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Seagreen Alpha and Bravo Site UXO clearance – European Protected Species Risk Assessment and Marine Mammal Mitigation Plan

Rev	Date	Reason for Issue	Originator	Checker	Approver
01	26/03/2021	For information	SMRU Consulting	[redacted]	
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1. Introduction

Seagreen Wind Energy Limited (SWEL, hereafter referred to as 'Seagreen') was awarded consents by Scottish Ministers in October 2014 for the Seagreen Alpha and Seagreen Bravo Offshore Wind Farms (OWFs) and the Offshore Transmission Asset (OTA), which includes the wind farm export cables. Seagreen Alpha and Seagreen Bravo, comprising up to 150 wind turbine generators (WTGs) in total[1] are located in the North Sea, in the outer Firth of Forth and Firth of Tay. The OWF site (WTGs and offshore substation platform) is entirely within offshore Scottish waters (>12 nm from shore), with a minimum distance of approximately 27 km to shore near Johnshaven on the Aberdeenshire coast. The primary export cable landfall is at Carnoustie on the Angus coast, with a potential additional export cable (Seagreen1A) making landfall at Cockenzie in the Firth of Forth.

In advance of commencing offshore construction activities, Seagreen are planning to undertake a campaign of unexploded ordnance (UXO) clearance of the Alpha and Bravo site, commencing in May 2021. A survey to identify potential UXOs (along with boulders, debris and other potential obstacles) in the site commenced in March 2021[2] (not assessed here); these survey activities will continue in parallel to the UXO clearance campaign as further investigation of potential UXOs takes place to inform clearance activities.

It is noted that UXO clearance activities are planned exclusively for the Seagreen Alpha and Bravo site. All potential UXOs in the export cable corridor have been avoided through micro-siting and will not require clearance.

The UXO clearance activities will generate underwater noise which may present a risk of death, physical and/or auditory injury or disturbance to noise-sensitive protected species, namely marine mammals. As European Protected Species (EPS), listed on Annex IV of the EU Habitats Directive, it is an offence to kill, injure or disturb **cetaceans**; if such an offence is likely to occur, an EPS licence is required. Further details of offences and their legislative context are provided in Section 1.1.

While **seals** are not EPS, they are also sensitive to underwater noise, and in Scottish inshore waters it is an offence to kill, injure or take a seal, or harass a seal at a designated haul-out site (Table 1.1). Additionally, seals may be interest features of protected sites, including Special Areas of Conservation (SACs) under the Habitats Directive. Therefore, potential effects on harbour and grey seals are also assessed.

This risk assessment considers the potential effects of the aforementioned activities on marine EPS in the context of relevant legislation and guidance (see Sections 1.1 and 1.2), therefore assessing the need for an EPS licence(s) and providing the information required by MS-LOT in support of any such applications[3].

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[1] The full build-out is 150 turbines, with 114 being built in the current phase.

[2] Risk assessment document reference: LF000009-CST-OF-SUR-REP-0005.

[3] For example, this document provides the 'Cetacean Risk Assessment' described in: *Marine Scotland. 2020. The protection of Marine European Protected Species from injury and disturbance. Guidance for Scottish Inshore Waters (July 2020 Version).*

Consideration is also given to the potential for the planned survey activities to impact seals and relevant protected sites (i.e. marine protected areas for cetaceans and seals; see Section 6).

1.1 Legislative context

Annex IV of the EC Habitats Directive (*European Council Directive 92/43/EEC on the conservation of natural habitats and of wild flora and fauna*) lists species of European interest in need of strict protection – European Protected Species. All species of cetacean whose natural range includes waters around the UK are marine EPS.

The Habitats Directive is transposed into UK and Scots law by different regulations which, along with accompanying guidance, define offences in relation to EPS. Regulations of relevance to this risk assessment are described in Table 1.1.

Table 1.1 Legislation and offences relating to EPS and seals in Scottish inshore and offshore waters.

Legislation and offences relating to EPS in Scottish inshore and offshore waters
Legislation: *The Conservation (Natural Habitats, &c.) Regulations 1994 (as amended)* **Applicable to:** Scottish inshore waters (<12 nm) **Offence(s): Regulation 39(1)** makes it an offence to deliberately or recklessly to capture, injure, kill, harass or disturb a wild animal of a European protected species; further, **Regulation 39(2)** provides that it is an offence to deliberately or recklessly disturb <u>any</u> dolphin, porpoise or whale (cetacean). This offence is considered to relate to disturbance at the individual level.
Legislation: *The Conservation of Offshore Marine Habitats and Species Regulations 2017* **Applicable to:** UK offshore waters (>12 nm) **Offence(s): Part 3 (Section 45)** states that it is an offence to deliberately capture, kill or injure any wild animal of a European protected species. It is also an offence to deliberately disturb wild animals of any such species, with disturbance defined as that which is likely to impair their ability to: survive, breed, reproduce, or nurture young; migrate or hibernate; or, which might affect significantly its local distribution or abundance.
Legislation and offences relating to seals in Scottish inshore waters
Legislation: *Marine (Scotland) Act 2010* **Applicable to:** Scottish inshore waters (< 12 nm) **Offence(s):** Under **Section 107** it is an offence to intentionally or recklessly kill, injure or take a seal except under licence or to alleviate suffering. Further, under **Section 117,** harassing a seal (intentionally or recklessly) at a haul-out site is an offence. Haul-out sites are those designated under *The Protection of Seals (Designated Sea Haul-out Sites) (Scotland) Order 2014*.

Should an EPS licence be required, for it to be granted the Habitats Regulations specify three tests which need to be met: (i) there must be a licensable purpose; (ii) there must be no satisfactory alternative; and, (iii) the activity must not be detrimental to the maintenance of the population of the species concerned at favourable conservation status in their natural range. This third test relates to impacts which might damage the status of the species in the long-term.

Specifically, the conservation status will be taken as 'favourable' when:

- *population dynamics data on the species concerned indicates that it is maintaining itself on a long-term basis as a viable component of its natural habitats; and*
- *the natural range of the species is neither being reduced nor is likely to be reduced for the foreseeable future; and*
- *there is, and will probably continue to be, a sufficiently large habitat to maintain its populations on a long-term basis.*

This risk assessment provides the necessary information to determine the third test relating to favourable conservation status.

1.2 Relevant guidance

This risk assessment has been prepared with consideration of the following guidance:

- JNCC et al. (2010). The protection of marine European Protected Species from injury and disturbance. Guidance for the marine area in England and Wales and the UK offshore marine area (June 2010 – Draft).
- Marine Scotland (2020). The protection of Marine European Protected Species from injury and disturbance. Guidance for Scottish Inshore Waters (July 2020 Version).
- JNCC (2010) Guidelines for minimising the risk of injury to marine mammals from using explosives.

1.3 Existing impact assessments

This EPS Risk Assessment has been informed by impact assessments and a subsequent Environmental Statement (ES) to inform applications for consents to build and operate Seagreen Alpha and Seagreen Bravo offshore wind farms (Seagreen, 2012). The wind farms were subsequently consented in 2014.

In 2015, an Appropriate Assessment (Marine Scotland, 2015) concluded that the Forth and Tay Developments, either alone or in-combination, will not adversely affect the integrity of relevant marine mammals SACs, including the Isle of May SAC, the Berwickshire & North Northumberland Coast SAC, Firth of Tay and Eden Estuary SAC and Moray Firth SAC, subject to compliance with relevant conditions[4]. Further information on these sites is provided in Section 6.

The EPS Risk Assessment has also been informed by a subsequent Environmental Impact Assessment Report (EIA Report) submitted in 2018 in support of consent applications for an optimised design for the same wind farm projects (Seagreen, 2018), along with previous EPS risk assessments for geophysical surveys related to the Seagreen site and export cable corridors.

1.4 Consultation

Seagreen consulted with MS-LOT, MSS and NatureScot to discuss the proposed methodology, indicative schedule, planned approach to UXO clearance activities and broad proposed approach to mitigating noise impacts on marine mammals. These consultations provided an opportunity for advice to be received in advance of submitting applications for the activities. Consultations included: (i) provision of a written proposed EPS risk assessment methodology in April 2020, to which NatureScot provided written advice via email in April 2020; and, (ii) a teleconference on 12th February 2021.

Table 1.2 summarises the advice received and details where this has been addressed in the current Risk Assessment.

Table 1.2. NatureScot (NS) and Marine Scotland Science (MSS) advice received through consultation prior to submission

Consultation activity		
In April 2020, Seagreen provided a short briefing note to Marine Scotland setting out the proposed methodology for a risk assessment (RA) in support of an EPS licence application for the planned UXO clearance within the Seagreen site. This included: • Using the semi-empirical model published in Soloway and Dahl (2014) to estimate peak pressure at specified ranges depending on the charge weight • Model outputs to be combined with appropriate effects thresholds to estimate impact ranges, including unweighted auditory effects thresholds recommended by Southall et al. (2019) for the onset of auditory injury (permanent threshold shift, PTS) and temporary threshold shift (TTS). • Using the onset of TTS as the criteria for disturbance. • For PTS, disturbance and physical injury/trauma, it was proposed that modelled impact ranges would be supplemented by information from relevant literature. • Appropriate mitigation to be developed and implemented, based on current best practice.		
Advice received	**Seagreen actions**	**Where addressed in RA**

[4] Conditions are listed from page 58 of https://marine.gov.scot/sites/default/files/appropriate_assessment_1.pdf

Consultation activity		
Overall, content with the proposed approach. (NS, MSS)	Proposed approach followed	Throughout
Recommended the use of sound pressure level (SPL) and sound exposure level (SEL) when assessing impact range. (NS)	Responded to advice by providing information on the uncertainty around the frequency spectrum of UXO detonations, and subsequent uncertainty in weighted SEL impact ranges. Noted that we can readily calculate unweighted SEL. Noted that SPL (unweighted) impact ranges from UXO are generally largest and therefore most precautionary. *Response accepted, with NS recommending that SPL and unweighted SEL are used.*	Section 4
Advised consideration of seasonal and locational differences in species densities e.g. cable route vs wind farm site. (NS)	Seasonal and locational differences in densities taken into account where available. Noted that UXO clearance in cable route is unlikely (subsequently confirmed). UXO clearance works are planned for summer months, which correspond to the season at which SCANS-III surveys took place (source of density information), and so are considered appropriate.	Section 3 and Section 4
Useful to consider best available information on UXO size and type and, where possible, update this with a more realistic worst-case-scenario (WCS) than an overly-precautious WCS. (NS)	Noted that detailed results from inspection surveys will not be available in sufficient time to inform the RA and therefore it will need to be suitably precautionary. The RA has considered desk-based studies, earlier geophysical survey results and experiences at other sites (e.g. Neart na Gaoithe) in an attempt to provide a more realistic WCS.	Section 2.2.
Welcome further discussions on development of RA, proposed mitigation and potential noise monitoring. (NS)	A teleconference was held in February 2021 (see below) to provide opportunity for such discussions.	N/A
Recommend that any associated acoustic report is included as an Appendix. (NS)	Noted that it is unlikely that there will be a separate acoustic report due to the relatively simplistic nature of the modelling; the full methodology and results will be presented in a section in the RA. *Response accepted.*	Section 4

