0077 individuals per km^2 (increase of approximately 335%), based on the latest SCANS-III survey. This increased density estimate has been used as a worst-case scenario, e.g. highest density estimate, in the updated assessment.

4. Grey seal has lowered by 0.71 individuals per km^2 (decrease of approximately 71%). However, as this is based on the most recent SMRU data, this was the most appropriate density estimate to use in the updated assessment.

Since the original assessment, the reference population for:

1. Harbour porpoise in the North Sea Management Unit (MU) has increased by an estimated 112,923 harbour porpoise (increase of approximately 48.5%). The estimates cover the same area and reflect a change in harbour porpoise number between the SCANS-II survey in 2005 and the latest SCANS-III survey in 2016.

2. White-beaked dolphin has lowered slightly by 641 individuals (decrease of approximately 4%). The estimates cover the same area and reflect a refinement of the estimate from the SCANS-II publication (Hammond *et al*., 2013) to the Inter-Agency Marine Mammal Working Group (IAMMWG, 2015) publication.

3. Minke whale has lowered by 2,195 individuals (decrease of approximately 8.5%). The estimates cover the same area and reflect a refinement of the estimate from the SCANS-II publication (Hammond *et al*., 2013) and Cetacean Offshore Distribution and Abundance in the European Atlantic (CODA) survey publication (Macleod *et al*., 2009) to the Inter-Agency Marine Mammal Working Group (IAMMWG, 2015) publication.

4. Grey seal has decreased slightly by 122 individuals (decrease of approximately 0.5%). The estimates are based, as closely as possible, on counts from the same areas and reflect slight changes in the number of grey seal in these areas.

Harbour seal were not assessed in the original assessment, but the reference population for the south-east coast of England has increased by approximately 840 individuals (increase of approximately 20%), reflecting an increase in the number of harbour seal in this area (SCOS, 2017).

Table 10 Marine mammal density estimates used in the original assessment and updated assessments

Species	Original assessment		Updated assessment	
	Density estimate used in ES	ES data source	Updated density estimate (number of individuals per km^2)	Updated data source
Harbour porpoise	0.6536/km^2 (95% CI = 0.4445-0.9409/km^2)	Site specific surveys; ES (Forewind, 2013)	0.888/km^2 (CV = 0.21)	SCANS-III survey block O* (Hammond *et al*., 2017)
White-beaked dolphin	0.0071/km^2 (95% CI = 0.0064-0.0948/km^2)	Site specific surveys; ES (Forewind, 2013)	0.002/km^2 (CV = 0.97)	SCANS-III survey block O* (Hammond *et al*., 2017)
Minke whale	0.0023/km^2 (95% CI = 0.0015-0.0048/km^2).	Site specific surveys; ES (Forewind, 2013)	0.010/km^2 (CV = 0.62)	SCANS-III survey block O* (Hammond *et al*., 2017)
Grey seal	Maximum mean density of 0.84 seals per km^2	SMRU (2013)	0.13/km^2	SMRU seal at-sea usage maps (Russell *et al*., 2017)
Harbour seal	N/A	N/A	0.005/km^2	SMRU seal at-sea usage maps (Russell

Species	Original assessment		Updated assessment	
	Density estimate used in ES	ES data source	Updated density estimate (number of individuals per km^2)	Updated data source
				et al., 2017)

*Creyke Beck A and B are both located in SCANS-III survey block O.

Table 11 Marine mammal reference populations used in the original assessment and updated assessments

Species	Reference population		
	Extent	Size	Year of estimate and data source
Harbour porpoise	North Sea MU	345,373 (CV = 0.18; 95% CI = 246,526-495,752) *[used in updated assessment*]	2016 based SCANS-III (Hammond *et al*., 2017)
		232,450 (95% CI = 154,451 – 310,449) [*used in original assessment*]	2005 based on SCANS-II (Hammond *et al*., 2013)
White-beaked dolphin	Celtic and Greater North Seas (CGNS) MU	15,895 (CV=0.29; 95% CI=9,107-27,743) [*used in updated assessment*]	2005; IAMMWG (2015) based on SCANS-II (Hammond *et al*., 2013)
	European	16,536 (95% CI=9,245 - 29,586) [*used in original assessment*]	2005 based on SCANS-II (Hammond *et al*., 2013)
Minke whale	Celtic and Greater North Seas (CGNS) MU	23,528 (CV=0.27; 95% CI=13,989-39,572) [*used in updated assessment*]	2005 & 2007; IAMMWG (2015) based on SCANS-II (Hammond *et al*., 2013) and CODA (Macleod *et al*., 2009)
	European	25,723 (95% CI=11,037-73,605) [*used in original assessment*]	2005 & 2007 based on SCANS-II (Hammond *et al*., 2013) and CODA (Macleod *et al*., 2009)
Grey seal	South-east England MU; North-east England MU; East coast of Scotland MU; & Waddenzee region	22,290 = 6,085 + 6,948 + 3,812 + 5,445 [*used in updated assessment*]	2016-2017; SCOS (2017) and TSEG (2017a)
	South-east England MU	6,085 [*used in updated assessment*]	2016; SCOS (2017)
	North Sea	22,412 = 19,100 (14,000 - 26,500) + 3,312 [*used in original assessment*]	2010 & 2011; UK North Sea (SCOS) and Mainland Europe (Waddensea Secretariat)
Harbour seal	South-east England MU; and Waddenzee region	43,161 = 5,061 + 38,100 [*used in updated assessment*]	2016-2017; SCOS (2017) and TSEG (2017b)
	South-east England	5,061	2016; SCOS (2017)

Species	Reference population		
	Extent	Size	Year of estimate and data source
	MU	[*used in updated assessment*]	
	England east coast	4,221 (minimum population size) [*used in original assessment*]	2007 – 2010; SCOS

5 Outcome of Assessment

5.1 Results of like for like comparison

The results presented in this section summarise the updated assessment based on the Subacoustech modelling of the predicted impact ranges for the maximum hammer energy of 3,000kJ and 4,000kJ using the same parameters as used in the original assessment. This allows for a like for like comparison of the potential impacts of increasing the maximum hammer energy to 4,000kJ compared to the consented maximum hammer energy of 3,000kJ.

Each comparison considers in turn:

- The increase in impact range; and
- The number of individuals and percentage of the reference population at risk.

It should be noted that whilst the percentage increase from the original assessment is provided for context purposes, the outcome of the comparison and conclusion that follows is based on the number of individuals and percentage of the reference population at risk, and how this compares to the original assessment.

In relation to each of the potential impacts for each of the receptors, the like for like comparison demonstrates that there is no difference in the impact significance between the impacts as assessed under the original assessment and the updated assessment. This demonstrates that an increase in maximum hammer energy from 3,000kJ and 4,000kJ does not affect impact significance on any of the assessed receptors.

A summary of the like for like comparison is provided in **Section 6, Table 68**.

5.1.1 Harbour porpoise

5.1.1.1 PTS

In the original assessment, the NPL modelling of instantaneous auditory injury (PTS) in harbour porpoise for a single strike of the maximum monopile hammer energy of 3,000kJ, based on the unweighted Lucke *et al*. (2009) criteria (pulse SEL 179 dB re 1 μPa^{2}s), predicted a potential impact range of <700m at Creyke Beck B (being the selected representative modelling location – see **Section 4.1.1**).

The updated modelling with the INSPIRE model using the same criteria for a maximum hammer energy of 3,000kJ resulted in a maximum impact range of 720m. The updated modelling with the INSPIRE model using the same criteria for a maximum hammer energy of 4,000kJ resulted in a maximum impact range of 860m at Creyke Beck B (**Table 12**).

Table 12 Like for like comparison of predicted impact ranges and areas for PTS in harbour porpoise based on Lucke et al. (2009) criteria (unweighted SEL_{ss} 179 dB re 1 μPa^2s)

Maximum predicted PTS impact range and area for monopiles				
ES assessment for maximum hammer energy of 3,000kJ	**Updated modelling for maximum hammer energy of 3,000kJ**	**Updated modelling for maximum hammer energy of 4,000kJ**	**Difference between 3,000kJ and 4,000kJ based on updated modelling**	**Difference between ES assessment for 3,000kJ and updated modelling for 4,000kJ**
<700m* (1.5km^2)	720m (1.6km^2)	860m (2.3km^2)	140m = +19% (0.7km^2 = +44%)	160m = +23% (0.8km^2 = +53%)

*700m used for calculating percentage differences

The maximum number of harbour porpoise that could be at risk of PTS in the original assessment was one harbour porpoise, based on an impact area of up to 1.5km^2 and a harbour porpoise density of 0.6536 harbour porpoise per km^2. The maximum number of harbour porpoise that could be at risk of PTS based on the assessment for a maximum hammer energy of 4,000kJ is 1.5 harbour porpoise, based on a maximum impact area of 2.3km^2 and a harbour porpoise density of 0.6536 harbour porpoise per km^2.

The assessment indicates that up to a maximum of an additional 0.5 harbour porpoise (0.0002% of the ES reference population) could potentially be at increased risk of PTS from a single strike of the maximum hammer energy of 4,000kJ compared to 3,000kJ hammer energy (**Table 13**). Therefore, there is no significant difference (i.e. the additional difference is less than 0.001% of the reference population, therefore the magnitude for any permanent impact is negligible, based on assessment of impacts criteria in ES; see **Annex B**) between the consented hammer energy of 3,000kJ and the proposed increase to a maximum hammer energy of 4,000kJ (**Table 13**).

*Table 13 Like for like comparison of the maximum number of harbour porpoise and % of reference population that could be at risk of PTS based on Lucke et al. (2009) criteria (unweighted SEL_{ss} 179 dB re 1 μPa^2s) and the density estimates and reference populations used in the ES**

Maximum number of individuals (% reference population) at risk of PTS				
ES assessment for maximum hammer energy of 3,000kJ	**Updated modelling for maximum hammer energy of 3,000kJ**	**Updated modelling for maximum hammer energy of 4,000kJ**	**Difference between 3,000kJ and 4,000kJ based on updated modelling**	**Difference between ES assessment for 3,000kJ and updated modelling for 4,000kJ**
1 harbour porpoise (0.0004%)	1 harbour porpoise (0.0004%)	1.5 harbour porpoise (0.0006%)	0.5 harbour porpoise (0.0002%)	0.5 harbour porpoise (0.0002%)

*ES harbour porpoise density = 0.6536/km^2 (95% CI = 0.4445-0.9409/km^2);
ES harbour porpoise reference population = 232,450 (95% CI = 154,451 – 310,449)

The original assessment concluded that there would be no impact for PTS in harbour porpoise with mitigation, based on a standard 500m mitigation zone. In the original assessment, it was determined that the reduction in the impacted area due to the exclusion / mitigation zone (out to 500m) would reduce the likelihood of PTS occurring, as the impacted area would be reduced to 0.75km^2, reducing the potential number of harbour porpoise that could be at risk of PTS to 0.49 harbour porpoise (0.0002% of the reference population).

During the 30 minute soft-start and ramp-up (**Table 4**) and based on a precautionary average swimming speed of 1.5m/s (Otani *et al*. 2000), harbour porpoise would move at least 2.7km from the pile location, which is considerably greater than the maximum predicted impact ranges for a maximum hammer energy of 3,000kJ and 4,000kJ (**Table 12**). Therefore, there should be no harbour porpoise in the potential impact area and at risk of instantaneous PTS from a single strike of the maximum hammer energy of 3,000kJ or 4,000kJ after the soft-start and ramp-up.

There is no difference in the impact significance for PTS in harbour porpoise (with or without mitigation) for the proposed increased maximum hammer energy to 4,000kJ compared to the maximum hammer energy of 3,000kJ assessed in the ES (**Table 14**).

Table 14 Like for like comparison of the impact significance for PTS in harbour porpoise from single strike of maximum hammer energy of 3,000kJ and 4,000kJ*

Impact significance for PTS in harbour porpoise	Maximum hammer energy of 3,000kJ	Maximum hammer energy of 4,000kJ
Without mitigation	Minor adverse (high sensitivity x permanent impact with negligible magnitude (<0.001% ref. pop.))	Minor adverse (high sensitivity x permanent impact with negligible magnitude (<0.001% ref. pop.))
With mitigation (residual impact)	No impact	No impact

*see Annex B for definitions of sensitivity, magnitude and impact significance matrix

5.1.1.2 TTS / fleeing response

In the original assessment, the NPL modelling for TTS / fleeing response in harbour porpoise for a single strike of the maximum monopile hammer energy of 3,000kJ, based on the unweighted Lucke *et al*. (2009) criteria (pulse SEL 164 dB re 1 μPa^{2}s), predicted a potential impact range of 5.5km at Creyke Beck B.

The updated modelling with the INSPIRE model using the same criteria for a maximum hammer energy of 3,000kJ resulted in a maximum impact range of 5.9km. The updated modelling using the same criteria for a maximum hammer energy of 4,000kJ resulted in a maximum impact range of 6.9km at Creyke Beck B (**Table 15**).

Table 15 Like for like comparison of predicted impact ranges and areas for TTS in harbour porpoise based on Lucke et al. (2009) criteria (unweighted SEL_{ss} 164 dB re 1 μPa^{2}s)

Maximum predicted TTS impact range and area for monopiles				
ES assessment for maximum hammer energy of 3,000kJ	Updated modelling for maximum hammer energy of 3,000kJ	Updated modelling for maximum hammer energy of 4,000kJ	Difference between 3,000kJ and 4,000kJ based on updated modelling	Difference between ES assessment for 3,000kJ and updated modelling for 4,000kJ
5.5km (>78.5km^2)	5.9km (110km^2)	6.9km (140km^2)	1km = +17% (30km^2 = +27%)	1.9km = +38% (>61.5km^2 = +78%)

Up to a maximum of an additional 29.5 or 19.5 harbour porpoise (0.01% or 0.008% of the ES reference population) could potentially be temporarily affected by TTS as a result of a single strike of the maximum hammer energy of 4,000kJ compared to 3,000kJ as assessed in the original assessment and updated noise modelling, respectively (**Table 16**). Therefore, there is no significant difference (i.e. the additional difference is less than 1% of the reference population, therefore the magnitude for a temporary impact is negligible, based on assessment of impacts criteria in ES; see **Annex B**) between the consented hammer energy of 3,000kJ and the proposed increase to a maximum hammer energy of 4,000kJ.

*Table 16 Like for like comparison of the maximum number of harbour porpoise and % of reference population that could be at risk of TTS based on Lucke et al. (2009) criteria (unweighted SEL_{ss} 164 dB re 1 μPa²s) and the density estimates and reference populations used in the ES**

Maximum number of individuals (% reference population)				
ES assessment for maximum hammer energy of 3,000kJ	**Updated modelling for maximum hammer energy of 3,000kJ**	**Updated modelling for maximum hammer energy of 4,000kJ**	**Difference between 3,000kJ and 4,000kJ based on updated modelling**	**Difference between ES assessment for 3,000kJ and updated modelling for 4,000kJ**
62 harbour porpoise (0.03%)	72 harbour porpoise (0.03%)	91.5 harbour porpoise (0.04%)	19.5 harbour porpoise (0.008%)	29.5 harbour porpoise (0.01%)

*ES harbour porpoise density = 0.6536/km² (95% CI = 0.4445-0.9409/km²);
ES harbour porpoise reference population = 232,450 (95% CI = 154,451 – 310,449)

The original assessment concluded that there would be a negligible impact for TTS in harbour porpoise, due to the medium sensitivity of the receptor to this impact and the negligible magnitude of the effect.

There is no difference in the impact significance for TTS in harbour porpoise for the proposed increased maximum hammer energy to 4,000kJ compared to the consented maximum hammer energy of 3,000kJ (**Table 17**).

Table 17 Like for like comparison of the impact significance for TTS in harbour porpoise from single strike of maximum hammer energy of 3,000kJ and 4,000kJ*

ES assessment for maximum hammer energy of 3,000kJ	Updated modelling for maximum hammer energy of 3,000kJ	Updated modelling for maximum hammer energy of 4,000kJ
Negligible (medium sensitivity x temporary impact with negligible magnitude (≤1% ref. pop.))	Negligible (medium sensitivity x temporary impact with negligible magnitude (≤1% ref. pop.))	Negligible (medium sensitivity x temporary impact with negligible magnitude (≤1% ref. pop.))

*see Annex B for definitions of sensitivity, magnitude and impact significance matrix

5.1.1.3 Possible avoidance

In the original assessment, the NPL modelling for possible avoidance of harbour porpoise from a single strike of the maximum monopile hammer energy of 3,000kJ, based on the unweighted Lucke *et al*. (2009) criteria (pulse SEL 145 dB re 1 μPa²s), predicted a potential impact range of up to 43km at Creyke Beck B.

The updated modelling with the INSPIRE model using the same criteria for a maximum hammer energy of 3,000kJ resulted in a maximum impact range of 39.1km. The updated modelling with the INSPIRE model using the same criteria for a maximum hammer energy of 4,000kJ resulted in a maximum impact range of 42.4km at Creyke Beck B (**Table 18**).

Table 18 Like for like comparison of predicted impact ranges and areas for possible avoidance of harbour porpoise based on Lucke et al. (2009) criteria (unweighted SEL_{ss} 145 dB re 1 μPa²s)

Maximum predicted possible avoidance impact range and area for monopiles				
ES assessment for maximum hammer energy of 3,000kJ	**Updated modelling for maximum hammer energy of 3,000kJ**	**Updated modelling for maximum hammer energy of 4,000kJ**	**Difference between 3,000kJ and 4,000kJ based on updated modelling**	**Difference between ES assessment for 3,000kJ and updated modelling for 4,000kJ**
43km (3,483km²)	39.1km (3,100km²)	42.6km (3,700km²)	3.5km = +9%) (600km² = +19%)	0.4km = -2%) (217km² = +6%)

Up to a maximum of an additional 142 or 392 harbour porpoise (0.06% or 0.17% of the ES reference population) could potentially be temporarily affected by possible avoidance as a result of a single strike of the maximum hammer energy of 4,000kJ compared to 3,000kJ hammer energy as assessed in the original assessment and updated noise modelling, respectively (**Table 19**). Therefore, there is no significant difference (i.e. the additional difference is 1% or less of the reference population, therefore the magnitude for a temporary impact is negligible, based on assessment of impacts criteria in ES; see **Annex B**) between the consented hammer energy of 3,000kJ and the proposed increase to a maximum hammer energy of 4,000kJ.

*Table 19 Like for like comparison of the maximum number of harbour porpoise and % of reference population that could have a possible avoidance reaction based on Lucke et al. (2009) criteria (unweighted SEL_{ss} 145 dB re 1 μPa²s) and the density estimates and reference populations used in the ES**

Maximum number of individuals (% reference population)				
ES assessment for maximum hammer energy of 3,000kJ	**Updated modelling for maximum hammer energy of 3,000kJ**	**Updated modelling for maximum hammer energy of 4,000kJ**	**Difference between 3,000kJ and 4,000kJ based on updated modelling**	**Difference between ES assessment for 3,000kJ and updated modelling for 4,000kJ**
2,276 harbour porpoise (0.98%)	2,026 harbour porpoise (0.87%)	2,418 harbour porpoise (1%)	392 harbour porpoise (0.17%)	142 harbour porpoise (0.06%)

*ES harbour porpoise density = 0.6536/km² (95% CI = 0.4445-0.9409/km²);
ES harbour porpoise reference population = 232,450 (95% CI = 154,451 – 310,449)

The original assessment concluded that there would be a negligible impact for possible avoidance of harbour porpoise, due to the low sensitivity of the receptor to this impact and the negligible magnitude of the effect.

There is no difference in the impact significance for possible avoidance of harbour porpoise for the proposed increased maximum hammer energy to 4,000kJ compared to the consented maximum hammer energy of 3,000kJ (**Table 20**).

Table 20 Like for like comparison of the impact significance for possible avoidance in harbour porpoise from single strike of maximum hammer energy of 3,000kJ and 4,000kJ*

ES assessment for maximum hammer energy of 3,000kJ	Updated modelling for maximum hammer energy of 3,000kJ	Updated modelling for maximum hammer energy of 4,000kJ
Negligible (low sensitivity x temporary impact with negligible magnitude (≤1% ref. pop.))	Negligible (low sensitivity x temporary impact with negligible magnitude (≤1% ref. pop.))	Negligible (low sensitivity x temporary impact with negligible magnitude (≤1% ref. pop.))

*see Annex B for definitions of sensitivity, magnitude and impact significance matrix

5.1.2 White-beaked dolphin

5.1.2.1 PTS

In the original assessment, the NPL modelling of instantaneous auditory injury (PTS) in white-beaked dolphin for a single strike of the maximum monopile hammer energy of 3,000kJ, based on the Southall *et al*. (2007) M-weighted criteria (SEL_{ss} 198 dB re 1 μPa^{2}s), predicted a potential impact range of less than 50m at Creyke Beck B.

The updated modelling with the INSPIRE model using the same criteria for a maximum hammer energy of 3,000kJ and 4,000kJ also resulted in a maximum impact range of less than 50m at Creyke Beck B (**Table 21**).

Table 21 Like for like comparison of predicted impact ranges and areas for PTS in white-beaked dolphin based on Southall et al. (2007) M-weighted criteria (SEL_{ss} 198 dB re 1 μPa^{2}s)

Maximum predicted PTS impact range and area for monopiles				
ES assessment for maximum hammer energy of 3,000kJ	Updated modelling for maximum hammer energy of 3,000kJ	Updated modelling for maximum hammer energy of 4,000kJ	Difference between 3,000kJ and 4,000kJ based on updated modelling	Difference between ES assessment for 3,000kJ and updated modelling for 4,000kJ
<50m (0.008km^2)	<50m (<0.1km^2)	<50m (<0.1km^2)	No difference	No difference

There is no difference in the potential risk of PTS in white-beaked dolphin (with or without mitigation) for the proposed increased maximum hammer energy to 4,000kJ compared to the consented maximum hammer energy of 3,000kJ. There is no difference in the impact significance for PTS in white-beaked dolphin for the proposed increased maximum hammer energy to 4,000kJ compared to the consented maximum hammer energy of 3,000Kj.

5.1.2.2 TTS / fleeing response

In the original assessment, the NPL modelling for TTS / fleeing response in white-beaked dolphin for a single strike of the maximum monopile hammer energy of 3,000kJ, based on the Southall *et al*. (2007) M-weighted criteria (SEL_{ss} 183 dB re 1 μPa^{2}s), predicted a potential impact range of less than 150m at Creyke Beck B.

The updated modelling with the INSPIRE model using the same criteria for a maximum hammer energy of 3,000kJ resulted in a maximum impact range of 140m. The updated modelling using the same criteria for a maximum hammer energy of 4,000kJ resulted in a maximum impact range of 170m at Creyke Beck B (**Table 22**).

Table 22 Like for like comparison of predicted impact ranges and areas for TTS in white-beaked dolphin based on Southall et al. (2007) M-weighted criteria (SEL_{ss} 183 dB re 1 μPa^{2}s)

Maximum predicted TTS impact range and area for monopiles				
ES assessment for maximum hammer energy of 3,000kJ	Updated modelling for maximum hammer energy of 3,000kJ	Updated modelling for maximum hammer energy of 4,000kJ	Difference between 3,000kJ and 4,000kJ based on updated modelling	Difference between ES assessment for 3,000kJ and updated modelling for 4,000kJ
<150m* (0.07km^2)	140m (0.1km^2)	170m (0.1km^2)	30m = +21% (no difference)	20m = +13% (0.03km^2 = +43%)

*150m used for calculating percentage differences

Up to an additional 0.0003 white-beaked dolphin (0.000002% of the ES reference population) could potentially be temporarily affected by TTS as a result of a single strike of the maximum hammer energy of 4,000kJ compared to 3,000kJ hammer energy as assessed in the original assessment (**Table 23**). Therefore, there is no significant difference (i.e. the additional difference is less than 1% of the reference population, therefore the magnitude for a temporary impact is negligible, based on assessment of impacts criteria in ES; see **Annex B**) between the consented hammer energy of 3,000kJ and the proposed increase to a maximum hammer energy of 4,000kJ.

*Table 23 Like for like comparison of the maximum number of white-beaked dolphin and % of reference population that could be at risk of TTS based on Southall et al. (2007) M-weighted criteria (SEL_{ss} 183 dB re 1 μPa^{2}s) and the density estimates and reference populations used in the ES**

Maximum number of individuals (% reference population)				
ES assessment for maximum hammer energy of 3,000kJ	Updated modelling for maximum hammer energy of 3,000kJ	Updated modelling for maximum hammer energy of 4,000kJ	Difference between 3,000kJ and 4,000kJ based on updated modelling	Difference between ES assessment for 3,000kJ and updated modelling for 4,000kJ
0.0004 white-beaked dolphin (<0.00001%)	0.0007 white-beaked dolphin (0.000004%)	0.0007 white-beaked dolphin (0.000004%)	No difference	0.0003 white-beaked dolphin (0.000002%)

*ES white-beaked dolphin density = 0.0071/km^2 (95% CI = 0.0064-0.0948/km^2);
ES white-beaked dolphin reference population = 16,536 (95% CI=9,245 - 29,586)

The original assessment concluded that there would be negligible / no impact for TTS in white-beaked dolphin, due to the medium sensitivity of the receptor to this impact and the negligible magnitude of the effect.

There is no difference in the impact significance for TTS in white-beaked dolphin for the proposed increased maximum hammer energy to 4,000kJ compared to the consented maximum hammer energy of 3,000kJ (**Table 24**).

Table 24 Like for like comparison of the impact significance for TTS in white-beaked dolphin from single strike of maximum hammer energy of 3,000kJ and 4,000kJ*

ES assessment for maximum hammer energy of 3,000kJ	Updated modelling for maximum hammer energy of 3,000kJ	Updated modelling for maximum hammer energy of 4,000kJ
Negligible / no impact (medium sensitivity x temporary impact with negligible magnitude (≤1% ref. pop.))	Negligible (medium sensitivity x temporary impact with negligible magnitude (≤1% ref. pop.))	Negligible (medium sensitivity x temporary impact with negligible magnitude (≤1% ref. pop.))

*see Annex B for definitions of sensitivity, magnitude and impact significance matrix

5.1.2.3 Likely or possible avoidance

In the original assessment, the NPL modelling for likely avoidance and possible avoidance of white-beaked dolphin from a single strike of the maximum monopile hammer energy of 3,000kJ, based on the Southall *et al*. (2007) M-weighted criteria of SEL_{ss} 170 dB re 1 μPa^{2}s for likely avoidance and SEL_{ss} 160 dB re 1 μPa^{2}s for possible avoidance, predicted a potential impact range of up to 2.5km and 9km, respectively, at Creyke Beck B.