Consultation activity		
Would expect noise monitoring and timeous reporting to be part of the consent conditions for the EPS licence. (NS)	Seagreen are anticipating noise monitoring as a licence condition. A scope of work will be developed for this if required and a suitable contractor appointed. Subsequent reporting will be conducted according to licence conditions.	N/A
Meeting (teleconference) with Marine Scotland and NatureScot, 12/02/2021. Seagreen provided an update on planned UXO clearance activities, including timing, location, anticipated size and number of UXOs, proposed approach to UXO clearance, development of the RA and broad proposed approach to mitigation.		
Advice received	**Seagreen actions**	**Where addressed in RA**
NS emphasised the desire for low-order disposal methods to be used where this was possible, noting that the EPS licensing process requires consideration of lower-impact alternatives, and low-order approaches are an example of such. Would a low-order method be considered? (NS)	Low-order approaches were under consideration at the time, and a contractor has been appointed that implement a low-yield or low-order approach to UXO disposal as far as is possible. It is noted that high-order disposal may still be required and therefore the RA needs to consider a high-order detonation of the largest potential UXO size as a worst-case scenario.	Section 2.7
Results from noise monitoring of UXO clearance are beginning to emerge but more data are required; measurements would be particularly beneficial if low-order methods are used. Monitoring via static acoustic arrays are the preferred approach. (NS, MSS) It was noted that noise monitoring data from UXO clearance at Neart na Gaoithe and Moray East were unlikely to be available in time to inform the RA. (MSS)	Seagreen are anticipating noise monitoring as a licence condition. A scope of work will be developed for this if required and a suitable contractor appointed.	N/A

Consultation activity		
The proposed broad approach to mitigation was accepted by NS and MSS: pre-detonation visual search (and PAM where necessary and safe to do so) plus ADD use and soft-start 'scarer' charges if required (scaled to the size of the UXO).	The proposed broad approach to mitigation has been developed, with mitigation actions specified for the different disposal approaches that may be used and ADD use and the configuration of soft-start charges scaled according to different anticipated UXO sizes.	Section 5
When advising on the approach to mitigation during UXO clearance at Neart na Gaoithe, it was determined that temporally closer-spaced soft-start charges were preferable to reduce the risk of animals returning to the site between soft-start detonations. (NS)	The five-minute interval between soft-start charges used at Neart na Gaoithe has been incorporated into the Seagreen mitigation plan.	Section 5

2. Description of the proposed UXO clearance activities

2.1 Purpose

There is the potential for UXOs to be present on the seabed in the area of the Seagreen offshore wind farm site, resulting from wartime military operations or more recent military training activities. These UXOs present a potentially significant health and safety hazard to offshore wind farm construction work. Where identified as a safety hazard, it is necessary to remove confirmed UXO prior to construction.

2.2 Potential for UXO

The current understanding of UXO occurrence in the Seagreen project area is primarily drawn from desk-based study (Ordtek, 2017, 2019). These studies have provided an assessment of the likelihood of encountering different categories of UXO within different parts of the project area (Table 2.1), accompanied by the anticipated size (net explosive quantity, NEQ) of these UXOs.

Table 2.1. Anticipated UXO occurrence in the Seagreen offshore wind farm site

UXO type	Probability of occurrence in Seagreen site	Net explosive quantity (NEQ) anticipated in the region
German ground mine	Unlikely	460 kg or 795 kg; low chance of 860-930 kg
British ground mine	Very unlikely	227-499 kg
British and German WW1 mines	Unlikely	n/a
Artillery and naval projectiles	Possible	Most 2-5 kg; lower likelihood of up to 25 kg
Small HE bombs (50 kg)	Unlikely	Most 25 kg
Large HE bombs (250 kg and greater)	Possible	Rarely exceeding 250 kg, but potentially up to maximum 900 kg
Depth charges and torpedoes	Unlikely	50-200 kg (depth charges); 250-280 kg (torpedoes)
British and German WW2 buoyant mines	Possible	145, 227 or 300 kg
Land service ammunition	Very unlikely	n/a (small)

In summary, the UXO types most likely to be encountered ('possible' probability) within the project area include:

- Artillery and naval projectiles: most 2-5 kg NEQ; lower likelihood of up to 25 kg NEQ
- Large HE air-dropped bombs: Unlikely to exceed 250 kg NEQ, but potentially up to maximum 900 kg NEQ
- British and German buoyant mines: 145-300 kg NEQ

Therefore, considering UXO with all likelihoods of occurrence in the Seagreen area, the most powerful UXO which may be present and require clearance would be **930 kg** NEQ; however, it is unlikely that individual items of UXO will exceed **300 kg** NEQ and most are likely to be considerably smaller.

A dedicated potential UXO, boulder and other object clearance survey commenced in March 2021 and is expected to be completed by the end of June 2021; this will provide information on the location, type and size of potential UXOs which may need to be cleared; however, the results of this survey will not be available in sufficient time to inform the current risk assessment.

A geophysical survey in 2018 identified 100 magnetic anomalies across the site, of which 11 overlap areas which require clearance. This provides some indication of the anticipated number of UXO which may require clearance, albeit with the following caveats: (i) not all magnetic anomalies will be potential UXO – some will be other metallic debris such as that associated with lost fishing gear; and, (ii) the 2018 survey was not calibrated to detect UXO targets, so further targets may be identified during the survey commencing in March 2021. For the purposes of this assessment, it is conservatively assumed that 20 UXOs will require clearance across the Seagreen site.

2.2.1 UXO at Neart na Gaoithe and Moray East offshore wind farms

UXO clearance operations took place in 2020 at the nearby **Neart na Gaoithe** (NnG) wind farm and export cable route. The potential for UXO at Seagreen differs to that at NnG, with the latter being closer to shore, closer to post-war ammunition dumping grounds, and also partially overlapping modern and historic firing ranges. As such, it is expected that UXO occurrence in the Seagreen area will be less than that of NnG. Nonetheless, the nature of UXOs identified and cleared at NnG provides relevant information on the nature of UXOs within the region.

A total of 53 items of UXO required detonation at NnG, 46 in the site and seven on the export cable route (NnG Offshore Wind Farm, 2020). These included:

- small projectiles and other items of ≤ 15 kg NEQ (n = 12);
- larger projectiles of c. 50-100 kg NEQ (n = 30);
- anti-submarine warfare (ASW) charges of 32.5 kg (n = 8);
- a paravane (towed anti-mine/submarine weapon) of 36 kg NEQ (n = 1);
- a buoyant mine of 227 kg (n = 1); and,

- a torpedo of unknown NEQ (n = 1).

The most frequently occurring items of UXO were 15" naval projectiles of an estimated 102 kg NEQ (n = 26), none of which resulted in a high-order detonation (i.e. the only detonation during clearance was of the donor charge). A total of 14 items of UXO resulted in a high-order detonation, including six smaller projectiles of ≤ 15 kg and eight ASW charges of 32.5 kg. The reason why so many items of UXO did not high-order detonate is believed to be related to their age, condition and type, with removal of encrusting growth by the donor charge detonation revealing some items to be marked as a practice round, which are not expected to contain explosives[5].

Noise measurements of 37 UXO detonations were collected during the NnG UXO clearance campaign, although detailed results are not yet available. Some preliminary results are noted in Section 4.7.

The UXO identification surveys at **Moray East** offshore wind farm identified 18 items of UXO requiring clearance, with size estimates for individual items ranging < 0.5 kg to up to 365 kg NEQ (Royal HaskoningDHV, 2019). The majority were estimated to be between 22-60 kg NEQ (n = 10), with one item estimated at 163-220 kg and one at 176-365 kg. No information is currently available on the number and type of UXO at Moray East which experienced high-order detonation.

2.3 Location and extent of UXO clearance works

The area of works includes the Seagreen Alpha and Bravo OWF site, located approximately 30 km off the east coast of Scotland between Montrose and Arbroath (Figure 1). The site is entirely within Scottish offshore waters (>12 nm from shore); the north-west and south-west corners of the site are approximately 4 and 7 km from the boundary of Scottish inshore waters, respectively.

The area from which UXOs will need to be cleared from the seabed includes:

- A bow-tie shaped area around each of 114 plus 23 'spare' WTG locations (137 total), each extending up to 380 m from the WTG location and covering an area of approximately 0.26 km^2. The shape reflects the area that would need to be cleared of obstructions for WTG installation and inter-array cables (IACs) to be laid from the WTG in any direction; therefore, given refinement of the IAC configuration, these areas represent a conservative maximum around each WTG location.
- A 50 m wide corridor centred on each of the inter-array cables.
- A 300 m radius around the OSP location.

[5] See minutes of 8th December 2020 meeting of he Forth and Tay Regional Advisroy Group – Marine Mammals Sub-Group: https://marine.gov.scot/data/ftrag-marine-mammals-meeting-minutes-04022021

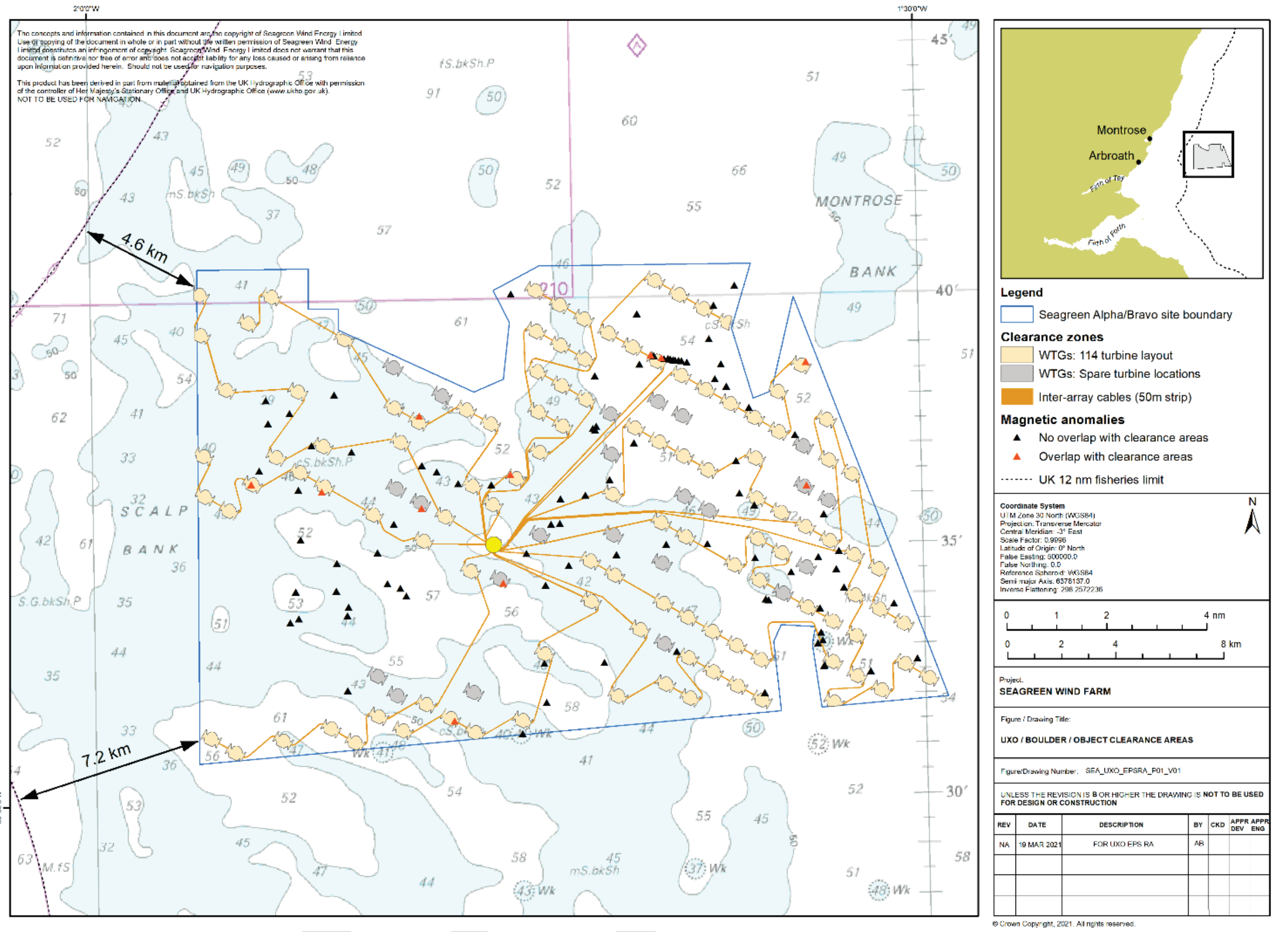

Figure 1. Wind farm site, including area from which UXOs (along with boulders and other debris) may need to be cleared, plus magnetic anomalies previously identified across the site.

2.4 Schedule

UXO clearance activities are planned to take place between June and August 2021, with UXO disposal activities occurring on an estimated maximum of approximately 20 days within this period.

The schedule of UXO clearance activities can be divided into two main phases:

Phase 1. ID and clearance of UXO from a 300 m radius around the OSP location, with clearance commencing at the earliest in June. If the geophysical survey does not identify any potential UXO (‘pUXO’) within the OSP clearance area, or the detailed UXO ID work (by ROV, prior to clearance) determines that explosive clearance is not required, then no UXO clearance operations will begin until Phase 2.

Phase 2. ID and clearance of UXO from the wider clearance area. UXO identification works will follow immediately on from operations at the OSP location commencing in June, but no further UXO clearance will commence until the identification works are complete.

If controlled detonations are required, they will only occur during daylight hours.

2.5 Vessels

A single offshore supply/multi-purpose vessel will be used for UXO identification and clearance operations. The current main vessel option is the *Wind of Pride*, a multi-purpose vessel of 82 m length, with an alternative option of the *Noordhoek Pathfinder*, an offshore supply vessel of 62 m length.

Both vessels are equipped with dynamic positioning (DP) systems and with ROV support capabilities. The ROV will be equipped with a multi-beam echo-sounder (MBES) for completing an as-left survey of UXO clearance sites following removal/disposal; an indicative MBES is the Kongsberg Em 2040 MKII Dual Head, which operates at frequencies in the range 200-700 kHz (likely to be operated at ≥ 300 kHz) and a source level of approximately 230 dB re 1 µPa (SPL_{rms}) (Hammerstad, 2005). An ultra-short baseline (USBL) acoustic positioning system will be used to monitor the location of the ROV relative to the vessel; an indicative USBL system is the Kongsberg HIPAP 502, which operates at frequencies of 21-31 kHz and has a source level of approximately 200 dB re 1 µPa (SPL_{rms}).

A support RHIB (rigid-hulled inflatable boat) will also be deployed from the main vessel to undertake certain tasks during UXO clearance (e.g. ADD deployment, connection of firing lines).

The *Georanger* will be operating within the Seagreen site between approximately mid-March and the end of July 2021 to undertake geophysical survey for potential UXO, boulder and debris (assessed under previous risk assessment - LF000009-CST-OF-SUR-REP-0005)

2.6 UXO clearance contractor

UXOcontrol[6] are the appointed contractor to undertake UXO identification and clearance operations. The company have experience in The Netherlands, Germany, Belgium, UK, Scandinavia and the Baltic States, and recently completed UXO clearance operations for the Viking Link interconnector project. The company offer alternatives to high-order UXO disposal, as is detailed below.

2.7 UXO clearance approach

Targets identified during the geophysical survey (pUXO) will be subject to detailed investigation by ROV. The ROV will use visual inspection supplemented by a metal detector (e.g. Teledyne TSS 440 pipe/cable tracker) for buried object location. Some excavation may also be required at the target location to enable full visual inspection of the target. The information gathered will be assessed by the expert team on the main vessel to determine an appropriate course of action.

There are many factors influencing the approach taken to deal with an item of UXO, including the location, type and condition, and the appropriate course of action for item will be approached on a case-by-case basis. While there is an initial preference for leaving the UXO in situ and micro-site construction work and

[6] https://uxocontrol.com/neutralisation-disintegration-of-live-uxos-using-the-hydra-jet-technique/

infrastructure around it (as has been done on the export cable route), this may not be possible due to factors such as unsuitable soil conditions, a lack of geotechnical info, technical constraints to the inter-array cable routing or requirements for minimum distance between turbines.

Where it is determined that a UXO presents an unacceptable risk to the safe construction of the wind farm if left in situ, and if it is not possible to safely leave the UXO in situ and micro-site, an appropriate clearance approach will be selected. In order of preference, these are:

1. Relocation
2. Low-yield disposal
3. Low-order disposal
4. High-order disposal

High-order disposal represents the most commonly used approach to date for disposal of underwater UXO in situ. This involves deliberate detonation initiated by a small donor charge placed on the UXO to initiate an explosion of the main charge, therefore neutralising it (Cheong et al., 2020). The resulting shock wave and noise level is therefore expected to be proportional to the combined explosive mass of the donor and main charge. By contrast, low-yield and low-order methods aim to neutralise the UXO without detonation of the main charge and, therefore, the energy generated should relate to the detonation of the donor charge only. Consequently, for a given size of UXO, the potential for impacts to marine life from low-yield or low-order disposal are considerably less than would be expected from a high-order disposal (Cheong et al., 2020).

2.7.1 Relocation

The suitability of a UXO for relocation depends on its condition and location, and will be assessed after the ID phase. To be suitable for relocation, items need to be in good condition i.e. sufficiently structurally sound to remain intact through a lift and tow. One such example would be ground mines that are in excellent condition; as these are difficult to be disposed of using the low-yield technique, the preference would be to relocate without attempting disposal. The distance for the UXO to be transported is also a consideration, with a greater distance representing a higher safety risk. A sufficiently large window of suitable (calm) weather is required for the relocation to be completed.

Where it is deemed safe to relocate a UXO, a Remote Ordnance Lifting System (including EOD grabs and surface initiation float) will be used to move the UXO to a safe distance outside of the installation areas/corridor. This system, consisting of a converted RHIB equipped with a lifting frame and electric winch, provides a safe and controlled means of remotely lifting, towing and setting down items of UXO in and alternative location. Once replaced on the seabed a construction traffic exclusion area will be defined around the UXO and the appropriate authorities will be informed.

In circumstances of multiple UXO located in close proximity, UXO may be relocated such that they can be disposed of in a single controlled detonation. In such circumstances, the order of preference for disposal options would be: low-yield, high-order, low-order.

2.7.2 Low-yield disposal

Where it is not possible to relocate the UXO, it will need to be neutralised in situ.

Low-yield, low-order and high-order approaches will all use the non-electric Barracuda Bomb and Mine Disposal system[7]. The system uses non-electric detonators and shock-tube lead-in lines to ensure no potential interference from radio-frequency energy or radars. The Barracuda disruptor (donor charge) consists of either a shaped or blast-fragmentation charge filled with a quantity of plastic explosive suited to the UXO to be disposed. The Barracuda charge is secured to a concrete clump weight and placed c. 30 cm from the UXO by the ROV.

The first-choice method of UXO disposal will be to apply a low-yield method using the ‘HYDRA Hyper High Pressure Water Jet Disintegration Technique’. This approach disrupts and disintegrates the UXO without combustion of the explosive material within the UXO. Two Barracuda shaped charges (HYDRA variants), each of 750 g NEQ, are placed in close proximity to the UXO in a position which targets the known vulnerable components and main explosive filling. When simultaneously detonated, the system generates two reciprocating high pressure, hyper water jets, resulting in the rupture or split of the UXO casing and disintegration of the primary energetic components of the UXO into either:

- Thousands of minute pieces of material (explosively stable), which will dissipate over a few months. This outcome is expected in ground mines and some high explosive bombs where the casings have not been compromised by the ingress of seawater.
- Production of an emulsion of tiny fragments of material, which forms a cloud and dissipates almost immediately. This outcome is expected in moored mines, high-explosive bombs and ground mines with severely corroded casings, depth charges, torpedo warheads where casing have been compromised by the ingress of seawater.

It is noted that for the largest potential UXO which may be encountered, such as German ground mines of ≥ 500 kg, up to four simultaneously detonated shaped charges may be required (total 3 kg NEQ).

Using this system, there is no plasma jet generated (see low-order disposal, below) and all internal components of the UXO are disrupted before they can function; therefore, there is no possibility of an unintended high-order detonation of the UXO.

Following the disruption / disintegration of the UXO, there will be residual explosive material remaining on the seabed. This will be recovered to the vessel using the Explosive Contamination Recovery System and

[7] The Barracuda system has been successfully utilised for disposal of historic ordnance since 2009, and has performed over 1,450 live firings without incident.

wet stored onboard the main vessel and eventually disposed of at a registered disposal facility on shore. In circumstances where it is suspected that there may unstable material within the residual explosive material than cannot be safely recovered or left in situ, such as primers or boosters, detonation of a small (500 g) charge as a 'clearing shot' may be required to neutralise this before safe recovery can proceed.