The updated modelling with the INSPIRE model using the same criteria for a maximum hammer energy of 3,000kJ resulted in a maximum impact range of 2.7km and 9.4km, respectively. The updated modelling using the same criteria for a maximum hammer energy of 4,000kJ resulted in a maximum impact range of 3.2km and 10.7km, respectively, for likely and possible avoidance at Creyke Beck B (**Table 25**).

Table 25 Like for like comparison of predicted impact ranges and areas for likely and possible avoidance of white-beaked dolphin based on the Southall et al. (2007) M-weighted criteria of SEL_{ss} 170 dB re 1 μPa^{2}s and 160 dB re 1 μPa^{2}s, respectively

ES assessment for maximum hammer energy of 3,000kJ	Updated modelling for maximum hammer energy of 3,000kJ	Updated modelling for maximum hammer energy of 4,000kJ	Difference between 3,000kJ and 4,000kJ based on updated modelling	Difference between ES assessment for 3,000kJ and updated modelling for 4,000kJ
Maximum predicted likely avoidance impact range and area for monopiles				
2.5km (20km^2)	2.7km (23km^2)	3.2km (31km^2)	0.5km = +37%) (8km^2 = +35%)	0.7km = +28%) (11km^2 = -+55%)
Maximum predicted possible avoidance impact range and area for monopiles				
9km (156km^2)	9.4km (260km^2)	10.7km (330km^2)	1.3km = +14%) (70km^2 = +27%)	1.7km = +19%) (174km^2 = +111%)

Up to a maximum of 0.1 or 1.2 additional white-beaked dolphin (0.0006% or 0.007% of the ES reference population) could potentially be temporarily affected by likely or possible avoidance as a result of a single strike of the maximum hammer energy of 4,000kJ compared to 3,000kJ hammer energy as assessed in the original assessment and updated noise modelling, respectively (**Table 26**). Therefore, there is no significant difference (i.e. the additional difference is 1% or less of the reference population, therefore the magnitude for a temporary impact is negligible, based on assessment of impacts criteria in ES; see **Annex B**) between the consented hammer energy of 3,000kJ and the proposed increase to a maximum hammer energy of 4,000kJ.

*Table 26 Like for like comparison of the maximum number of white-beaked dolphin and % of reference population that could have a likely or possible avoidance reaction based on the Southall et al. (2007) M-weighted criteria of SEL_{ss} 170 dB re 1 μPa²s and 160 dB re 1 μPa²s, respectively and the density estimates and reference populations used in the ES**

ES assessment for maximum hammer energy of 3,000kJ	Updated modelling for maximum hammer energy of 3,000kJ	Updated modelling for maximum hammer energy of 4,000kJ	Difference between 3,000kJ and 4,000kJ based on updated modelling	Difference between ES assessment for 3,000kJ and updated modelling for 4,000kJ
Maximum number of individuals (% reference population) for likely avoidance				
0.1 white-beaked dolphin (0.0006%)	0.2 white-beaked dolphin (0.001%)	0.2 white-beaked dolphin (0.001%)	No difference	0.1 white-beaked dolphin (0.0006%)
Maximum number of individuals (% reference population) for possible avoidance				
1.1 white-beaked dolphin (0.007%)	1.85 white-beaked dolphin (0.01%)	2.3 white-beaked dolphin (0.01%)	0.45 white-beaked dolphin (no difference)	1.2 white-beaked dolphin (0.007%)

*ES white-beaked dolphin density = 0.0071/km² (95% CI = 0.0064-0.0948/km²);
ES white-beaked dolphin reference population = 16,536 (95% CI=9,245 - 29,586)

The original assessment concluded that there would be a negligible impact for likely or possible avoidance in white-beaked dolphin, due to the low sensitivity of the receptor to this impact and the negligible magnitude of the effect.

There is no difference in the impact significance for likely or possible avoidance in white-beaked dolphin for the proposed increased maximum hammer energy to 4,000kJ compared to the consented maximum hammer energy of 3,000kJ (**Table 27**).

Table 27 Like for like comparison of the impact significance for likely or possible avoidance in white-beaked dolphin from single strike of maximum hammer energy of 3,000kJ and 4,000kJ*

Maximum hammer energy of 3,000kJ	Maximum hammer energy of 4,000kJ
Impact significance for likely avoidance	
Negligible (low sensitivity x temporary impact with negligible magnitude (≤1% ref. pop.))	Negligible (low sensitivity x temporary impact with negligible magnitude (≤1% ref. pop.))
Impact significance for possible avoidance	
Negligible (low sensitivity x temporary impact with negligible magnitude (≤1% ref. pop.))	Negligible (low sensitivity x temporary impact with negligible magnitude (≤1% ref. pop.))

*see Annex B for definitions of sensitivity, magnitude and impact significance matrix

5.1.3 Minke whale

5.1.3.1 PTS

In the original assessment, the NPL modelling of instantaneous auditory injury (PTS) in minke whale for a single strike of the maximum monopile hammer energy of 3,000kJ, based on the Southall *et al*. (2007) M-weighted criteria (SEL_{ss} 198 dB re 1 μPa^{2}s), predicted a potential impact range of less than 50m at Creyke Beck B.

The updated modelling with the INSPIRE model using the same criteria for a maximum hammer energy of 3,000kJ and 4,000kJ also resulted in a maximum impact range of 50m or less at Creyke Beck B (**Table 28**).

Table 28 Like for like comparison of predicted impact ranges and areas for PTS in minke whale based on Southall et al. (2007) M-weighted criteria (SEL_{ss} 198 dB re 1 μPa^{2}s)

Maximum predicted PTS impact range and area for monopiles				
ES assessment for maximum hammer energy of 3,000kJ	Updated modelling for maximum hammer energy of 3,000kJ	Updated modelling for maximum hammer energy of 4,000kJ	Difference between 3,000kJ and 4,000kJ based on updated modelling	Difference between ES assessment for 3,000kJ and updated modelling for 4,000kJ
<50m (0.008km^2)	50m (<0.1km^2)	50m (<0.1km^2)	No difference	No difference

Therefore, there is no difference in the potential risk of PTS in minke whale (with or without mitigation) for the proposed increased maximum hammer energy to 4,000kJ compared to the consented maximum hammer energy of 3,000kJ. There is no difference in the impact significance for PTS in minke whale for the proposed increased maximum hammer energy to 4,000kJ compared to the consented maximum hammer energy of 3,000kJ.

5.1.3.2 TTS / fleeing response

In the original assessment, the NPL modelling for TTS / fleeing response in minke whale for a single strike of the maximum monopile hammer energy of 3,000kJ, based on the Southall *et al*. (2007) M-weighted criteria (SEL_{ss} 183 dB re 1 μPa^{2}s), predicted a potential impact range of less than 350m at Creyke Beck B.

The updated modelling with the INSPIRE model using the same criteria for a maximum hammer energy of 3,000kJ resulted in a maximum impact range of 390m. The updated modelling using the same criteria for a maximum hammer energy of 4,000kJ resulted in a maximum impact range of 470m at Creyke Beck B (**Table 29**).

Table 29 Like for like comparison of predicted impact ranges and areas for TTS in minke whale based on Southall et al. (2007) M-weighted criteria (SEL_{ss} 183 dB re 1 μPa²s)

Maximum predicted TTS impact range and area for monopiles				
ES assessment for maximum hammer energy of 3,000kJ	**Updated modelling for maximum hammer energy of 3,000kJ**	**Updated modelling for maximum hammer energy of 4,000kJ**	**Difference between 3,000kJ and 4,000kJ based on updated modelling**	**Difference between ES assessment for 3,000kJ and updated modelling for 4,000kJ**
<350m* (0.4km²)	390m (0.5km²)	470m (0.7km²)	80m = +20% (0.2km² = +40%)	120m = +34% (0.3km² = +75%)

*350m used for calculating percentage differences

Up to an additional 0.0011 minke whale (0.000004% of the ES reference population) could potentially be temporarily affected by TTS as a result of a single strike of the maximum hammer energy of 4,000kJ compared to 3,000kJ hammer energy as assessed in the original assessment (**Table 30**). Therefore, there is no significant difference (i.e. the additional difference is less than 1% of the reference population, therefore the magnitude for a temporary impact is negligible, based on assessment of impacts criteria in ES; see **Annex B**) between the consented hammer energy of 3,000kJ and the proposed increase to a maximum hammer energy of 4,000kJ.

*Table 30 Like for like comparison of the maximum number of minke whale and % of reference population that could be at risk of TTS based on Southall et al. (2007) M-weighted criteria (SEL_{ss} 183 dB re 1 μPa²s) and the density estimates and reference populations used in the ES**

Maximum number of individuals (% reference population)				
ES assessment for maximum hammer energy of 3,000kJ	**Updated modelling for maximum hammer energy of 3,000kJ**	**Updated modelling for maximum hammer energy of 4,000kJ**	**Difference between 3,000kJ and 4,000kJ based on updated modelling**	**Difference between ES assessment for 3,000kJ and updated modelling for 4,000kJ**
0.0009 minke whale (<0.00001%)	0.001 minke whale (0.0000045%)	0.002 minke whale (0.000008%)	0.0001 minke whale (0.0000045%)	0.0011 minke whale (0.000004%)

*ES minke whale density = 0.0023/km² (95% CI = 0.0015- 0.0048/km²);
ES minke whale reference population = 25,723 (95% CI=11,037-73,605)

The original assessment concluded that there would be a negligible impact for TTS in minke whale, due to the medium sensitivity of the receptor to this impact and the negligible magnitude of the effect.

There is no difference in the impact significance for TTS in minke whale for the proposed increased maximum hammer energy to 4,000kJ compared to the consented maximum hammer energy of 3,000kJ (**Table 31**).

Table 31 Like for like comparison of the impact significance for TTS in minke whale from single strike of maximum hammer energy of 3,000kJ and 4,000kJ*

ES assessment for maximum hammer energy of 3,000kJ	Updated modelling for maximum hammer energy of 3,000kJ	Updated modelling for maximum hammer energy of 4,000kJ
Negligible / no impact (medium sensitivity x temporary impact with negligible magnitude (≤1% ref. pop.))	Negligible (medium sensitivity x temporary impact with negligible magnitude (≤1% ref. pop.))	Negligible (medium sensitivity x temporary impact with negligible magnitude (≤1% ref. pop.))

*see Annex B for definitions of sensitivity, magnitude and impact significance matrix

5.1.3.3 Likely or possible avoidance

In the original assessment, the NPL modelling for likely avoidance and possible avoidance of minke whale from a single strike of the maximum monopile hammer energy of 3,000kJ, based on the Southall *et al*. (2007) M-weighted criteria of SEL_{ss} 152 dB re 1 μPa²s for likely avoidance and SEL_{ss} 142 dB re 1 μPa²s for possible avoidance, predicted a potential impact range of up to 19.5km and 56km, respectively, at Creyke Beck B.

The updated modelling with the INSPIRE model using the same criteria for a maximum hammer energy of 3,000kJ resulted in a maximum impact range of 21.3km and 48.4km, respectively. The updated modelling using the same criteria for a maximum hammer energy of 4,000kJ resulted in a maximum impact range of 23.9km and 52.5km, respectively, for likely and possible avoidance at Creyke Beck B (**Table 32**).

Table 32 Like for like comparison of predicted impact ranges and areas for likely and possible avoidance of minke whale based on the Southall et al. (2007) M-weighted criteria of SEL_{ss} 152 dB re 1 μPa²s and 142 dB re 1 μPa²s, respectively

ES assessment for maximum hammer energy of 3,000kJ	Updated modelling for maximum hammer energy of 3,000kJ	Updated modelling for maximum hammer energy of 4,000kJ	Difference between 3,000kJ and 4,000kJ based on updated modelling	Difference between ES assessment for 3,000kJ and updated modelling for 4,000kJ
Maximum predicted likely avoidance impact range and area for monopiles				
19.5km (986.9km²)	21.3km (1,100km²)	23.9km (1,300km²)	2.6km = +12%) (200km² = +18%)	4.4km = +23%) (313.1km² = -+32%)
Maximum predicted possible avoidance impact range and area for monopiles				
56km (5,665km²)	48.4km (4,600km²)	52.5km (5,400km²)	4.1km = +8.5%) (800km² = +17%)	-3.5km = -6.7%) (-265km² = -4.9%)

Up to a maximum of an additional 0.8 minke whale (0.003% of the ES reference population) could potentially be temporarily affected by likely avoidance as a result of a single strike of the maximum hammer energy of 4,000kJ compared to 3,000kJ hammer energy as assessed in the original assessment and updated noise modelling (**Table 33**).

There is a predicted increase of up to 1.8 minke whale that could potentially be temporarily affected by possible avoidance as a result of a single strike of the maximum hammer energy of 4,000kJ compared to 3,000kJ hammer energy as assessed in the updated noise modelling (**Table 33**).

Therefore, there is no significant difference (i.e. the additional difference is 1% or less of the reference population, therefore the magnitude for a temporary impact is negligible, based on assessment of impacts criteria in ES; see **Annex B**) between the consented hammer energy of 3,000kJ and the proposed increase to a maximum hammer energy of 4,000kJ.

*Table 33 Like for like comparison of the maximum number of minke whale and % of reference population that could have a likely or possible avoidance reaction based on the Southall et al. (2007) M-weighted criteria of SEL_{ss} 152 dB re 1 μPa²s and 142 dB re 1 μPa²s, respectively and the density estimates and reference populations used in the ES**

ES assessment for maximum hammer energy of 3,000kJ	Updated modelling for maximum hammer energy of 3,000kJ	Updated modelling for maximum hammer energy of 4,000kJ	Difference between 3,000kJ and 4,000kJ based on updated modelling	Difference between ES assessment for 3,000kJ and updated modelling for 4,000kJ
Maximum number of individuals (% reference population) for likely avoidance				
2.2 minke whale (0.009%)	2.5 minke whale (0.01%)	3 minke whale (0.01%)	0.5 minke whale (0.002%)	0.8 minke whale (0.003%)
Maximum number of individuals (% reference population) for possible avoidance				
13 minke whale (0.05%)	10.6 minke whale (0.04%)	12.4 minke whale (0.05%)	1.8 minke whale (0.007%)	-0.6 minke whale (0.002%)

*ES minke whale density = 0.0023/km² (95% CI = 0.0015- 0.0048/km²);
ES minke whale reference population = 25,723 (95% CI=11,037-73,605)

The original assessment concluded that there would be a negligible impact for likely or possible avoidance in minke whale, due to the low sensitivity of the receptor to this impact and the negligible magnitude of the effect.

There is no difference in the impact significance for likely or possible avoidance in minke whale for the proposed increased maximum hammer energy to 4,000kJ compared to the consented maximum hammer energy of 3,000kJ (**Table 34**).

Table 34 Like for like comparison of the impact significance for likely or possible avoidance in minke whale from single strike of maximum hammer energy of 3,000kJ and 4,000kJ*

Updated modelling for maximum hammer energy of 3,000kJ	Updated modelling for maximum hammer energy of 4,000kJ
Impact significance for likely avoidance	
Negligible (low sensitivity x temporary impact with negligible magnitude (≤1% ref. pop.))	Negligible (low sensitivity x temporary impact with negligible magnitude (≤1% ref. pop.))
Impact significance for possible avoidance	
Negligible (low sensitivity x temporary impact with negligible magnitude (≤1% ref. pop.))	Negligible (low sensitivity x temporary impact with negligible magnitude (≤1% ref. pop.))

*see Annex B for definitions of sensitivity, magnitude and impact significance matrix

5.1.4 Grey seal

5.1.4.1 PTS

In the original assessment, the NPL modelling of instantaneous auditory injury (PTS) in grey seal for a single strike of the maximum monopile hammer energy of 3,000kJ, based on the Southall *et al*. (2007) M-weighted criteria (SEL_{ss} 186 dB re 1 μPa^{2}s), predicted a potential impact range of less than 150m at Creyke Beck B.

The updated modelling with the INSPIRE model using the same criteria for a maximum hammer energy of 3,000kJ and 4,000kJ resulted in a maximum impact ranges of 150m and 170m, respectively at Creyke Beck B (**Table 35**).

Table 35 Like for like comparison of predicted impact ranges and areas for PTS in grey seal based on Southall et al. (2007) M-weighted criteria (SEL_{ss} 186 dB re 1 μPa^{2}s)

Maximum predicted PTS impact range and area for monopiles				
ES assessment for maximum hammer energy of 3,000kJ	Updated modelling for maximum hammer energy of 3,000kJ	Updated modelling for maximum hammer energy of 4,000kJ	Difference between 3,000kJ and 4,000kJ based on updated modelling	Difference between ES assessment for 3,000kJ and updated modelling for 4,000kJ
<150m* (0.07km^2)	150m (0.1km^2)	170m (0.1km^2)	20m = +13% (no difference)	20m = +13% (0.03km2 = +42%)

*150m used for calculating percentage differences

Up to a maximum of an additional 0.024 grey seal (0.0001% of the ES reference population) could potentially be at increased risk of PTS from a single strike of the maximum hammer energy of 4,000kJ compared to 3,000kJ hammer energy (**Table 36**). Therefore, there is no significant difference (i.e. the additional difference is less than 0.001% of the reference population, therefore the magnitude for any permanent impact is negligible, based on assessment of impacts criteria in ES; see **Annex B**) between the consented hammer energy of 3,000kJ and the proposed increase to a maximum hammer energy of 4,000kJ (**Table 13**).

*Table 36 Like for like comparison of the maximum number of grey seal and % of reference population that could be at risk of PTS based on Southall et al. (2007) M-weighted criteria (SEL_{ss} 186 dB re 1 μPa^{2}s) and the density estimates and reference populations used in the ES**

Maximum number of individuals (% reference population) at risk of PTS				
ES assessment for maximum hammer energy of 3,000kJ	Updated modelling for maximum hammer energy of 3,000kJ	Updated modelling for maximum hammer energy of 4,000kJ	Difference between 3,000kJ and 4,000kJ based on updated modelling	Difference between ES assessment for 3,000kJ and updated modelling for 4,000kJ
0.06 grey seal (<0.0004%)	0.084 grey seal (0.00037%)	0.084 grey seal (0.00037%)	No difference	0.024 grey seal (0.0001%)

*ES grey seal density = 0.84/km^2
ES grey seal reference population = 22,412

The original assessment concluded that there could be a minor adverse (not significant) impact for PTS in grey seal, even with a standard 500m mitigation zone, which is greater than the predicted PTS range for grey seal.

During the 30 minute soft-start and ramp-up (**Table 4**) and based on a precautionary average swimming speed of 1.5m/s (Otani *et al*. 2000), grey seal would move at least 2.7km from the pile location, which is considerably greater than the maximum predicted impact range for a maximum hammer energy of 3,000kJ and 4,000kJ (**Table 35**). Therefore, there should be no grey seal (or harbour seal) in the potential impact area and at risk of instantaneous PTS from a single strike of the maximum hammer energy of 3,000kJ or 4,000kJ after the soft-start and ramp-up.

There is no difference in the impact significance for PTS in grey seal (with or without mitigation) for the proposed increased maximum hammer energy to 4,000kJ compared to the consented maximum hammer energy of 3,000kJ (**Table 37**).

Table 37 Like for like comparison of the impact significance for PTS in grey seal from single strike of maximum hammer energy of 3,000kJ and 4,000kJ*

Impact significance for PTS in harbour porpoise	Maximum hammer energy of 3,000kJ	Maximum hammer energy of 4,000kJ
Without mitigation	Minor adverse (high sensitivity x permanent impact with negligible magnitude (<0.001% ref. pop.))	Minor adverse (high sensitivity x permanent impact with negligible magnitude (<0.001% ref. pop.))
With mitigation (residual impact)	No impact	No impact

*see Annex B for definitions of sensitivity, magnitude and impact significance matrix

5.1.4.2 TTS / fleeing response

In the original assessment, the NPL modelling for TTS / fleeing response in grey seal for a single strike of the maximum monopile hammer energy of 3,000kJ, based on the Southall *et al*. (2007) M-weighted criteria (SEL_{ss} 171 dB re 1 μPa^{2}s), predicted a potential impact range of less than 1.9km at Creyke Beck B.

The updated modelling with the INSPIRE model using the same criteria for a maximum hammer energy of 3,000kJ resulted in a maximum impact range of 1.4km. The updated modelling using the same criteria for a maximum hammer energy of 4,000kJ resulted in a maximum impact range of 1.7km at Creyke Beck B (**Table 38**).

There is no difference in the potential risk of TTS / fleeing response in grey seal for the proposed increased maximum hammer energy to 4,000kJ compared to the maximum hammer energy of 3,000kJ in the original assessment.

Table 38 Like for like comparison of predicted impact ranges and areas for TTS in grey seal based on Southall et al. (2007) M-weighted criteria (SEL_{ss} 171 dB re 1 μPa²s)

Maximum predicted TTS impact range and area for monopiles				
ES assessment for maximum hammer energy of 3,000kJ	**Updated modelling for maximum hammer energy of 3,000kJ**	**Updated modelling for maximum hammer energy of 4,000kJ**	**Difference between 3,000kJ and 4,000kJ based on updated modelling**	**Difference between ES assessment for 3,000kJ and updated modelling for 4,000kJ**
<1.9km* ($10km^2$)	1.4km ($6.2km^2$)	1.7km ($8.8km^2$)	0.3km = +21% ($2.6km^2$ = +42%)	-0.2km = -12% ($-1.2km^2$ = +14%)

*1.9km used for calculating percentage differences

Up to an additional 2.2 grey seal (0.01% of the ES reference population) could potentially be temporarily affected by TTS as a result of a single strike of the maximum hammer energy of 4,000kJ compared to 3,000kJ hammer energy (**Table 39**). Therefore, there is no significant difference (i.e. the additional difference is less than 1% of the reference population, therefore the magnitude for a temporary impact is negligible, based on assessment of impacts criteria in ES; see **Annex B**) between the consented hammer energy of 3,000kJ and the proposed increase to a maximum hammer energy of 4,000kJ.

*Table 39 Like for like comparison of the maximum number of grey seal and % of reference population that could be at risk of TTS based on Southall et al. (2007) M-weighted criteria (SEL_{ss} 171 dB re 1 μPa²s) and the density estimates and reference populations used in the ES**

Maximum number of individuals (% reference population)				
ES assessment for maximum hammer energy of 3,000kJ	**Updated modelling for maximum hammer energy of 3,000kJ**	**Updated modelling for maximum hammer energy of 4,000kJ**	**Difference between 3,000kJ and 4,000kJ based on updated modelling**	**Difference between ES assessment for 3,000kJ and updated modelling for 4,000kJ**
8.5 grey seal (0.04%)	5.2 grey seal (0.02%)	7.4 grey seal (0.03%)	2.2 grey seal (0.01%)	-1.1 grey seal (-0.005%)

*ES grey seal density = $0.84/km^2$ ES grey seal reference population = 22,412

The original assessment concluded that there would be a negligible impact for TTS in grey seal, due to the medium sensitivity of the receptor to this impact and the negligible magnitude of the effect.

There is no difference in the impact significance for TTS in grey seal for the proposed increased maximum hammer energy to 4,000kJ compared to the consented maximum hammer energy of 3,000kJ (**Table 40**).

Table 40 Like for like comparison of the impact significance for TTS in grey seal from single strike of maximum hammer energy of 3,000kJ and 4,000kJ*

ES assessment for maximum hammer energy of 3,000kJ	Updated modelling for maximum hammer energy of 3,000kJ	Updated modelling for maximum hammer energy of 4,000kJ
Negligible (medium sensitivity x temporary impact with negligible magnitude (≤1% ref. pop.))	Negligible (medium sensitivity x temporary impact with negligible magnitude (≤1% ref. pop.))	Negligible (medium sensitivity x temporary impact with negligible magnitude (≤1% ref. pop.))

*see Annex B for definitions of sensitivity, magnitude and impact significance matrix

5.2 Results of updated assessment based on the new criteria

As with the like for like comparison set out in **Section 5.1**, each assessment considers in turn:

- The increase in impact range; and
- The number of individuals and percentage of the reference population at risk.

It should be noted that whilst the percentage increase in impact range from the original assessment is provided for context purposes, the assessment outcome and conclusion that follows is based on the number of individuals and percentage of the reference population at risk, and how this compares to the original assessment.

In relation to each of the potential impacts for each of the receptors, the updated assessment based on the new criteria demonstrates that there is no difference in the impact significance between the impacts as assessed for a maximum hammer energy from 3,000kJ or 4,000kJ for any of the assessed receptors.

A summary of the updated assessment is provided in **Section 6**, **Table 68**.

5.2.1 Harbour porpoise

5.2.1.1 PTS

To assess the potential for auditory injury (PTS), the NOAA (NMFS, 2016) criteria for unweighted SPL_{peak} and PTS from cumulative exposure (SEL_{cum}) have been modelled for the increased monopile hammer energy (up to 4,000kJ), as well as the maximum hammer energy for monopiles (3,000kJ).

The difference between the predicted PTS range for the 3,000kJ and 4,000kJ maximum hammer energies, based on the NOAA (NMFS, 2016) unweighted SPL_{peak} criteria (202 dB re 1 µPa) for single strike, is up to 170m (0.6km^2) for harbour porpoise (**Table 41**).

Cumulative SEL assessments have been based on the worst-case soft-start and ramp-up scenario, sequence 3, which assumes 12,600 strikes over 330 minutes.

For harbour porpoise there is no difference between the maximum predicted PTS cumulative SEL ranges for the maximum hammer energy of 3,000kJ and 4,000kJ (**Table 41**).

Table 41 Maximum predicted impact ranges (and areas) for PTS from a single strike (SPL_{peak}) and from cumulative exposure (SEL_{cum}) based on NOAA (NMFS, 2016) criteria for harbour porpoise

Receptor	Threshold	Maximum predicted impact range and area		
		Maximum hammer energy of 3,000kJ for monopiles	Maximum hammer energy of 4,000kJ for monopiles	Difference between 3,000kJ and 4,000kJ
SPL_{peak} single strike				
Harbour porpoise	unweighted SPL_{peak} 202 dB re 1 µPa	490m (0.7km^2)	660m (1.3km^2)	**170m = +35% (0.6km^2 = +86%)**
Cumulative SEL				
Harbour porpoise	SEL_{cum} Weighted 155 dB re 1 µPa^{2}s	<100m (<0.1km^2)	<100m (<0.1km^2)	**No difference**

Up to an additional 0.6 harbour porpoise (0.0002% NS MU), based on the SCANS-III density estimate, could be at increased risk of PTS from a single strike of the maximum hammer energy of 4,000kJ compared to 3,000kJ hammer energy, based on the NOAA (NMFS, 2016) unweighted criteria for SPL_{peak}. Therefore, there is no significant difference (i.e. the additional difference is less than 0.001% of the reference population, therefore the magnitude for any permanent impact is negligible, based on assessment of impacts criteria in ES; see **Annex B**) between the consented hammer energy of 3,000kJ and the proposed increase to a maximum hammer energy of 4,000kJ (**Table 42**).