The low-yield HYDRA system was formally launched in 2020, and has been used to dispose of five historic UXOs since 2015, in good and poor condition, all of which have been successful. These disposals included British and German WWII sea mines of c. 250 kg NEQ, a UK depth charge of 164 kg NEQ, and UK HE bombs of 300 kg NEQ; projects in UK waters included the Galloper and East Anglia ONE wind farms and the IFA2 interconnector (National Grid).

2.7.3 Low-order disposal

Where the UXO is deemed unsuitable for low-yield disposal, a low-order method will be considered. This approach disrupts the UXO by deflagration (subsonic combustion) without an explosive combustion of the main explosive filling. Low-order deflagration techniques are tried and tested for UXOs on land and have been used successfully underwater (Cheong et al., 2020). A single Barracuda shaped charges (30 mm variant) of 30-80 g NEQ is placed in close proximity to the UXO to target a specific entry point. When detonated, a shaped charge penetrates the casing of the UXO to introduce a small, clinical plasma jet into the main explosive filling. The intention is to excite the explosive molecules within the main filling to generate enough pressure to burst the UXO casing, producing a deflagration of the main filling and neutralising the UXO.

Recent controlled experiments showed low-order deflagration to result in a substantial reduction in acoustic output over traditional high-order methods, with SPL_{peak} and SEL being typically more than 20 dB lower for the deflagration of the same size munition, and with the acoustic output being proportional to the size of the shaped charge (rather than the size of the UXO itself) (Cheong et al., 2020)

Using this low-order deflagration method, the probability of a low-order outcome is high (approximately 80-90%); however, there is an inherent risk that the UXO will detonate or deflagrate violently, and appropriate safety and environmental precautions are required accordingly.

As for low-yield disposal, there will be residual explosive material remaining on the seabed following low-order disposal. Recovery will be performed as outlined above for low-yield disposal, including the potential need of a small (500 g) 'clearing shot'.

2.7.4 High-order disposal

Where the UXO is deemed unsuitable for low-yield or low-order disposal, a high-order method will be used. A Barracuda charge will be secured to a concrete clump weight and placed c. 30 cm from the UXO by the ROV. The charge will comprise either a 1.2 kg shaped charge or a 3.5 kg blast-fragmentation charge. This approach is designed to penetrate the UXO casing and trigger detonation of the main explosive filling, leaving minimal residue and recovery requirements. It is noted that while a risk of the main explosive filling detonating is always present during a high-order disposal, in many instances the UXO may be sufficiently degraded (e.g. casing corroded and seawater ingress) that the donor charge fragments and neutralises the

UXO without full detonation of the main explosive filling. For example, at the Neart na Gaoithe wind farm, only c. 25% of attempted high-order disposals experienced a true high-order detonation of the main explosive filling.

3. Marine mammal occurrence in the Seagreen area

A relatively wide range of cetacean species can potentially occur in Scottish waters; for example, Marine Scotland state that at least 23 species of whales, dolphins and porpoise occur in the nation's inshore waters (Marine Scotland, 2014) and a similar diversity can be expected in the offshore area. Notwithstanding this, based on the available literature (Hague et al., 2020), as well as site-specific surveys, the Seagreen EIA (Seagreen, 2012) identified a restricted sub-set of four cetacean (EPS) and two seal species as key marine mammals in relation to the focus of the impact assessment. The same species were the focus of the 2018 EIA Report (Seagreen, 2018) and 2020 Piling Strategy (Seagreen, 2020). The species are as follows:

- harbour porpoise (*Phocoena phocoena*);
- bottlenose dolphin (*Tursiops truncatus*);
- minke whale (*Balaenoptera acutorostrata*);
- white-beaked dolphin (*Lagenorhynchus albirostris*);
- harbour seal (*Phoca vitulina*); and,
- grey seal (*Halichoerus grypus*).

Although the Risk Assessment focuses upon the above species it should be noted that together this group includes representatives of all Southall et al. (2019) functional hearing groups of marine mammals which may occur in Scottish waters: very high-, high- and low-frequency cetaceans, as well as phocid carnivores (grey and harbour seal).

Table 3.1 outlines the relevant species-specific density estimates and management unit abundance data for marine mammals used in the 2018 EIAR (presented in Volume 3 Appendix 10A: Marine Mammal Baseline Technical Report (2018)).

Table 3.1. Species-specific Management Units (MU), MU estimates and density estimates taken forward for impact assessment

Species	MU	MU estimate	MU Source	Density Estimate	Density Source
Harbour porpoise	North Sea (ICES Assessment Unit)	345,373	SCANS III (Hammond et al., 2017)	SCANS III Block R 0.599 porpoise/km^2	SCANS III (Hammond et al., 2017)
Bottlenose dolphin	Coastal East Scotland	195	Cheney et al. (2013)	98 bottlenose dolphins spread evenly across the area inshore of 20 m depth contour	Agreed in consultation on Seagreen Optimised project assessment (2017 Scoping Opinion)
Minke whale	Celtic and Greater North Seas	23,528	IAMMWG (2015)	SCANS III Block R 0.039 whales/km^2	SCANS III (Hammond et al., 2017)
White-beaked dolphin	Celtic and Greater North Seas	36,287	SCANS III (Hammond et al., 2017)	SCANS III Block R 0.243 dolphins/km^2	SCANS III (Hammond et al., 2017)
Harbour seal	East Scotland	475	Scaled August 2018 haul-out count†	5x5 km grid cell-specific relative density‡	Carter et al. (2020)
Grey seal	East Scotland	15,740	Scaled August 2018 haul-out count†	5x5 km grid cell-specific relative density‡	Carter et al. (2020)

Notes: † MU estimates for seals are derived from August counts scaled to the species-specific estimated proportion of animals hauled out at that time; for grey seals this is based on a count of 3,762 and proportion hauled out of 23.9% (Russell et al., 2016 but note currently under review); for harbour seals a count of 342 and proportion hauled out of 72% (Lonergan et al., 2013). ‡ Relative density estimates for seals presented in Carter et al. (2020) can be scaled according to the most recent at-sea population estimates for the British Isles to provide absolute density.

3.1 Cetaceans

3.1.1 Harbour porpoise

Harbour porpoise are the smallest and most abundant cetacean species in UK waters (Reid et al., 2003). They are typically sighted in small groups between one and three individuals. Animals are frequently sighted throughout coastal habitats with studies suggesting they are highly mobile and cover large distances (Nabe-Nielsen et al., 2011). The most recent UK assessment of the conservation status of harbour porpoise (in contribution to the fourth Article 17 Habitats Directive Report) concluded an 'Unknown' conservation status, but with 'Favourable' range and future prospects (JNCC, 2019b). An overall 'Unknown' status was concluded for all cetacean species regularly occurring in UK waters, largely due to insufficient data on the status of the population (i.e. trends) and habitat (JNCC, 2019b).

Breeding occurs mainly between May and August, with a peak in June, though some calves can be born as early as March. Social groups often gather in late summer (August-September) for mating (Anderwald and Evans, 2010). The gestation period of the harbour porpoise is ten months, with peak mating activity likely to occur in August. Evidence for social and sexual activity in late summer has been widely reported. Females are believed to nurse their calves for between eight and twelve months. Weaning is a gradual process with young starting to take solid food after a month or two.

Site-specific boat-based survey data presented in 2010 and 2011 showed sightings of harbour porpoise in the Seagreen wind farm area in most months; however, encounter rates were generally highest in the spring and summer and relatively low in autumn and winter. The site-specific surveys and a wide range of other data sources, such as SCANS and ECOMMAS, demonstrate that harbour porpoise are common in the study area and there is potential for animals to be impacted by underwater noise generated by UXO clearance activities.

3.1.2 Bottlenose dolphin

In the UK, bottlenose dolphins have been assessed as having an 'Unknown' overall conservation status, with 'Favourable' range (JNCC, 2019a). The Coastal East Scotland population of bottlenose dolphins is the only known remaining resident population in the North Sea and it was for this reason that the Moray Firth SAC was established in order to protect this population. The conservation objectives of the Moray Firth SAC are to avoid the deterioration of the bottlenose dolphin habitat, to achieve a favourable conservation status and to ensure the population size and distribution of the bottlenose dolphins is maintained in the long-term.

The number of individuals using the SAC between 2001 and 2015 has remained stable, albeit with some inter-annual variability, whilst an assessment of the total abundance of the east coast population indicates that the overall population is increasing (Cheney et al., 2018). This means that the proportion of the population that uses the SAC has declined (Graham et al., 2016). Whilst the Moray Firth is clearly an important area for this population, these animals are highly mobile, and have a large range that extends east along the outer Moray Firth coastline and south to the Firth of Tay, Firth of Forth and coastal waters off north-east England (Cheney et al., 2013).

The resident East Scotland bottlenose dolphin population is strictly coastal with most animals encountered in waters less than 20 m deep and within 2 km from the coastline. UXO clearance activities within the wind farm site are unlikely to have potential to impact upon bottlenose dolphin.

3.1.3 Minke whale

Minke whales are widely distributed around the UK, with higher densities recorded on the west coast of Scotland and the western North Sea (Reid et al., 2003). They occur mainly on the continental shelf in water depths less than 200 m and are sighted more frequently in the summer months between May and September. Minke whales in the UK are considered to be part of a single, large MU: the Celtic and Greater North Seas MU (IAMMWG, 2015); their overall conservation status has been assessed as 'Unknown' with 'Favourable' range (JNCC, 2019e).

During site-specific boat-based surveys in 2010 and 2011 minke whale were seen throughout the Seagreen wind farm area. A strong seasonal pattern was recorded, with most minke whales encountered during the spring and summer months in 2010 and 2011, with high rates in May 2010 and June 2011. This seasonal pattern is supported by Anderwald and Evans (2010).

Site-specific surveys, together with other information sources such as SCANS, confirm that although minke whale are present at low densities they have been sighted relatively often in the study area, and more frequently in the summer months. Therefore, they have the potential to be impacted by the effects of underwater noise generated by UXO clearance activities.

3.1.4 White-beaked dolphin

White-beaked dolphins are wide-spread across the northern European continental shelf. The species is the most abundant cetacean in the North Sea after the harbour porpoise (Banhuera-Hinestroza et al., 2009), and the waters off the coast of Scotland and north-east England are one of the four global centres of peak abundance. The species occurs mainly in waters of 50-100 m depth (Reid et al., 2003). Evidence supports the assumption that white-beaked dolphins from around the British Isles and North Sea represent one population, with movement between Scottish waters and the Danish North Sea and Skagerrak (Banhuera-Hinestroza et al., 2009).