Table 42 The maximum number of harbour porpoise and % of reference population that could be at risk of PTS from a single strike (SPL_{peak}) based on NOAA (NMFS, 2016) criteria when the proposed maximum hammer energy is increased from 3,000kJ to 4,000kJ

Receptor	Threshold	Maximum number of individuals (% reference population)*		
		Maximum hammer energy of 3,000kJ for monopiles	Maximum hammer energy of 4,000kJ for monopiles	Difference between 3,000kJ and 4,000kJ
SPL_{peak} single strike				
Harbour porpoise	unweighted SPL_{peak} 202 dB re 1 µPa	0.6 harbour porpoise (0.0002% NS MU) based on SCANS-III density 0.5 harbour porpoise (0.0001% NS MU) based on site specific density	1.2 harbour porpoise (0.0003% NS MU) based on SCANS-III density 0.8 harbour porpoise (0.0002% NS MU) based on site specific density	**0.6 harbour porpoise (0.0002% NS MU) based on SCANS-III density** **0.3 harbour porpoise (0.0001% NS MU) based on site specific density** ***No significant difference***

*Updated SCANS-III harbour porpoise density = 0.888/km^2 (CV = 0.21);
Updated SCANS-III harbour porpoise reference population = 345,373 (CV = 0.18; 95% CI = 246,526-495,752)

The MMMP will detail the proposed mitigation measures to reduce the risk of any permanent auditory injury (PTS) to marine mammals as a result of underwater noise during piling.

During the 30 minute soft-start and ramp-up (**Table 4**) and based on a precautionary average swimming speed of 1.5m/s (Otani *et al*. 2000), harbour porpoise would move at least 2.7km from the pile location, which is considerably greater than the maximum predicted impact range for a maximum hammer energy of 3,000kJ and 4,000kJ (Table 12). Therefore, there should be no harbour porpoise in the potential impact area and at risk of instantaneous PTS from a single strike of the maximum hammer energy of 3,000kJ or 4,000kJ after the soft-start and ramp-up.

There is no difference in the impact significance for PTS in harbour porpoise (with or without mitigation) for the proposed increased maximum hammer energy to 4,000kJ compared to the consented maximum hammer energy of 3,000kJ (**Table 43**).

Table 43 Impact significance for PTS in harbour porpoise from maximum hammer energy of 3,000kJ and 4,000kJ*

Impact significance for PTS in harbour porpoise	Maximum hammer energy of 3,000kJ	Maximum hammer energy of 4,000kJ
Without mitigation	Minor adverse (high sensitivity x permanent impact with negligible magnitude (<0.001% ref. pop.))	Minor adverse (high sensitivity x permanent impact with negligible magnitude (<0.001% ref. pop.))
With mitigation (residual impact)	No impact	No impact

*see Appendix B for definitions of sensitivity, magnitude and impact significance matrix

5.2.1.2 TTS / fleeing response

NOAA (NMFS, 2016) criteria for unweighted SPL_{peak} and TTS from cumulative exposure (SEL_{cum}) have been modelled for the increased monopile hammer energy (up to 4,000kJ), as well as the maximum hammer energy for monopiles (3,000kJ).

The difference between the predicted TTS range for the maximum hammer energies of 3,000kJ and 4,000kJ, based on the NOAA (NMFS, 2016) unweighted SPL_{peak} criteria (196 dB re 1 µPa) for single strike, is a maximum of 0.4km (2.8km^2) for harbour porpoise (**Table 44**).

For the TTS SELcum criteria, the difference between the maximum predicted range for hammer energies of 3,000kJ and 4,000kJ is up to 3.2km for harbour porpoise (**Table 44**).

Table 44 Maximum predicted impact ranges (and areas) for TTS from a single strike (SPL_{peak}) and from cumulative exposure (SEL_{cum}) based on NOAA (NMFS, 2016) criteria for harbour porpoise

Receptor	Threshold	Maximum predicted impact range and area		
		Maximum hammer energy of 3,000kJ for monopiles	Maximum hammer energy of 4,000kJ for monopiles	Difference between 3,000kJ and 4,000kJ
SPL_{peak} single strike				
Harbour porpoise	unweighted SPL_{peak} 196 dB re 1 µPa	1.1km (3.6km^2)	1.5km (6.4km^2)	**0.4km = +36% (2.8km^2 = +78%)**
Cumulative SEL				
Harbour porpoise	SEL_{cum} Weighted 140 dB re 1 µPa^{2}s	20km (750km^2)	23.2km (990km^2)	**3.2km = +16% (240km^2 = +32%)**

Up to an additional 2.5 harbour porpoise (0.0007% NS MU), based on the SCANS-III density estimate, could temporarily be impacted by TTS from a single strike of the maximum hammer energy of 4,000kJ compared to a 3,000kJ hammer energy, based on the NOAA (NMFS, 2016) unweighted criteria for SPL_{peak}. Therefore, there is no significant difference (i.e. the additional difference is less than 1% of the reference population could be temporarily affected, therefore magnitude is negligible, based on assessment of impacts criteria in ES; see **Annex B**) as a result of increasing the maximum hammer energy from 3,000kJ to the proposed 4,000kJ (**Table 45**).

Up to an additional 213 harbour porpoise (0.06% NS MU), based on the SCANS-III density estimate, could temporarily be impacted by cumulative TTS from the maximum hammer energy of 4,000kJ compared to a 3,000kJ hammer energy, based on the NOAA (NMFS, 2016) criteria. However, there is no significant difference (i.e. the additional difference is less than 1% of the reference population could be temporarily affected) as a result of increasing the maximum hammer energy from 3,000kJ to the proposed 4,000kJ (**Table 45**).

Table 45 The maximum number of harbour porpoise and % of reference population that could be at risk of TTS from a single strike (SPL_{peak}) and from cumulative exposure (SEL_{cum}) based on NOAA (NMFS, 2016) criteria

Receptor	Threshold	Maximum number of individuals (% reference population)		
		Maximum hammer energy of 3,000kJ for monopiles	Maximum hammer energy of 4,000kJ for monopiles	Difference between 3,000kJ and 4,000kJ
SPL_{peak} single strike				
Harbour porpoise	unweighted SPL_{peak} 196 dB re 1 µPa	3.2 harbour porpoise (0.0009% NS MU) based on SCANS-III density 2.4 harbour porpoise (0.0007% NS MU) based on site specific density	5.7 harbour porpoise (0.002% NS MU) based on SCANS-III density 4.2 harbour porpoise (0.001% NS MU) based on site specific density	**2.5 harbour porpoise (0.0007% NS MU) based on SCANS-III density** **1.8 harbour porpoise (0.0005% NS MU) based on site specific density** ***No significant difference***
Cumulative SEL				
Harbour porpoise	SEL_{cum} Weighted 140 dB re 1 µPa²s	666 harbour porpoise (0.2% NS MU) based on SCANS-III density 490 harbour porpoise (0.1% NS MU) based on site specific density	879 harbour porpoise (0.25% NS MU) based on SCANS-III density 647 harbour porpoise (0.2% NS MU) based on site specific density	**213 harbour porpoise (0.06% NS MU) based on SCANS-III density** **157 harbour porpoise (0.045% NS MU) based on site specific density** ***No significant difference***

*Updated SCANS-III harbour porpoise density = 0.888/km² (CV = 0.21);
Updated SCANS-III harbour porpoise reference population = 345,373 (CV = 0.18; 95% CI = 246,526-495,752)

There is no difference in the impact significance for TTS in harbour porpoise for the proposed increased maximum hammer energy to 4,000kJ compared to the maximum hammer energy of 3,000kJ (**Table 46**).

Table 46 Impact significance for TTS in harbour porpoise from maximum hammer energy of 3,000kJ and 4,000kJ*

Updated modelling for maximum hammer energy of 3,000kJ	Updated modelling for maximum hammer energy of 4,000kJ
Negligible (medium sensitivity x temporary impact with negligible magnitude (≤1% ref. pop.))	Negligible (medium sensitivity x temporary impact with negligible magnitude (≤1% ref. pop.))

*see Annex B for definitions of sensitivity, magnitude and impact significance matrix

5.2.1.3 *Possible avoidance*

The maximum predicted impact ranges (and areas) for possible behavioural response or avoidance from a single strike (SEL_{ss}) based on Lucke *et al*. (2009) unweighted criteria for harbour porpoise have been modelled for the increased monopile hammer energy (up to 4,000kJ), as well as the maximum hammer energy for monopiles (3,000kJ) assessed in the ES (**Table 47**).

The difference between the predicted maximum ranges for the possible avoidance of harbour porpoise is up to 4.1km for a maximum hammer energy of 4,000kJ compared to 3,000kJ, based on the SPL_{peak} criteria for single strike (**Table 47**).

Table 47 Maximum predicted impact ranges (and areas) for possible behavioural response in harbour porpoise from a single strike of maximum hammer energy of 3,000kJ and 4,000kJ based on Lucke et al. (2009) unweighted criteria

Receptor	Threshold	Maximum predicted impact range and area		
		Maximum hammer energy of 3,000kJ for monopiles	Maximum hammer energy of 4,000kJ for monopiles	Difference between 3,000kJ and 4,000kJ
Harbour porpoise – possible avoidance	unweighted SPL_{peak} 168 dB re 1 µPa	20.5km ($1,000km^2$)	24.6km ($1,400km^2$)	**4.1km = +20% ($400km^2$ = +40%)**
	unweighted SEL_{ss} 145 dB re 1 $µPa^2a$	39.1km ($3,100km^2$)	42.6km ($3,700km^2$)	**3.5km = +9% ($600km^2$ = +19%)**

The response of individuals to a noise stimulus will vary and not all animals within the range of potential behavioural response will respond. A study of harbour porpoise at Horns Rev (Brandt *et al*., 2011) showed that at closer distances (2.5 to 4.8km) there was 100% avoidance, however, this proportion decreased significantly moving away from the pile driving activity, such that at distances of 10.1 to 17.8km, avoidance occurred in 32 to 49% of the population and at 21.2km, the abundance reduced by just 2%. This suggests that an assumption of behavioural displacement of all individuals is unrealistic and that in reality not all individuals would move out of the area. To take this into account, the proportion of individuals that may show a behavioural response has been calculated based on 50%, 75% or 100% responding.

The SCANS-III density estimates, rather than the site specific survey density estimates, have been used to take into account the wider area of potential impact.

The assessment indicates that up to an additional 400 harbour porpoise (0.1% NS MU), could have a possible avoidance reaction, based on a precautionary 75% of individuals responding to a single strike of the maximum hammer energy of 4,000kJ compared to a 3,000kJ hammer energy (**Table 48**). This is based on Lucke *et al*. (2009) criteria for possible avoidance of harbour porpoise (unweighted SEL_{ss} 145 dB re 1 $µPa^2a$).

There is no significant difference (i.e. the additional difference is less than 1% of the reference population could be temporarily affected) as a result of increasing the maximum hammer energy from 3,000kJ to the proposed 4,000kJ (**Table 48**).

Table 48 The maximum number of harbour porpoise and % of reference population taking into account that 50%, 75% or 100% of individuals could exhibit a possible behavioural response from a single strike (SELss) based on Lucke et al. (2009) unweighted criteria

Receptor Threshold and criteria	% of individuals that could respond	Maximum number of individuals (% reference population)*		
		Maximum hammer energy of 3,000kJ for monopiles	Maximum hammer energy of 4,000kJ for monopiles	Difference between 3,000kJ and 4,000kJ
Harbour porpoise – possible avoidance unweighted SPL$_{peak}$ 168 dB re 1 µPa	100%	888 harbour porpoise (0.3% NS MU) based on SCANS-III density	1,243 harbour porpoise (0.4% NS MU) based on SCANS-III density	**355 harbour porpoise (0.1% NS MU) based on SCANS-III density** ***No significant difference***
	75%	666 harbour porpoise (0.2% NS MU) based on SCANS-III density	932 harbour porpoise (0.3% NS MU) based on SCANS-III density	**266 harbour porpoise (0.08% NS MU) based on SCANS-III density** ***No significant difference***
	50%	444 harbour porpoise (0.1% NS MU) based on SCANS-III density	621.5 harbour porpoise (0.2% NS MU) based on SCANS-III density	**177.5 harbour porpoise (0.05% NS MU) based on SCANS-III density** ***No significant difference***
Harbour porpoise – possible avoidance unweighted SEL$_{ss}$ 145 dB re 1 µPa^{2}a	100%	2,753 harbour porpoise (0.8% NS MU) based on SCANS-III density	3,286 harbour porpoise (0.95% NS MU) based on SCANS-III density	**533 harbour porpoise (0.15% NS MU) based on SCANS-III density** ***No significant difference***
	75%	2,065 harbour porpoise (0.6% NS MU) based on SCANS-III density	2,465 harbour porpoise (0.7% NS MU) based on SCANS-III density	**400 harbour porpoise (0.1% NS MU) based on SCANS-III density** ***No significant difference***
	50%	1,376 harbour porpoise (0.4% NS MU) based on SCANS-III density	1,643 harbour porpoise (0.5% NS MU) based on SCANS-III density	**267 harbour porpoise (0.08% NS MU) based on SCANS-III density** ***No significant difference***

*Updated SCANS-III harbour porpoise density = 0.888/km^2 (CV = 0.21);
Updated SCANS-III harbour porpoise reference population = 345,373 (CV = 0.18; 95% CI = 246,526-495,752)

There is no difference in the impact significance for possible avoidance in harbour porpoise for the proposed increased maximum hammer energy of 4,000kJ compared to the maximum hammer energy of 3,000kJ (**Table 49**).