During site-specific boat-based surveys of the Seagreen wind farm site, white-beaked dolphins were recorded most often during the summer in both 2010 and 2011. Site-specific surveys, together with other information sources such as SCANS, confirm that white-beaked dolphins have been sighted occasionally in the wind farm area, and, similar to minke whales, are seen more frequently in the summer months. Although present at low densities, they have the potential to be impacted by the effects of underwater noise generated by UXO clearance activities.

3.2 Pinnipeds

3.2.1 Harbour seal

The harbour seal is the smaller of the two seal species resident in UK waters. Seals forage at sea and haul-out on land to rest, moult and breed. Harbour seals normally feed within 40 to 50 km around their haul-out sites and take a wide variety of prey including sandeels, gadoids, herring and sprat, flatfish, octopus and squid (SCOS, 2019).

Harbour seals come ashore in sheltered waters, typically on sandbanks and in estuaries, but also in rocky areas. They give birth to their pups in June and July and moult in August. At these, as well as other times of the year, harbour seals haul-out on land regularly in a pattern that is often related to the tidal cycle.

Harbour seals are widespread around the west coast of Scotland and throughout the Hebrides and Northern Isles. On the east coast, their distribution is more restricted with concentrations in the major estuaries of the Thames, The Wash, the Moray Firth and the Firth of Forth. The harbour seal is a qualifying feature of the Firth of Tay and Eden Estuary SAC, located 46 km south-west of the wind farm site.

Harbour seals were recorded in low numbers during the boat-based surveys of the wind farm site in 2010-2011. Modelled at-sea densities in the wind farm and adjacent areas are estimated to be low (< 1 seal per 5x5 km grid cell); higher densities are estimated closer to the coast, within inshore waters, particularly in the Firth of Forth (Russell et al., 2017). Recently published habitat preference-based modelling of harbour seal at-sea distribution (Carter et al., 2020) show a similar pattern, with areas closer to the coast of greater importance to harbour seal and very low estimated densities of ≤ 0.1 seals per 5x5 km grid cell across the wind farm site.

In the UK, the harbour seal has been assessed as having an overall conservation status of 'Unfavourable – Inadequate' (JNCC, 2019d). Population trajectories vary considerably between regions around the UK; however, populations in the East Scotland MU (and North Coast & Orkney MU) have declined considerably over the past two decades and are continuing to decline (SCOS, 2019).

Harbour seals have the potential to be impacted by the effects of underwater noise generated by UXO clearance activities, although they are present in very low numbers in the wind farm site and adjacent waters, consistent with the relatively large distance from the principal haul-out sites in the region.

3.2.2 Grey seal

The grey seal is the larger of the two seal species resident in UK waters. Grey seals haul-out on land to rest, moult and breed and forage at sea where they range widely, frequently travelling for up to 30 days with over 100 km between haul-out sites (SCOS, 2019). Approximately 38% of the worlds grey seal population breeds in the UK with 86% of these breeding in Scotland. Grey seal population data are assessed using pup counts during the autumn breeding season when females haul-out to give birth. The number of pups throughout Britain has grown steadily since the 1960s but there is clear evidence that the population growth is levelling off in all areas, except the central and southern North Sea where growth rates remain high. The grey seal is considered to have a Favourable Conservation Status in the UK (JNCC, 2019c).

The grey seal is a qualifying feature of the Isle of May SAC, located 52 km south-west of the wind farm site, and the Berwickshire and North Northumberland Coast SAC, located 64 km south of the wind farm site.

Grey seals were recorded in the wind farm site throughout the boat-based surveys in 2010 and 2011, with highest encounter rates in June in both years. Modelled at-sea densities in the wind farm and immediately adjacent areas are estimated to be variable, ranging between 3 and 44 seals per 5x5 km grid cell, and averaging ~11 seals per grid cell (Russell et al., 2017). Higher densities are estimated closer to the coast within the Firth of Tay and St Andrews Bay. Recently published habitat preference-based modelling of grey seal at-sea distribution (Carter et al., 2020) show a similar pattern, with density estimates ranging between 10 and 38 seals per 5x5 km grid cell across the wind farm site and immediately adjacent areas.

It is therefore likely that grey seals will be present in and around the wind farm site during UXO clearance activities and there is potential for animals to be impacted by the effects of underwater noise.

4. Assessment of potential effects of UXO clearance operations

4.1 Potential effects of underwater explosions

Underwater explosions produce a broadband acoustic pulse with very high peak source level and rise time which is extremely brief relative to airgun array and other non-explosive seismic sources (Richardson, 1995). At distances close to the explosion a shockwave is formed, after which the wave propagates as a normal sound wave (Parvin et al., 2007). Example source sound pressure levels (SPL_{peak} dB re 1 µPa @ 1 m) for detonation of freely-suspended certain charge weights (TNTe) include: 0.5 kg = 267 dB; 2 kg = 271 dB; 40 kg = 285 dB (Richardson, 1995; Parvin et al., 2007). The majority of emitted acoustic energy is below a few hundred Hz, decreasing on average by about SEL 10 dB per decade above 100 Hz and a particularly pronounced drop-off in energy levels above c. 5-10 kHz (von Benda-Beckmann et al., 2015; Salomons et al., 2021).

The main potential effects of concern of underwater explosions on an individual animal are: (i) physical trauma (from direct or indirect blast wave effect injury) such as damage to body tissues caused by the blast wave, resulting in immediate or eventual mortality; (ii) auditory impairment (from exposure to the acoustic wave), resulting in a temporary hearing loss (temporary threshold shift, TTS) or permanent auditory injury (permanent threshold shift, PTS) shift in an animal’s hearing threshold; or (iii) behavioural disturbance, such as displacement from habitat and consequent interruption of feeding, mating, breeding, and/or resting (von Benda-Beckmann et al., 2015). Studies of blast effects on cetaceans indicate that smaller species are at greatest risk for shock wave or blast injuries than larger ones (Ketten, 2004), while the risk of auditory impairment is dependent on species- or species group-specific auditory abilities (e.g. Southall et al., 2019).

4.2 Approach to assessment

Scientific understanding of the sound levels generated by UXO clearance and resulting impact ranges is a developing field of research. While dedicated noise monitoring has recently been undertaken during UXO clearance activities at other wind farms in the UK (e.g. Neart na Gaoithe and Moray East), detailed results are not yet available and there is a paucity of empirical data on the sounds from historic UXO detonation activities. As such, a semi-empirical approach to assessing noise levels at range is adopted, with outputs used in conjunction with recommended thresholds for different impacts as detailed in Section 4.2.2. Relevant empirical data from UXO clearance elsewhere in Europe is also discussed in Section 4.7.1.

4.2.1 Estimation of noise levels at range

There are currently no empirically-validated approaches to predicting the underwater noise generated during UXO detonation encompassing the nature and size of all devices that may be present at the Seagreen site. Therefore, impact ranges are estimated using the semi-empirical model published in Soloway and Dahl (2014). This study carried out experimental measurements of peak pressure and sound exposure level (SEL) from underwater detonations of charges from 100 g to 6.1 kg, collected 7 km off the coast of Virginia Beach in the USA.

Equation 1 from Soloway and Dahl (2014) predicts peak pressure at specified ranges depending on the charge weight (in kg TNT equivalent):

$$P_{peak} = 52.4 \times 10^6 \left(\frac{R}{W^{1/3}} \right)^{-1.13}$$

where P_{peak} is the peak pressure in the initial shock wave (in Pa), R is the range (in meters), and W is the UXO charge weight (in kg TNT equivalent).

This equation can be re-arranged to calculate the predicted impact range (R), using specified UXO charge weights (W) and defined impact thresholds (P_{peak}):

$$R = \sqrt[1.13]{\frac{52.4 \times 10^6 \times \left(\sqrt[3]{W}\right)^{1.13}}{P_{peak}}}$$

Soloway and Dahl (2014) also provided an equation for the prediction of SEL (unweighted) at specified ranges:

$$SEL = 6.14 \times \log_{10}\left(W^{1/3} \left(\frac{R}{W^{1/3}} \right)^{-2.12} \right) + 219$$

In this way, impact ranges can be estimated for recommended thresholds for physical trauma, auditory injury (permanent threshold shift, PTS) and temporary hearing loss (temporary threshold shift, TTS) for specific charge/UXO sizes.

4.2.2 Impact thresholds

Physical trauma

Based on data from Yelverton et al. (1973) relating to controlled exposure experiments on submerged terrestrial mammals, Parvin et al. (2007) suggest that with exposure to transient pressure waves of $SPL_{peak} \geq$ 240 dB re 1µPa there is an increasing likelihood of death or severe injury leading to death in a short time. This noise level is taken to be the threshold at which physical trauma to marine mammals may occur.

An energy-based threshold is also considered here for a much lower severity of physical trauma: blast-wave induced ear trauma. Based on exposure of fresh odontocete cadavers (including harbour porpoises) to explosions from varying charge masses in a controlled environment (Ketten, 2004), von Benda-Beckmann et al. (2015) presented that received SEL (unweighted) of > 203 dB re $1\mu Pa^2 \cdot s$ from a single underwater explosion in shallow water (< 50 m depth) were 'very likely' (i.e. > 95% probability) to cause blast wave-induced ear trauma and result in a permanent, acute hearing loss, which is likely to be broad spectrum and a loss of several tens of dB overall. This contrasts to noise-induced PTS (see below), the criteria for the onset of which is considered to represent a permanent elevated threshold of a few dB in some frequencies (Southall et al., 2007).

Auditory impairment

Impact ranges for PTS are based on the functional hearing group-specific thresholds for impulsive sounds proposed by Southall et al. (2019), as presented in Table 4.1. From the dual-criterion, only the unweighted SPL_{peak} threshold is used, as agreed in consultation (see Table 1.2); this metric generally results in larger and more precautionary impact ranges for loud single impulses than weighted SEL (e.g. Salomons et al., 2021). Estimates of ranges for different unweighted SEL values based on different charge sizes are provided in Appendix 1.

Table 4.1. Marine mammal hearing groups, estimated hearing range and sensitivity and injury criteria and corresponding species used in this assessment (Southall et al., 2019).