Table 49 Impact significance for possible avoidance in harbour porpoise from maximum hammer energy of 3,000kJ and 4,000kJ*

Updated modelling for maximum hammer energy of 3,000kJ	Updated modelling for maximum hammer energy of 4,000kJ
Negligible (low sensitivity x temporary impact with negligible magnitude (≤1% ref. pop.))	Negligible (low sensitivity x temporary impact with negligible magnitude (≤1% ref. pop.))

*see Annex B for definitions of sensitivity, magnitude and impact significance matrix

5.2.2 White-beaked dolphin

5.2.2.1 PTS

There is no difference between the predicted PTS ranges for the 3,000kJ and 4,000kJ maximum hammer energies, based on the NOAA (NMFS, 2016) criteria for white-beaked dolphin (**Table 50**). There is no difference in the impact significance for PTS in white-beaked dolphin for the proposed increased maximum hammer energy to 4,000kJ compared to the consented maximum hammer energy of 3,000kJ.

Table 50 Maximum predicted impact ranges (and areas) for PTS from a single strike (SPL_{peak}) and from cumulative exposure (SEL_{cum}) based on NOAA (NMFS, 2016) criteria for white-beaked dolphin

Receptor	Threshold	Maximum predicted impact range and area		
		Maximum hammer energy of 3,000kJ for monopiles	Maximum hammer energy of 4,000kJ for monopiles	Difference between 3,000kJ and 4,000kJ
SPL_{peak} single strike				
Dolphin species	unweighted SPL_{peak} 230 dB re 1 µPa	<50m (<0.1km^2)	<50m (<0.1km^2)	**No difference**
Cumulative SEL				
Dolphin species	SEL_{cum} Weighted 185 dB re 1 µPa^{2}s	<100m (<0.1km^2)	<100m (<0.1km^2)	**No difference**

5.2.2.2 TTS / fleeing response

There is no difference between the predicted TTS ranges for the 3,000kJ and 4,000kJ maximum hammer energies, based on the NOAA (NMFS, 2016) criteria for white-beaked dolphin (**Table 51**).

Table 51 Maximum predicted impact ranges (and areas) for TTS from a single strike (SPL_{peak}) and from cumulative exposure (SEL_{cum}) based on NOAA (NMFS, 2016) criteria for white-beaked dolphin

Receptor	Threshold	Maximum predicted impact range and area		
		Maximum hammer energy of 3,000kJ for monopiles	Maximum hammer energy of 4,000kJ for monopiles	Difference between 3,000kJ and 4,000kJ
SPL_{peak} single strike				
Dolphin species	unweighted SPL_{peak} 224 dB re 1 µPa	<50m (<0.1km²)	<50m (<0.1km²)	**No difference**
Cumulative SEL				
Dolphin species	SEL_{cum} Weighted 170 dB re 1 µPa²s	<100m (<0.1km²)	<100m (<0.1km²)	**No difference**

1.1.1.1 Likely or possible avoidance

The maximum predicted impact ranges (and areas) for likely or possible behavioural response or avoidance from a single strike (SEL_{ss}) based on Southall *et al*. (2007) unweighted criteria for dolphin species have been modelled for the increased monopile hammer energy (up to 4,000kJ), as well as the maximum hammer energy for monopiles (3,000kJ) assessed in the ES (**Table 52**).

For the possible avoidance of white-beaked dolphin the difference between the maximum hammer energies of 3,000kJ and 4,000kJ is up to 1.3km and 4.1km, respectively (**Table 52**).

Table 52 Maximum predicted impact ranges (and areas) for likely or possible behavioural response from a single strike (SEL_{ss}) based on Southall et al. (2007) unweighted criteria for dolphin species

Receptor	Threshold	Maximum predicted impact range and area		
		Maximum hammer energy of 3,000kJ for monopiles	Maximum hammer energy of 4,000kJ for monopiles	Difference between 3,000kJ and 4,000kJ
Dolphin species – likely avoidance	unweighted SEL_{ss} 170 dB re 1 µPa²a	2.7km (23km²)	3.2km (31km²)	**0.5km = +18.5% (8km² = +35%)**
Dolphin species – possible avoidance	unweighted SEL_{ss} 160 dB re 1 µPa²a	9.4km (260km²)	10.7km (330km²)	**1.3km = +14% (70km² = +27%)**

Up to an additional 0.01 or 0.2 white-beaked dolphin (0.000003% or 0.001% CGNS MU) could have a likely or possible avoidance reaction, respectively, based on a precautionary 100% of individuals responding to a single strike of the maximum hammer energy of 4,000kJ compared to a 3,000kJ hammer energy (**Table 53**).

There is no significant difference (i.e. the additional difference is less than 1% of the reference population could be temporarily affected) as a result of increasing the maximum hammer energy from 3,000kJ to the proposed 4,000kJ (**Table 53**).

Table 53 The maximum number of white-beaked dolphin (and % of reference population) taking into account that 100% of individuals could exhibit a likely or possible behavioural response from a single strike (SELss) based on Southall et al. (2007) unweighted criteria for dolphin species

Receptor Threshold and criteria	% of individuals that could respond	Maximum number of individuals (% reference population)		
		Maximum hammer energy of 3,000kJ for monopiles	Maximum hammer energy of 4,000kJ for monopiles	Difference between 3,000kJ and 4,000kJ
White-beaked dolphin – likely avoidance unweighted SEL_{ss} 170 dB re 1 $\mu Pa^2 a$	100%	0.05 white-beaked dolphin (0.0003% CGNS MU) based on SCANS-III density	0.06 white-beaked dolphin (0.0004% CGNS MU) based on SCANS-III density	**0.01 white-beaked dolphin (0.000003% CGNS MU) based on SCANS-III density** ***No significant difference***
White-beaked dolphin – possible avoidance unweighted SEL_{ss} 160 dB re 1 $\mu Pa^2 a$	100%	0.5 white-beaked dolphin (0.003% CGNS MU) based on SCANS-III density	0.7 white-beaked dolphin (0.004% CGNS MU) based on SCANS-III density	**0.2 white-beaked dolphin (0.001% CGNS MU) based on SCANS-III density** ***No significant difference***

*Updated SCANS-III white-beaked dolphin density = 0.002/km^2 (CV = 0.97);
Updated white-beaked dolphin reference population = 15,895 (CV=0.29; 95% CI=9,107-27,743)

There is no difference in the impact significance for likely or possible avoidance of white-beaked dolphin for the proposed increased maximum hammer energy to 4,000kJ compared to the maximum hammer energy of 3,000kJ (**Table 54**).

Table 54 Impact significance for the likely or possible avoidance of white-beaked dolphin from maximum hammer energy of 3,000kJ and 4,000kJ*

Updated modelling for maximum hammer energy of 3,000kJ	Updated modelling for maximum hammer energy of 4,000kJ
Negligible (low sensitivity x temporary impact with negligible magnitude (≤1% ref. pop.))	Negligible (low sensitivity x temporary impact with negligible magnitude (≤1% ref. pop.))

*see Annex B for definitions of sensitivity, magnitude and impact significance matrix

5.2.3 Minke whale

5.2.3.1 PTS

The difference between the predicted PTS range for the 3,000kJ and 4,000kJ hammer energies, based on the SPL_{peak} criteria for single strike, is very small (up to 10m) for minke whale (**Table 55**).

For the PTS SELcum criteria, larger ranges are predicted for minke whale up to 8.1km for the largest hammer energy and worst-case ramp-up sequence, compared to 5.9km for the 3,000kJ hammer energy. This relates to their sensitivity to low-frequency noise. This is a difference of up to 2.2km (52km^2) between the predicted PTS cumulative SEL ranges for the maximum hammer energy of 3,000kJ and 4,000kJ (**Table 55**).

Table 55 Maximum predicted impact ranges (and areas) for PTS from a single strike (SPL_{peak}) and from cumulative exposure (SEL_{cum}) based on NOAA (NMFS, 2016) criteria for minke whale

Receptor	Threshold	Maximum predicted impact range and area		
		Maximum hammer energy of 3,000kJ for monopiles	Maximum hammer energy of 4,000kJ for monopiles	Difference between 3,000kJ and 4,000kJ
SPL_{peak} single strike				
Minke whale	unweighted SPL_{peak} 219 dB re 1 µPa	60m (<0.1km²)	70m (<0.1km²)	**10m = +17% (no difference)**
Cumulative SEL				
Minke whale	SEL_{cum} Weighted 183 dB re 1 µPa²s	5.9km (58km²)	8.1km (110km²)	**2.2km = +37% (52km² = +90%)**

Up to an additional 0.5 minke whale (0.002% CGNS MU) could be at increased risk of PTS from cumulative exposure for the proposed hammer energy of 4,000kJ compared to 3,000kJ hammer energy, based on the NOAA (NMFS, 2016) criteria (**Table 56**).

Table 56 The maximum number of minke whale and % of reference population that could be at risk of PTS from a single strike (SPL_{peak}) and from cumulative exposure (SEL_{cum}) based on NOAA (NMFS, 2016) criteria when the proposed maximum hammer energy is increased from 3,000kJ to 4,000kJ

Receptor	Threshold	Maximum number of individuals (% reference population)		
		Maximum hammer energy of 3,000kJ for monopiles	Maximum hammer energy of 4,000kJ for monopiles	Difference between 3,000kJ and 4,000kJ
Cumulative SEL				
Minke whale	SEL_{cum} Weighted 183 dB re 1 µPa²s	0.6 minke whale (0.003% CGNS MU) based on SCANS-III density 0.1 minke whale (0.0004% CGNS MU) based on site specific density	1.1 minke whale (0.005% CGNS MU) based on SCANS-III density 0.25 minke whale (0.001% CGNS MU) based on site specific density	**0.5 minke whale (0.002% CGNS MU) based on SCANS-III density** **0.15 minke whale (0.0006% CGNS MU) based on site specific density** ***No significant difference***

*Updated SCANS-III minke whale density = 0.010/km² (CV = 0.62);
Updated minke whale reference population = 23,528 (CV=0.27; 95% CI=13,989-39,572)

The MMMP will detail the proposed mitigation measures to reduce the risk of any permanent auditory injury (PTS) to marine mammals as a result of underwater noise during piling.

During the 30 minute soft-start and ramp-up (**Table 4**) and based on a constant speed of 3.25m/s for minke whale (Blix and Folkow, 1995), minke whale would move at least 5.85km from the pile location. If acoustic deterrent devices (ADDs) were activated for 20 minutes before the soft-start, minke whale would move an additional 3.6km. Therefore, there should be no minke whale in the potential impact area and at risk of instantaneous or cumulative PTS from the maximum hammer energy of 3,000kJ or 4,000kJ.

There is no difference in the impact significance for PTS in minke whale (with or without mitigation) for the proposed increased maximum hammer energy to 4,000kJ compared to the maximum hammer energy of 3,000kJ assessed in the ES (**Table 57**).

Table 57 Impact significance for PTS in minke whale from maximum hammer energy of 3,000kJ and 4,000kJ*

Impact significance for PTS in harbour porpoise	Maximum hammer energy of 3,000kJ	Maximum hammer energy of 4,000kJ
Without mitigation	Moderate adverse (high sensitivity x permanent impact with low magnitude (<0.001% ref. pop.))	Moderate adverse (high sensitivity x permanent impact with low magnitude (<0.001% ref. pop.))
With mitigation	No impact / negligible	No impact / negligible

*see Annex B for definitions of sensitivity, magnitude and impact significance matrix

It should be noted that these cannot be compared like-for-like with criteria in the ES as cumulative SELs were not considered for marine mammals.

5.2.3.2 TTS / fleeing response

The difference between the predicted TTS / fleeing response range for the maximum hammer energies of 3,000kJ and 4,000kJ, based on the SPL_{peak} criteria for single strike, is up to 30m for minke whale, with no difference in the predicted impact area (**Table 58**).

For the TTS SELcum criteria, the difference between the maximum predicted range for hammer energies of 3,000kJ and 4,000kJ is up to 5.1km for minke whale (**Table 58**).

Table 58 Maximum predicted impact ranges (and areas) for TTS from a single strike (SPL_{peak}) and from cumulative exposure (SEL_{cum}) based on NOAA (NMFS, 2016) criteria for minke whale

Receptor	Threshold	Maximum predicted impact range and area		
		Maximum hammer energy of 3,000kJ for monopiles	Maximum hammer energy of 4,000kJ for monopiles	Difference between 3,000kJ and 4,000kJ
SPL_{peak} single strike				
Minke whale	unweighted SPL_{peak} 213 dB re 1 µPa	120m (<0.1km^2)	150m (0.1km^2)	**30m = +25% (no difference)**
Cumulative SEL				
Minke whale	SEL_{cum} Weighted 168 dB re 1 µPa^{2}s	50.8km (4,100km^2)	55.9km (5,000km^2)	**5.1km = +10% (900km^2 = +22%)**

There is no difference in the predicted impact area (**Table 58**) and therefore the number of minke whale, that could experience TTS for the previous 3,000kJ and proposed 4,000kJ maximum hammer energy, based on the NOAA (NMFS, 2016) criteria SPL_{peak} for a single strike.