Estimated hearing range	Estimated region of greatest sensitivity † [peak sensitivity]	Injury criteria (Permanent threshold shift, PTS) for impulsive sounds		Temporary threshold shift (TTS) for impulsive sounds
		SPL_{peak} dB re 1 µPa (unweighted)	SEL_{24} dB re 1 µPa²s (weighted)	$SPL_{0\text{-}peak}$ dB re 1 µPa (unweighted)
Low-frequency (LF) cetaceans (minke whale)				
7 Hz – 35 kHz	200 Hz – 19 kHz	219	183	213
High-frequency (HF) cetaceans (white-beaked dolphin, bottlenose dolphin)				
150 Hz – 160 kHz	8.8 – 110 kHz [58 kHz]	230	185	224
Very high-frequency (VHF) cetaceans (harbour porpoise)				
275 Hz – 160 kHz	12 – 140 kHz [105 kHz]	202	155	196
Phocid carnivores in water (PCW) (grey seal, harbour seal)				
50 Hz – 86 kHz	1.9 – 30 kHz [13 kHz]	218	185	212

Notes: † Region of greatest sensitivity represents low-frequency (F_1) and high-frequency (F_2) inflection points, while peak sensitivity is the frequency at which the lowest threshold of audibility was measured (T_0) (parameters specified in Southall et al., 2019).

Behavioural disturbance

There are no agreed thresholds for the onset of a behavioural response from underwater noise generated by explosions during UXO clearance activities. Empirically-derived relationships between noise levels and the probability of a response to pile driving noise are not appropriate to apply here due to the very different nature of the sound. Other assessments of UXO clearance activities have used the TTS-onset threshold to indicate the level at which a 'fleeing' response may be expected to occur in marine mammals. This is a result of discussion in Southall et al. (2007) which states that in the absence of empirical data on responses, the use of the TTS-onset threshold may be appropriate for single pulses (like UXO detonation):

"Even strong behavioral responses to single pulses, other than those that may secondarily result in injury or death (e.g., stampeding), are expected to dissipate rapidly enough as to have limited long-term consequence. Consequently, upon exposure to a single pulse, the onset of significant behavioral disturbance is proposed to occur at the lowest level of noise exposure that has a measurable transient effect on hearing (i.e., TTS-onset). We recognize that this is not a behavioral effect per se, but we use this auditory effect as a de facto behavioral threshold until better measures are identified. Lesser exposures to a single pulse are not expected to cause significant disturbance, whereas any compromise, even temporarily, to hearing functions has the potential to affect vital rates through altered behavior." (Southall et al., 2007).

Therefore, an estimation of the extent of behavioural disturbance is based on the sound levels at which the onset of TTS is predicted to occur from impulsive sounds. TTS thresholds are taken as those proposed for different functional hearing groups by Southall et al. (2019), as presented in Table 4.1.

4.3 Charge and UXO sizes for predicting impact ranges

In the sections below, impacts are predicted for a variety of explosive sizes which encompass the range of potential UXO which may require disposal in the Seagreen site (Section 2.2) and different sizes of donor charges which may be used (Section 2.7).

Table 4.2 summarises these charges and UXO sizes. For some smaller UXOs of specific size (based on experiences at Neart na Gaoithe), a combined UXO and donor charge size is provided to help guide mitigation planning should such UXO also be commonly encountered at Seagreen.

It is noted that the approach to estimating impact ranges presented in Soloway and Dahl (2014) relates to the TNT equivalent (TNTe) – a common reference point for assessing the relative power of explosive materials. For high-explosives and donor charges, the NEQ can be taken to equal TNTe. For other UXO, particularly WWII mines, it was common to mix TNT with an alternative explosive material (due to shortages of TNT) and therefore the NEQ may differ to the TNTe. In most such instances, the alternative material had a lower relative effectiveness than TNT and so the NEQ represents a conservative estimate of the TNTe and therefore impact ranges. Where the composition of the UXO may have a TNTe exceeding its NEQ, the TNTe is likely to be within 10% of the NEQ, and this has been accounted for in the maximum possible UXO size which has been assessed in the sections below. In reality, the age and anticipated condition of WWII UXOs is such that there is a high probability of degradation of the explosive material.

Table 4.2. UXO and charge sizes for which impact ranges are predicted

Charge/UXO size (NEQ)	Description / Relevance to Seagreen site
Low-order and low-yield donor charge configurations	
80 g	Maximum size of Barracuda shaped charge used for low-order disposal (range 30-80 g).
500 g	Size of charge used to provide a 'clearing shot' to neutralise any remaining unstable material following a low-yield or low-order disposal.
1.5 kg	2 x 750 g Barracuda shaped charges (HYDRA variant) used for low-yield disposal of most UXO
3 kg	4 x 750 g Barracuda shaped charges (HYDRA variant) used for low-yield disposal of German ground mines
High-order donor charge options	
1.2 kg	Single Barracuda shaped charge; most common donor charge to be used in high-order disposal
3.5 kg	Single Barracuda blast-fragmentation charge; used in high-order disposal
Potential UXOs	
6.5 kg	Approximate upper limit of most artillery and naval projectiles which may be found in the site (5 kg) plus typical 1.2 kg donor charge.
15 kg	Representative of intermediate size artillery and naval projectile, and upper limit of some of the most frequently encountered UXO at Neart na Gaoithe.
25 kg	Upper limit of artillery and naval projectiles with a lower likelihood of occurring in the site; typical NEQ of small high-explosive bombs
36 kg	100 lb (32.5 kg) ASW charge: the UXO type encountered at Neart na Gaoithe which accounted for the majority of true high-order detonations. UXO plus worst-case donor charge (3.5 kg)
50 kg	Lower limit of depth charges that may be encountered.
100 kg	Within the range of depth charges that may be encountered. Approximate size of most commonly encountered UXO at Neart na Gaoithe (15" artillery shell).
227 kg	Common size of British buoyant mine. Largest UXO cleared at Neart na Gaoithe wind farm. Approximate likely upper limit of large high-explosive bomb.
300 kg	Upper limit of British or German buoyant mine and torpedoes.
500 kg	Approximate lower limit of German ground mine / upper limit of British ground mine.
800 kg	Most likely upper limit of German ground mine.
1,000 kg	Upper limit of UXOs which may occur, but with a low likelihood, in the site (i.e. German ground mine or large HE bomb of 900 kg), including 10% buffer to account for uncertainty over TNTe.

Notes: UXOs of ≥ 500 kg are shaded grey as desk-based studies suggest that encountering UXOs exceeding 300 kg are unlikely or very unlikely. Any UXO exceeding 300 kg will be discussed with NS and MMS on a case by case basis.

In the estimation of noise impact ranges for high-order disposal of UXOs, it is not possible to take into account a range of variables such as UXO design, composition, age, condition, orientation, or whether the UXO is covered by sediment. Therefore, these estimates provide an indication of the noise output from each detonation, but are subject to uncertainty. Estimates are precautionary, as they assume the UXO is not buried, degraded or subject to any other significant departure from its original condition. The estimates also assume a worst-case freely suspended charge, and that the blast from the main and donor charges are combined. The same applies to low-order disposal with the worst-case assumption that a high-order detonation of the UXO occurs.

For low-yield disposal, the only explosive detonation will be that of the donor charge(s); these are of a known explosive quantity, condition and position, and therefore estimated impact ranges are subject to less uncertainty and precaution than those of UXO detonations.

4.4 Impact assessment results

4.4.1 Physical trauma

Impact ranges

The predicted ranges at which potentially lethal physical trauma or blast-wave ear trauma may occur for a range of UXO and charge sizes are shown in
Table 4.3.

Table 4.3. Estimated impact ranges for potentially lethal physical trauma (SPL_{peak} ≥ 240 dB re 1µPa) and very likely blast wave-induced ear trauma (SEL > 203 dB re 1µPa^2·s)

Charge/UXO size (NEQ)	Impact range (m) for potentially lethal physical trauma	Impact range (m) for 'very likely' blast wave ear trauma
Low-order and low-yield donor charge configurations		
80 g	14	5
500 g	26	12
1.5 kg	38	21
3 kg	48	29
High-order donor charge options		
1.2 kg	35	19
3.5 kg	50	31
Potential UXOs (assuming full high-order detonation)		
6.5 kg	62	42
15 kg	82	64
25 kg	97	82
36 kg	110	98
50 kg	122	116
100 kg	154	162
227 kg	203	243
300 kg	222	278
500 kg	264	357
800 kg	308	450
1,000 kg	332	502

Notes: UXOs of ≥ 500 kg are shaded grey as desk-based studies suggest that encountering UXOs exceeding 300 kg are unlikely or very unlikely. Any UXO exceeding 300 kg will be discussed with NS and MMS on a case by case basis.

Number of animals potentially impacted

Estimated impact ranges for physical trauma are all ≤ 502 m, and ≤ 278 m for UXO up to 300 kg NEQ (Table 4.3). Based on the anticipated density of animals in the area, without mitigation, less than one individual of any species would be impacted. The estimated physical trauma impact ranges for detonation of low-order or low-yield donor charges only is no more than a few tens of metres. This indicates that there is a very low risk of physical trauma to any EPS even from high-order detonation of UXO of 1,000 kg, and that standard mitigation measures of ensuring no animals are within a 1 km radius of the detonation (JNCC, 2010) will be sufficient to reduce the risk of physical trauma to effectively zero.

4.5 Auditory injury

Impact ranges

The predicted ranges at which PTS may occur for a range of UXO and charge sizes are shown in Table 4.4.

Table 4.4. Estimated impact ranges for auditory injury (PTS) based on the functional hearing group-specific unweighted impulsive noise SPL_{peak} threshold proposed by Southall et al. (2019).

Charge/UXO size (NEQ)	PTS impact range (km) for each species			
	Minke whale	Dolphins	Harbour porpoise	Seals
Low-order and low-yield donor charge configurations				
80 g	0.1	< 0.1	0.7	0.1
500 g	0.2	< 0.1	1.3	0.5
1.5 kg	0.3	0.1	1.8	0.4
3 kg	0.4	0.1	2.3	0.5
High-order donor charge options				
1.2 kg	0.3	0.1	1.7	0.3
3.5 kg	0.4	0.1	2.4	0.5
Potential UXOs (assuming full high-order detonation)				
6.5 kg	0.5	0.2	3.0	0.6
15 kg	0.7	0.2	3.9	0.8
25 kg	0.8	0.3	4.7	0.9
36 kg	0.9	0.3	5.3	1.0
50 kg	1.0	0.3	5.9	1.2
100 kg	1.3	0.4	7.4	1.5
227 kg	1.7	0.6	9.7	1.9
300 kg	1.9	0.6	10.7	2.1
500 kg	2.2	0.7	12.7	2.5
800 kg	2.6	0.9	14.8	2.9
1,000 kg	2.8	0.9	16.0	3.1

Notes: UXOs of ≥ 500 kg are shaded grey as desk-based studies suggest that encountering UXOs exceeding 300 kg are unlikely or very unlikely. Any UXO exceeding 300 kg will be discussed with NS and MMS on a case by case basis.