Up to an additional 9 minke whale (0.04% CGNS MU) could temporarily be impacted by cumulative TTS from the maximum hammer energy of 4,000kJ compared to a 3,000kJ hammer energy, based on the NOAA (NMFS, 2016) criteria. There is no significant difference (i.e. the additional difference is less than

1% of the reference population could be temporarily affected) as a result of increasing the maximum hammer energy from 3,000kJ to the proposed 4,000kJ (**Table 59**).

Table 59 The maximum number of minke whale and % of reference population that could be at risk of TTS from cumulative exposure (SEL_{cum}) based on NOAA (NMFS, 2016) criteria for minke whale

Receptor	Threshold	Maximum number of individuals (% reference population)		
		Maximum hammer energy of 3,000kJ for monopiles	Maximum hammer energy of 4,000kJ for monopiles	Difference between 3,000kJ and 4,000kJ
Cumulative SEL				
Minke whale	SEL_{cum} Weighted 168 dB re 1 µPa^{2}s	41 minke whale (0.2% CGNS MU) based on SCANS-III density 9.4 minke whale (0.04% CGNS MU) based on site specific density	50 minke whale (0.2% CGNS MU) based on SCANS-III density 11.5 minke whale (0.05% CGNS MU) based on site specific density	**9 minke whale (0.04% CGNS MU) based on SCANS-III density** **2 minke whale (0.009% CGNS MU) based on site specific density** ***No significant difference***

*Updated SCANS-III minke whale density = 0.010/km^2 (CV = 0.62);
Updated minke whale reference population = 23,528 (CV=0.27; 95% CI=13,989-39,572)

There is no difference in the impact significance for TTS in minke whale for the proposed increased maximum hammer energy to 4,000kJ compared to the maximum hammer energy of 3,000kJ (**Table 60**).

Table 60 Impact significance for TTS in minke whale from maximum hammer energy of 3,000kJ and 4,000kJ*

Updated modelling for maximum hammer energy of 3,000kJ	Updated modelling for maximum hammer energy of 4,000kJ
Negligible (medium sensitivity x temporary impact with negligible magnitude (≤1% ref. pop.))	Negligible (medium sensitivity x temporary impact with negligible magnitude (≤1% ref. pop.))

*see Annex B for definitions of sensitivity, magnitude and impact significance matrix

5.2.3.3 *Likely or possible avoidance*

For the possible avoidance of minke whale the difference between the maximum hammer energies of 3,000kJ and 4,000kJ is up to 4.1km (**Table 61**).

Table 61 Maximum predicted impact ranges (and areas) for likely or possible behavioural response from a single strike (SEL_{ss}) based on Southall et al. (2007) unweighted criteria for minke whale

Receptor	Threshold	Maximum predicted impact range and area		
		Maximum hammer energy of 3,000kJ for monopiles	Maximum hammer energy of 4,000kJ for monopiles	Difference between 3,000kJ and 4,000kJ
Minke whale – likely avoidance	unweighted SEL_{ss} 152 dB re 1 µPa^{2}a	21.3km (1,100km^2)	23.9km (1,300km^2)	**2.6km = +12%** **(200km^2 = +18%)**

Receptor	Threshold	Maximum predicted impact range and area		
		Maximum hammer energy of 3,000kJ for monopiles	Maximum hammer energy of 4,000kJ for monopiles	Difference between 3,000kJ and 4,000kJ
Minke whale – possible avoidance	unweighted SEL_{ss} 142 dB re 1 µPa^2a	48.4km ($4,600km^2$)	52.5km ($5,400km^2$)	**4.1km = +8.5% ($800km^2$ = +17%)**

Up to an additional 6 minke whale (0.03% CGNS MU) could have a possible avoidance reaction, based on a precautionary 75% of individuals responding to a single strike of the maximum hammer energy of 4,000kJ compared to 3,000kJ hammer energy. There is no significant difference (i.e. the additional difference is less than 1% of the reference population could be temporarily affected) as a result of increasing the maximum hammer energy from 3,000kJ to the proposed 4,000kJ (**Table 62**).

Table 62 The maximum number of minke whale (and % of reference population) taking into account that 50%, 75% or 100% of individuals could exhibit a likely or possible behavioural response from a single strike (SELss) based on Southall et al. (2007) unweighted criteria for minke whale

Receptor Threshold and criteria	% of individuals that could respond	Maximum number of individuals (% reference population)		
		Maximum hammer energy of 3,000kJ for monopiles	Maximum hammer energy of 4,000kJ for monopiles	Difference between 3,000kJ and 4,000kJ
Minke whale – likely avoidance unweighted SEL_{ss} 152 dB re 1 µPa^2a	100%	11 minke whale (0.05% CGNS MU) based on SCANS-III density	13 minke whale (0.06% CGNS MU) based on SCANS-III density	**2 minke whale (0.008% CGNS MU) based on SCANS-III density** ***No significant difference***
	75%	8 minke whale (0.03% CGNS MU) based on SCANS-III density	10 minke whale (0.04% CGNS MU) based on SCANS-III density	**2 minke whale (0.008% CGNS MU) based on SCANS-III density** ***No significant difference***
	50%	5.5 minke whale (0.02% CGNS MU) based on SCANS-III density	6.5 minke whale (0.03% CGNS MU) based on SCANS-III density	**1 minke whale (0.004% CGNS MU) based on SCANS-III density** ***No significant difference***
Minke whale – possible avoidance unweighted SEL_{ss} 142 dB re 1	100%	46 minke whale (0.2% CGNS MU) based on SCANS-III density	54 minke whale (0.2% CGNS MU) based on SCANS-III density	**8 minke whale (0.03% CGNS MU) based on SCANS-III density** ***No significant difference***

Receptor Threshold and criteria	% of individuals that could respond	Maximum number of individuals (% reference population)		
		Maximum hammer energy of 3,000kJ for monopiles	Maximum hammer energy of 4,000kJ for monopiles	Difference between 3,000kJ and 4,000kJ
µPa²a	75%	34.5 minke whale (0.2% CGNS MU) based on SCANS-III density	40.5 minke whale (0.2% CGNS MU) based on SCANS-III density	**6 minke whale (0.03% CGNS MU) based on SCANS-III density** ***No significant difference***
	50%	23 minke whale (0.1% CGNS MU) based on SCANS-III density	27 minke whale (0.1% CGNS MU) based on SCANS-III density	**4 minke whale (0.02% CGNS MU) based on SCANS-III density** ***No significant difference***

There is no difference in the impact significance for likely or possible avoidance in minke whale for the proposed increased maximum hammer energy to 4,000kJ compared to the consented maximum hammer energy of 3,000kJ (**Table 63**).

Table 63 Impact significance for likely or possible avoidance in minke whale from maximum hammer energy of 3,000kJ and 4,000kJ*

Updated modelling for maximum hammer energy of 3,000kJ	Updated modelling for maximum hammer energy of 4,000kJ
Negligible (low sensitivity x temporary impact with negligible magnitude (≤1% ref. pop.))	Negligible (low sensitivity x temporary impact with negligible magnitude (≤1% ref. pop.))

*see Annex B for definitions of sensitivity, magnitude and impact significance matrix

5.2.4 Grey and harbour seal

5.2.4.1 PTS

The difference between the predicted PTS range for the 3,000kJ and 4,000kJ hammer energies, based on the SPL_{peak} criteria for single strike, is very small (up to 10m) for seals with no predicted difference in the potential impact area (**Table 64**).

For seals there is no difference between the maximum predicted PTS cumulative SEL ranges or areas for the maximum hammer energy of 3,000kJ and 4,000kJ (**Table 64**).

Table 64 Maximum predicted impact ranges (and areas) for PTS from a single strike (SPL_{peak}) and from cumulative exposure (SEL_{cum}) based on NOAA (NMFS, 2016) criteria for seals

Receptor	Threshold	Maximum predicted impact range and area		
		Maximum hammer energy of 3,000kJ for monopiles	Maximum hammer energy of 4,000kJ for monopiles	Difference between 3,000kJ and 4,000kJ
SPL_{peak} single strike				
Grey seal and harbour seal	unweighted SPL_{peak} 218 dB re 1 µPa	70m (<0.1km²)	80m (<0.1km²)	**10m = +17% (no difference)**
Cumulative SEL				
Grey seal and harbour seal	SEL_{cum} Weighted 185 dB re 1 µPa²s	<100m (<0.1km²)	<100m (<0.1km²)	**No difference**

There is no difference in the number of grey seal or harbour seal that could be at risk of PTS for the consented hammer energy of 3,000kJ and proposed 4,000kJ maximum hammer energy, based on the NOAA (NMFS, 2016) criteria SPL_{peak} for a single strike and SEL_{cum} for cumulative exposure, due to there being no difference in the predicted impact area (**Table 64**).

There is no difference in the impact significance for PTS in grey and harbour seal for the proposed increased maximum hammer energy to 4,000kJ compared to the consented maximum hammer energy of 3,000kJ.

The MMMP will detail the proposed mitigation measures to reduce the risk of any permanent auditory injury (PTS) to marine mammals as a result of underwater noise during piling.

5.2.4.2 TTS

The difference between the predicted TTS range for the maximum hammer energies of 3,000kJ and 4,000kJ, based on the SPL_{peak} criteria for single strike, is up to 40m for seals with no predicted difference in the potential impact area (**Table 65**).

For the TTS SELcum criteria, the difference between the maximum predicted range for hammer energies of 3,000kJ and 4,000kJ is up to 3km for seals (**Table 65**).

Table 65 Maximum predicted impact ranges (and areas) for TTS from a single strike (SPL_{peak}) and from cumulative exposure (SEL_{cum}) based on NOAA (NMFS, 2016) criteria for seals

Receptor	Threshold	Maximum predicted impact range and area		
		Maximum hammer energy of 3,000kJ for monopiles	Maximum hammer energy of 4,000kJ for monopiles	Difference between 3,000kJ and 4,000kJ
SPL_{peak} single strike				
Grey seal and harbour seal	unweighted SPL_{peak} 212 dB re 1 µPa	130m (0.1km²)	170m (0.1km²)	**40m = +31% (no difference)**
Cumulative SEL				
Grey seal and	SEL_{cum} Weighted	16.5km	19.5km	**3km = +18%**

Receptor	Threshold	Maximum predicted impact range and area		
		Maximum hammer energy of 3,000kJ for monopiles	Maximum hammer energy of 4,000kJ for monopiles	Difference between 3,000kJ and 4,000kJ
harbour seal	170 dB re 1 µPa²s	(530km²)	(720km²)	**(190km² = +35%)**

There is no difference in the predicted impact area and therefore the number of grey seal or harbour seal that could experience TTS for the previous 3,000kJ and proposed 4,000kJ maximum hammer energy, based on the NOAA (NMFS, 2016) criteria SPL_{peak} for a single strike.

Up to an additional 17 grey seal and 0.19 harbour seal could be temporarily impacted by cumulative TTS from the maximum hammer energy of 4,000kJ compared to 3,000kJ hammer energy. There is no significant difference (i.e. the additional difference is less than 1% of the reference population could be temporarily affected) as a result of increasing the maximum hammer energy from 3,000kJ to the proposed 4,000kJ (**Table 66**).

Table 66 The maximum number of grey and harbour seal (and % of reference population) that could be at risk of TTS from a single strike (SPL_{peak}) and from cumulative exposure (SEL_{cum}) based on NOAA (NMFS, 2016) criteria

Receptor	Threshold	Maximum number of individuals (% reference population)		
		Maximum hammer energy of 3,000kJ for monopiles	Maximum hammer energy of 4,000kJ for monopiles	Difference between 3,000kJ and 4,000kJ
Cumulative SEL				
Grey seal	SEL_{cum} Weighted 170 dB re 1 µPa²s	47.7 grey seal (0.2% of ref. pop.; 0.8% of SE MU)	64.8 grey seal (0.3% of ref. pop.; 1% of SE MU)	**17 grey seal (0.08% of ref. pop.; 0.3% of SE MU)** ***No significant difference***
Harbour seal	SEL_{cum} Weighted 170 dB re 1 µPa²s	0.53 harbour seal (0.001% of ref. pop.; 0.01% of SE MU)	0.72 harbour seal (0.002% of ref. pop.; 0.01% of SE MU)	**0.19 harbour seal (0.0004% of ref. pop.; 0.004% of SE MU)** ***No significant difference***

There is no difference in the impact significance for TTS in grey and harbour seal for the proposed increased maximum hammer energy to 4,000kJ compared to the maximum hammer energy of 3,000kJ (**Table 67**).

It should be noted that these cannot be compared like-for-like with criteria in the ES as cumulative SELs were not considered for marine mammals.

Table 67 Impact significance for TTS in grey and harbour seal from maximum hammer energy of 3,000kJ and 4,000kJ*

Updated modelling for maximum hammer energy of 3,000kJ	Updated modelling for maximum hammer energy of 4,000kJ
Negligible (medium sensitivity x temporary impact with negligible magnitude (≤1% ref. pop.))	Negligible (medium sensitivity x temporary impact with negligible magnitude (≤1% ref. pop.))

*see Annex B for definitions of sensitivity, magnitude and impact significance matrix

5.3 Comparison with cumulative impact assessment

As demonstrated, there is no significant difference in the potential impacts on marine mammals from increasing the maximum monopile hammer energy to 4,000kJ and the monopile diameter to 12m compared to the maximum monopile hammer energy of 3,000kJ and the monopile diameter of 10m in the original assessment, therefore there will be no significant difference to the outcome of the cumulative impact assessment in the original assessment.

5.4 Comparison with HRA

As demonstrated, there is no significant difference in the potential impacts on marine mammals from increasing the maximum monopile hammer energy to 4,000kJ and the monopile diameter to 12m compared to the maximum monopile hammer energy of 3,000kJ and the monopile diameter of 10m in the original assessment. As a result the conclusions of the HRA which underpin the DCO (DECC, 2015) are not affected and the proposed changes themselves do not have the potential to give rise to likely significant effects on any European site (including the Southern North Sea candidate Special Area of Conservation (cSAC)).

6 Conclusions

This marine mammal technical report has reviewed and re-modelled the impacts on marine mammals which could arise from the proposed amendments to the Creyke Beck Projects on a like for like basis with the modelling that informed the ES and HRA which underpin the DCO. In addition, due to the change in noise thresholds and criteria that have occurred since the projects were consented, an assessment of the potential impacts based on these has also been undertaken

The modelling carried out on a 'like for like' basis with the original consent showed that there was no significant difference between the potential impact for a maximum hammer energy of 3,000kJ compared to 4,000kJ for permanent auditory injury (PTS), temporary auditory injury (TTS) and likely or possible avoidance for all species, as summarised in **Table 68**. Therefore, the proposed increase in maximum hammer energy from 3,000kJ to 4,000kJ would not alter the outcomes of the original assessment made within the ES, including the cumulative impact assessment and, where relevant, the HRA.

In addition, the updated underwater noise modelling, based on the NOAA (NMFS, 2016) thresholds and criteria for PTS and TTS and updated density estimates and reference populations, also showed that there is no predicted difference in the potential impacts on marine mammals from increasing the maximum monopile hammer energy to 4,000kJ and the monopile diameter to 12m compared to the consented monopile hammer energy of 3,000kJ and the monopile diameter of 10m, as summarised in **Table 69**.

The assessments undertaken demonstrate that there is no difference in the impact significance between the impacts as assessed under the original assessment and the updated assessment. Therefore, the assessments demonstrate that an increase in maximum hammer energy from 3,000kJ to 4,000kJ and an increase in monopile diameter from 10m to 12m do not affect impact significance on any of the assessed receptors.

It is therefore concluded that as there is no material difference between the impacts assessed in the ES and those resulting from the proposed amendments to the Projects, the conclusions of the ES and its associated documents are not affected by the proposed changes and that the recommendations of the Examining Authority and the conclusions of the HRA which underpin the DCO, are similarly not affected. The proposed changes do not have the potential to give rise to likely significant effects on any European sites (including the Southern North Sea cSAC). Therefore the proposed amendments to the DCO will not give rise to any new or materially different likely significant effects in relation to marine mammals and no further assessment is required for marine mammals in support of the proposed amendment to the DCO.

Therefore, it is appropriate for the application to amend the maximum hammer energy and monopile diameter to be consented as an NMC to the DCO.

Table 68 Summary of the like for like comparison of the predicted impact ranges, number of marine mammals and% of reference population (based on values used in ES) and impact assessment for maximum hammer energy of 3,000kJ in ES and proposed increased maximum hammer energy of 4,000kJ

Species	PTS		TTS / fleeing response		Behavioural response	
	3,000kJ in ES	4,000kJ	3,000kJ in ES	4,000kJ	3,000kJ in ES	4,000kJ
Harbour porpoise[1]	<700m 1 harbour porpoise (0.0004%) Minor adverse No impact with mitigation	860m 1.5 harbour porpoise (0.0006%) Minor adverse No impact with mitigation	5.5km 62 harbour porpoise (0.03%) Negligible	6.9km 91.5 harbour porpoise (0.04%) Negligible	43km 2,276 harbour porpoise (0.98%) Negligible	42.6km 2,418 harbour porpoise (1%) Negligible
	No significant difference		**No significant difference**		**No significant difference**	
White-beaked dolphin[2]	<50m	<50m	<150m 0.0004 white-beaked dolphin (<0.00001%) Negligible	170m 0.0007 white-beaked dolphin (0.000004%) Negligible	9km 1.1 white-beaked dolphin (0.007%) Negligible	10.7km 2.3 white-beaked dolphin (0.01%) Negligible
	No difference		No significant difference		No significant difference	
Minke whale[3]	<50m	50m	<350m 0.0009 minke whale (<0.00001%) Negligible	470m 0.002 minke whale (0.000008%) Negligible	56km 13 minke whale (0.05%) Negligible	52.5km 12.4 minke whale (0.05%) Negligible
	No difference		**No significant difference**		**No difference**	
Grey seal[4]	<150m 0.06 grey seal (<0.0004%) Minor adverse No impact with mitigation	700m 0.084 grey seal (0.00037%) Minor adverse No impact with mitigation	<1.9m	1.7m	N/A	
	No significant difference		**No increase**			

[1]based on Lucke *et al*. (2009) unweighted criteria for instantaneous PTS (SEL_{ss} 179 dB re 1 μPa^2s); TTS / fleeing response (SEL_{ss} 164 dB re 1 μPa^2s); and possible avoidance (SEL_{ss} 145 dB re 1 μPa^2s). ES harbour porpoise density = 0.6536/km^2; ES harbour porpoise reference population = 232,450.
[2]based on Southall *et al*. (2007) M-weighted criteria for instantaneous PTS (SEL_{ss} 198 dB re 1 μPa^2s); TTS / fleeing response (SEL_{ss} 183 dB re 1 μPa^2s); and possible avoidance (SEL_{ss} 160 dB re 1 μPa^2s). ES white-beaked dolphin density = 0.0071/km^2; ES white-beaked dolphin reference population = 16,536.
[3]based on Southall *et al*. (2007) M-weighted criteria for instantaneous PTS (SEL_{ss} 198 dB re 1 μPa^2s); TTS / fleeing response (SEL_{ss} 183 dB re 1 μPa^2s); and possible avoidance (SEL_{ss} 142 dB re 1 μPa^2s). ES minke whale density = 0.0023/km^2; ES minke whale reference population = 25,723
[4]based on Southall *et al*. (2007) M-weighted criteria for instantaneous PTS (SEL_{ss} 186 dB re 1 μPa^2s); TTS / fleeing response (SEL_{ss} 171 dB re 1 μPa^2s); and possible avoidance ES grey seal density = 0.84/km^2; ES grey seal reference population = 22,412.

Table 69 Summary of the predicted impact ranges, number of marine mammals and% of reference population (based on updated values) and impact assessment for updated assessment of maximum hammer energy of 3,000kJ and 4,000kJ

Species	PTS		TTS / fleeing response		Behavioural response	
	3,000kJ	4,000kJ	3,000kJ	4,000kJ	3,000kJ	4,000kJ
Harbour porpoise[1]	490m 0.6 harbour porpoise (0.0002% NS MU) Minor adverse No impact with mitigation	660m 1.2 harbour porpoise (0.0003% NS MU) Minor adverse No impact with mitigation	1.1km 3.2 harbour porpoise (0.0009% NS MU) Negligible	1.5km 5.7 harbour porpoise (0.002% NS MU) Negligible	39.1km 2,065 harbour porpoise (0.6% NS MU) Negligible	42.6km 2,465 harbour porpoise (0.7% NS MU) Negligible
	No significant difference		**No significant difference**		**No significant difference**	
White-beaked dolphin[2]	<50m	<50m	<50m	<50m	9.4km 0.5 white-beaked dolphin (0.003% CGNS MU) Negligible	10.7km 0.7 white-beaked dolphin (0.004% CGNS MU) Negligible
	No difference		**No difference**		**No significant difference**	
Minke whale[3]	60m (<0.1km^2)	70m (<0.1km^2)	120m (<0.1km^2)	150m (0.1km^2)	48.4km 34.5 minke whale (0.2% CGNS MU) Negligible	52.5km 40.5 minke whale (0.2% CGNS MU) Negligible
	No difference in impact area		**No difference in impact area**		**No difference**	
Grey seal[4]	70m (<0.1km^2)	80m (<0.1km^2)			N/A	
	No difference in impact area		**No increase**			

Species	PTS		TTS / fleeing response		Behavioural response	
	3,000kJ	4,000kJ	3,000kJ	4,000kJ	3,000kJ	4,000kJ
Harbour seal[4]	70m (<0.1km^2)	80m (<0.1km^2)	130m (0.1km^2)	170m (0.1km^2)	N/A	
	No difference in impact area		**No difference in impact area**			

[1]based on the NOAA (NMFS, 2016) unweighted SPL_{peak} criteria for PTS (202 dB re 1 µPa); TTS (196 dB re 1 µPa); and Lucke *et al*. (2009) unweighted criteria for 75% possible avoidance (SEL_{ss} 145 dB re 1 µPa^{2}s). Updated SCANS-III harbour porpoise density = 0.888/km^2; updated SCANS-III harbour porpoise reference population = 345,373.

[2]based on the NOAA (NMFS, 2016) unweighted SPL_{peak} criteria for PTS (230 dB re 1 µPa); TTS (224 dB re 1 µPa); and Southall *et al*. (2007) M-weighted criteria for 100% possible avoidance (SEL_{ss} 160 dB re 1 µPa^{2}s). Updated SCANS-III white-beaked dolphin density = 0.002/km^2; updated white-beaked dolphin reference population = 15,895.

[3]based on the NOAA (NMFS, 2016) unweighted SPL_{peak} criteria for PTS (219 dB re 1 µPa); TTS (213 dB re 1 µPa); and Southall *et al*. (2007) M-weighted criteria for 75% possible avoidance (SEL_{ss} 142 dB re 1 µPa^{2}s). Updated SCANS-III minke whale density = 0.010/km^2; updated minke whale reference population = 23,528.

[4]based on the NOAA (NMFS, 2016) unweighted SPL_{peak} criteria for PTS (218 dB re 1 µPa); and TTS (213 dB re 1 µPa).

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Annex A – Subacoustech underwater noise modelling report

[See standalone document]

Annex B – Impact methodology

B.1 Assessment of impacts methodology

This section contains a copy of the assessment of impacts methodology from ES (Forewind, 2013a).

B1.1 Value

All marine mammals are considered to have high value in the assessment.

B1.2 Sensitivity

Table B.1 Sensitivity of individuals in the reference population to the different impacts of noise from pile driving

Species	Auditory injury (PTS)	TTS	Likely avoidance	Possible avoidance
Harbour porpoise	High	Medium	Medium	Low
White-beaked dolphin	High	Medium	Medium	Low
Minke whale	High	Medium	Medium	Low
Grey seal	Medium	Medium	N/A	N/A
Harbour seal	Medium	Medium	N/A	N/A

B1.3 Magnitude

Table B.2 Definitions of magnitude levels for marine mammals

Magnitude	Definition
High	Permanent irreversible change to exposed receptors or feature(s) of the habitat which are of particular importance to the receptor. Assessment indicates that >1% of the reference population are anticipated to be exposed to the effect. OR Temporary effect (limited to phase of development or Project timeframe) to the exposed receptors or feature(s) of the habitat which are of particular importance to the receptor. Assessment indicates that >10% of the reference population are anticipated to be exposed to the effect.
Medium	Permanent irreversible change to exposed receptors or feature(s) of the habitat of particular importance to the receptor. Assessment indicates that between >0.01% and <=1% of the reference population anticipated to be exposed to effect. OR Temporary effect (limited to phase of development or Project timeframe) to the exposed

Magnitude	Definition
	receptors or feature(s) of the habitat which are of particular importance to the receptor. Assessment indicates that between >5% and <=10% of the reference population anticipated to be exposed to effect.
Low	Permanent irreversible change to exposed receptors or feature(s) of the habitat of particular importance to the receptor. Assessment indicates that between >0.001 and <=0.01% of the reference population anticipated to be exposed to effect. OR Intermittent and temporary effect (limited to phase of development or Project timeframe) to the exposed receptors or feature(s) of the habitat which are of particular importance to the receptor. Assessment indicates that between >1% and <=5% of the reference population anticipated to be exposed to effect.
Negligible	Permanent irreversible change to exposed receptors or feature(s) of the habitat of particular importance to the receptor. Assessment indicates that <=0.001% of the reference population anticipated to be exposed to effect. OR Intermittent and temporary effect (limited to phase of development or Project timeframe) to the exposed receptors or feature(s) of the habitat which are of particular importance to the receptor. Assessment indicates that <=1% of the reference population anticipated to be exposed to effect.

B1.4 Impact significance

Table B.3 Impact significance matrix

Impact significance		Sensitivity			
		High	Medium	Low	Negligible
Magnitude	High	*Major*	*Major*	*Moderate*	*Minor*
	Medium	*Major*	*Moderate*	*Minor*	*Negligible*
	Low	*Moderate*	*Minor*	*Minor*	*Negligible*
	Negligible	*Minor*	*Negligible*	*Negligible*	*Negligible*