Number of animals potentially impacted

The predicted impact ranges can be combined with estimates of animal density (see Table 3.1) to predict the number of animals that may potentially experience PTS. Results are presented in Table 4.5 for minke whale, white-beaked dolphin and harbour porpoise, assuming no mitigation measures are taken. The east Scotland bottlenose dolphin population is restricted to coastal waters, largely within 2 km of the shore and the 20 m depth contour; as the UXO clearance activities will all occur over 20 km from such areas, and the PTS impact ranges for dolphins are all < 1 km, no bottlenose dolphins are predicted to be exposed to noise levels which may result in PTS.

For minke whales and white-beaked dolphins, assuming no mitigation, less than one individual per species is predicted to experience PTS for all UXO sizes, with the exception of a predicted one minke whale to experience PTS for high-order detonation of a 1,000 kg UXO. For harbour porpoise, assuming no mitigation, up to 10 individuals are predicted to experience PTS from low-yield disposal and between 17-482 individuals for high-order disposal, depending on the UXO size.

Table 4.5. Estimated numbers of EPS at risk of potential auditory injury (PTS) from the clearance of UXO of different sizes, including the proportion of the reference population, assuming no mitigation in place.

Charge/UXO size (NEQ)	Estimated numbers of individuals at risk of PTS (proportion of management unit)		
	Minke whale	White-beaked dolphin	Harbour porpoise
	0.039 animals/km^2	0.243 animals/km^2	0.599 animals/km^2
Low-order and low-yield donor charge configurations			
80 g	< 0.1 (< 0.001)	< 0.1 (< 0.001)	1 (< 0.001)
500 g	< 0.1 (< 0.001)	< 0.1 (< 0.001)	5 (< 0.001)
1.5 kg	< 0.1 (< 0.001)	< 0.1 (< 0.001)	6 (< 0.001)
3 kg	< 0.1 (< 0.001)	< 0.1 (< 0.001)	10 (< 0.001)
High-order donor charge options			
1.2 kg	< 0.1 (< 0.001)	< 0.1 (< 0.001)	5 (< 0.001)
3.5 kg	< 0.1 (< 0.001)	< 0.1 (< 0.001)	11 (< 0.001)
Potential UXOs (assuming full high-order detonation)			
6.5 kg	< 0.1 (< 0.001)	< 0.1 (< 0.001)	17 (< 0.001)
15 kg	0.1 (< 0.001)	0.0 (< 0.001)	29 (< 0.001)
25 kg	0.1 (< 0.001)	0.1 (< 0.001)	42 (< 0.001)
36 kg	0.1 (< 0.001)	0.1 (< 0.001)	52 (< 0.001)
50 kg	0.1 (< 0.001)	0.1 (< 0.001)	66 (< 0.001)
100 kg	0.2 (< 0.001)	0.1 (< 0.001)	103 (< 0.001)
227 kg	0.4 (< 0.001)	0.3 (< 0.001)	177 (0.001)
300 kg	0.4 (< 0.001)	0.3 (< 0.001)	215 (0.001)
500 kg	0.6 (< 0.001)	0.4 (< 0.001)	304 (0.001)
800 kg	0.8 (< 0.001)	0.6 (< 0.001)	412 (0.001)
1,000 kg	1.0 (< 0.001)	0.6 (< 0.001)	482 (0.001)

Notes: Bottlenose dolphin are not included here as due to their near-shore distribution (see Section 3.1.2) they are not expected to be present within the extent of predicted PTS impact.

4.6 Behavioural disturbance

Impact ranges

The predicted ranges at which the onset of TTS, as a proxy for disturbance, may occur for a range of UXO and charge sizes are shown in Table 4.6.

Table 4.6. Estimated impact ranges for behavioural disturbance, using temporary threshold shift criteria for functional hearing groups for unweighted impulsive noise ($SPL_{0\text{-}peak}$) proposed by Southall et al. (2019)

Charge/UXO size (NEQ)	Behavioural disturbance (TTS) impact range (km) for each species			
	Minke whale	Dolphins	Harbour porpoise	Seals
Low-order and low-yield donor charge configurations				
80 g	0.2	0.1	1.3	0.2
500 g	0.4	0.1	2.3	0.5
1.5 kg	0.6	0.2	3.4	0.7
3 kg	0.8	0.2	4.2	0.8
High-order donor charge options				
1.2 kg	0.6	0.2	3.1	0.6
3.5 kg	0.8	0.3	4.5	0.9
Potential UXOs (assuming full high-order detonation)				
6.5 kg	1.0	0.3	5.5	1.1
15 kg	1.3	0.4	7.3	1.4
25 kg	1.5	0.5	8.6	1.7
36 kg	1.7	0.6	9.7	1.9
50 kg	1.9	0.6	10.8	2.1
100 kg	2.4	0.8	13.6	2.7
227 kg	3.2	1.0	17.9	3.5
300 kg	3.5	1.1	19.7	3.9
500 kg	4.1	1.3	23.3	4.6
800 kg	4.8	1.6	27.3	5.3
1,000 kg	5.2	1.7	29.4	5.8

Number of animals potentially impacted

The predicted impact ranges are combined with estimates of animal density (see Table 3.1) to predict the number of animals that may potentially experience behavioural disturbance. Results are presented in Table 4.5 for minke whale, white-beaked dolphin and harbour porpoise, assuming no mitigation measures are taken. The maximum predicted range of behavioural disturbance to dolphins is 1.7 km; therefore, no bottlenose dolphins are predicted to be subject to behavioural disturbance.

For all species and charge sizes, the proportion of the management unit (MU) predicted to be disturbed is ≤ 0.005%, with this maximum proportion corresponding to a conservative worst-case scenario of 1,627 harbour porpoise disturbed by the high-order detonation of a 1,000 kg UXO. A more realistic conservative worst-case scenario would be a high-order detonation of a 300 kg UXO, resulting in the potential disturbance of 730 harbour porpoise (0.002% MU). For minke whale and white-beaked dolphin, fewer than 4 individuals per species are predicted to be disturbed for high-order detonation of a 1,000 kg UXO.

Table 4.7. Estimated numbers of EPS at risk of behavioural disturbance (TTS) from the clearance of UXO of different sizes, including the proportion of the reference population

Charge/UXO size (NEQ)	Estimated numbers of individuals at risk of TTS (proportion of management unit)		
	Minke whale	White-beaked dolphin	Harbour porpoise
	0.039 animals/km^2	0.243 animals/km^2	0.599 animals/km^2
Low-yield donor charge configurations			
80 g	< 0.1 (< 0.001)	< 0.1 (< 0.001)	3 (< 0.001)
500 g	< 0.1 (< 0.001)	< 0.1 (< 0.001)	10 (< 0.001)
1.5 kg	< 0.1 (< 0.001)	< 0.1 (< 0.001)	22 (< 0.001)
3 kg	0.1 (< 0.001)	< 0.1 (< 0.001)	33 (< 0.001)
High-order donor charge options			
1.2 kg	< 0.1 (< 0.001)	< 0.1 (< 0.001)	18 (< 0.001)
3.5 kg	0.1 (< 0.001)	0.1 (< 0.001)	38 (< 0.001)
Potential UXOs (assuming full high-order detonation)			
6.5 kg	0.1 (< 0.001)	0.1 (< 0.001)	57 (< 0.001)
15 kg	0.2 (< 0.001)	0.1 (< 0.001)	99 (< 0.001)
25 kg	0.3 (< 0.001)	0.2 (< 0.001)	139 (< 0.001)
36 kg	0.4 (< 0.001)	0.2 (< 0.001)	177 (0.001)
50 kg	0.4 (< 0.001)	0.3 (< 0.001)	219 (0.001)
100 kg	0.7 (< 0.001)	0.5 (< 0.001)	348 (0.001)
227 kg	1.3 (< 0.001)	0.8 (< 0.001)	603 (0.002)
300 kg	1.5 (< 0.001)	0.9 (< 0.001)	730 (0.002)
500 kg	2.1 (< 0.001)	1.3 (< 0.001)	1,022 (0.003)
800 kg	2.8 (< 0.001)	2.0 (< 0.001)	1,402 (0.004)
1,000 kg	3.3 (< 0.001)	2.2 (< 0.001)	1,627 (0.005)

Notes: Bottlenose dolphin are not included here as due to their near-shore distribution (see Section 3.1.2) they are not expected to be present within the extent of predicted TTS impact.

4.7 Areas of uncertainty and precaution in predictions of impact ranges

In the estimation of noise impact ranges for high-order disposal of UXOs, it is not possible to take into account a range of variables which complicate model-based predictions. Cheong et al. (2020) identify these variables as including: type, physical dimensions and shape of the UXO; degradation of UXO due to long exposure to the environment; degree to which the munition is buried in the sediment; seabed type; and, the potential for multiple items of UXO to be aggregated (Cheong et al., 2020). Furthermore, sound levels at range from the donor charge and UXO itself will also be affected the type of explosive used, water depth at UXO location, and variations in environmental conditions (e.g. seabed, bathymetry, sea state) between the source and receiver. Many of these factors, for example the degradation of explosive material over time or burial of munition, are likely to result in sound levels significantly lower than predicted by models based just on charge size (Cheong et al., 2020), such as are presented here. The estimates also assume a worst-case freely suspended charge, and that the blast from the main and donor charges are combined (i.e. a full high-order detonation of both the donor and main charge). The same applies to low-order disposal with the worst-case assumption that a high-order detonation of the UXO occurs.

A further limitation that must be considered is that there will be variation in noise levels at different positions in the water column, which are not taken into account. Noise levels near the surface, and hence the exposure, can be lower than elsewhere in the water column – to which the prediction of noise levels at range relates (von Benda-Beckmann et al., 2015). Therefore, the risk to animals near the surface may therefore be lower than indicated by the impact ranges and so the results in this assessment can be considered conservative in that not all animals will be at the depth for which impact ranges relate.

With specific reference to low-order deflagration approaches to UXO disposal, Cheong et al. (2020) conclude that the overall combined acoustic output of the UXO and donor charge(s) potentially observed from real-world UXO clearances will likely lie somewhere between the theoretical prediction of two limits: (i) at minimum, that of just the donor charge assuming no additional contribution from the explosives within the UXO; and, (ii) a potential worst case maximum of the combined explosive charge of both the donor and main UXO explosive filling, detonating at levels predicted for a non-degraded, freely-suspended state.

Therefore, the estimates presented here provide an indication of the noise output from each detonation, and associated impacts, but are subject to uncertainty, and, for the reasons outline above, are generally expected to over-estimate noise levels for larger UXOs.

4.7.1 Evidence from noise monitoring of UXO clearance

During the UXO clearance campaign at Neart na Gaoithe wind farm (overview provided in Section 2.2.1), 37 UXO detonations were monitored, of sizes ranging from 1-102 kg (NEQ) and with donor charges of 2.5 or 5 kg. Of the 37, only four items experienced high-order detonation, largely a result of the age, condition and type of the munition[8]. Static monitoring equipment was deployed at locations; depending on the location of the UXO the range of monitoring was 1.3 – 33 km. Initial evaluation of recordings showed that transmission loss was higher than expected, with no influence of environmental factors (although noting that clearance did take place in calm conditions), and with no significant changes between UXO sizes for those that were monitored.

von Benda-Beckmann et al. (2015) reported results of noise measurements from controlled high-order detonations of seven UXOs in the Dutch sector of the southern North Sea. UXOs were aerial bombs found on land but detonated on the seafloor in 26-28 m water depth, and included six UXO at 263 kg TNTe and one of 121 kg TNTe. Noise measurements were taken at different depths in the water column at distance between 100m and 2 km of the detonation. In terms of impact ranges associated with the 263 kg UXO detonations, the authors noted that the largest distance at which there was a risk of ear trauma (> 203 dB re 1 $\mu Pa^2 \cdot s$) was approximately 500 m, while measurements at the furthest distance of 2 km recorded a

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[8] See minutes of 8th December 2020 meeting of he Forth and Tay Regional Advisroy Group – Marine Mammals Sub-Group: https://marine.gov.scot/data/ftrag-marine-mammals-meeting-minutes-04022021

minimum SEL of 191 dB re 1 µPa²·s, exceeding the SEL-based risk threshold above which noise-induced PTS in harbour porpoise was considered very likely (190 dB re 1 µPa²·s; see Appendix 1 for further details of SEL-based thresholds of injury). These results confirm that for a UXO of 263 kg, noise-induced PTS in harbour porpoise is highly likely to a distance of 2 km, with an onset of PTS (179 dB re 1 µPa²·s) expected at a greater distance, as was shown for the semi-empirical modelling and use of an SPL_{peak} threshold for onset of PTS presented in Table 4.4.

More recently, Salomons et al (2021) presented noise measurements at distances between 1.5 km and 12 km of the high-order detonation of two historical UXOs in 20 m water depth in the North Sea, including a 325 kg TNTe British ground mine and a 140 kg TNTe British buoyant mine. Both UXOs exhibited corroded outer casings, but comparisons between measured and predicted noise levels suggest full high-order detonations. Measurements indicate that for both UXO, noise levels were such that thresholds for the onset of noise-induced PTS in harbour porpoise (across all metrics) were exceeded at 1.5 km distance, but not at 6 km distance (Table 4.8). The higher noise levels for the smaller UXO at distances of ≥ 6 km were suggested to be a result of different propagation conditions related to sediment characteristics. The authors provide calculated PTS impact ranges for different metrics: 4 km for SPL_{peak}; 2-6 km for unweighted SEL levels, dominated by frequencies around 250-400 Hz; and 2.5-4 km for weighted SEL levels, dominated by frequencies around 5-8 kHz due to the VHF frequency weighting. These results confirm the more precautionary use of SPL_{peak} vs weighted SEL in estimating impact ranges (as has been adopted in the current assessment, but that estimates using different metrics were comparable, at least for the UXOs and conditions in question. Their general conclusion was that harbour porpoises are at risk of permanent hearing loss at distances of several kilometres from large explosives, and therefore recommended that mitigation measures are applied such as deterring animals from the area, use of bubble curtains, or considering methods of UXO disposal which do not cause full detonation (e.g. low-yield or low-order) (Salomons et al., 2021).

Table 4.8. Measured sound levels at range from two detonated UXOs as reported in Salomons et al. (2021)

Measurement distance	SPL_{peak} dB re 1 1 µPa²	Unweighted SEL dB 1 µPa²·s	Weighted SEL 1 µPa²·s (harbour porpoise)†
UXO: 325 kg TNTe (British ground mine)			
1.5 km	212.9	194.7	160.2
6 km	193.8	174.4	145.2
12 km	183.7	165.1	135.3
UXO: 140 kg TNTe (British buoyant mine)			
1.5 km	211.6	195.0	164.8
6 km	197.9	178.2	149.1
12 km	187.2	170.2	140.4

Notes: † Based on VHF functional hearing group in Southall et al. (2019). Source: Salomons et al. (2021).

4.7.2 Transition from impulsive to non-impulsive sounds

With increased distance from the source, impulsive noise loses some of its impulsive characteristics and becomes more of a non-impulsive noise (Hastie et al., 2019; Southall et al., 2019). For a sound of a given amplitude, the potential for auditory injury is less from non-impulsive compared to impulsive sounds, and therefore such a transition in acoustic characteristics has implications for the range at which auditory injury may occur. This is particularly relevant for assessments of auditory injury from underwater detonations due to the sometimes large ranges over which injury effects are predicted to occur, especially for harbour porpoise. However, it is difficult to determine the distance at which an impulsive noise becomes more like a non-impulsive noise, as results for seismic pulses and pile-driving show considerable variability both within and between different measures of impulsiveness at range and measurement sites, and there is currently no agreed best measure of impulsiveness on which to base such assessments (Hastie et al., 2019). Specific methods by which to estimate the transition from impulsive to non-impulsive noise are currently being developed (Southall et al., 2019; Martin et al., 2020), but this is an ongoing area of uncertainty and requires further research, not least in what the marine mammal ear senses as impulsive or non-impulsive.

With reference to 3 km as an estimate of a distance at which transition away from an impulsive to a more non-impulsive type of noise could occur, as suggested in draft NMFS (2018) guidance[9], an upper conservative estimate of 5 km for the transition from impulsive to non-impulsive noise was suggested by Subacoustech in recent risk assessments for some offshore wind UXO clearance campaigns (e.g. Moray East, Norfolk Boreas). For Moray East, they suggested that, as the impact ranges based on non-impulsive PTS criteria are less than 1 km for all species (for a charge of up to 390 kg), a distance of 5 km is likely to be the limit of PTS onset (Royal HaskoningDHV, 2019). Such a distance limit to the onset of PTS from impulsive sounds has not been widely adopted in subsequent risk assessments, and more research is required to understand the transition from impulsive to non-impulsive sounds and its implications for auditory injury to marine mammals. Evidence for other impulsive sound sources (pile-driving and airguns) does indicate that some measures of impulsiveness change markedly within c. 10 km of the source (Hastie et al., 2019) and, therefore, PTS impacts at ranges of multiple kilometres are likely to be over-estimated.

[9] But not listed in final guidance.

5. Mitigation measures

A Marine Mammal Mitigation Plan (MMMP) has been developed for the purpose of mitigating the risk of physical trauma and auditory injury (PTS) to marine mammals by the proposed UXO clearance activities at the Seagreen offshore wind farm site, as are described in Section 2. The MMMP specifies measures which correspond to the assessment of potential effects presented in Section 4, to ensure that, as far as is possible, no marine mammals are present within the area where either physical trauma or PTS could arise.

For convenience during operations, the MMMP is provided as a stand-alone document in Appendix 3. Here, the procedures specified in the MMMP are justified and summarised prior to making conclusions on the potential for residual effects (i.e. post-mitigation) in Section 6.

It is noted that the MMMP presented here can be considered a proposed list of measures and procedures, which can be modified in accordance with advice received from the MS-LOT and their advisors as appropriate prior to UXO clearance activities commencing. Additionally, once UXO identification surveys are complete, MS-LOT will be provided with further details of the anticipated number, location and type of UXO that may require clearance.

5.1 Alternative methods of UXO disposal

In the first instance, mitigation will take the form of avoiding the need for the use of explosives, either by leaving the confirmed UXO in situ and micro-siting construction work and infrastructure around it, or by relocating the UXO to a safe place and leaving in situ. However, avoidance or relocation may not be possible for some UXO and, therefore, as a worst-case scenario up to 20 UXO detonations may be required.

High-order disposal of UXO, where an attempt is made to fully detonate the contents of the UXO, represents the highest potential for impacts to marine mammals. Therefore, low-yield and low-order disposal will be preferentially applied where it is suitable to do so. The donor charge sizes for low-order disposal are the smallest of all disposal approaches and therefore, where successful, low-order disposal represents the lowest potential impact. However, as a risk remains that a low-order disposal attempt may result in a high-order detonation of the UXO, low-yield disposal is preferred. As identified in Section 4, the potential for physical trauma, PTS or behavioural disturbance is much reduced for low-yield disposal, corresponding only to the size of the donor charges to be used.

Due to the ongoing UXO identification survey and need to approach each UXO on a case-by-case basis to determine the most appropriate method of disposal, it is not currently possible to determine how many UXO may require high-order disposal vs how many may be suitable for low-yield or low-order disposal. Nonetheless, it can be assumed that fewer than the maximum anticipated 20 UXO will need to undergo high-order disposal, and of those, only a subset are likely to undergo a full high-order detonation of the main UXO in addition to the donor charge. While there is a small (10-20%) chance that any low-order disposal attempted may result in a high-order detonation, even if this approach were to be applied to a maximum of 20 UXOs, only between 2-4 of those attempts might be expected to result in a high-order detonation of the main UXO. Consequently, it is likely that the majority of explosive detonations during the planned UXO clearance operations will exhibit an acoustic output largely proportional to that of the donor charges of up to 3.5 kg NEQ each.

In the sections below, where relevant, a distinction is made between the different disposal approaches when outlining mitigation measures. Due to the potential risk of low-order disposal resulting in a high-order detonation, mitigation measures for low-order disposal assume the worst-case scenario of full high-order detonation of the UXO.

5.2 Noise abatement approaches

Verfuss et al. (2019) provide a recent review of the suitability of noise-abatement approaches to UXO detonation, identifying big bubble curtains as the only technique to have been tested and used in the field for such purpose. Significant reductions in noise levels up to c. 20 dB have been reported for a range of charges sizes from 1 kg to 300 kg, although noise reductions have generally been lower for larger UXO sizes. Successful applications have generally been restricted to shallow waters of 30 m depth or shallower. While applications for mitigating pile-driving noise have been conducted in water depths up to 45 m, the application of big bubble curtains in waters deeper than 40 m is challenging due to the need for an increasing number of compressors to form a suitable bubble curtain at higher hydrostatic pressures, and to counteract against the drift of the bubbles on their path to the water surface (Verfuss et al., 2019). There are also operational limitations in terms of maximum current speeds and significant wave height, and implementation may be costly and time-consuming.

It is not proposed to deploy bubble curtains as a noise abatement approach to mitigation during UXO clearance operations at the Seagreen site. As the minimum water depth throughout the Seagreen site is c. 40 m at Lowest Astronomical Tide, the use of bubble curtains is considered to be technically challenging and may be of limited effectiveness. Alternatives methods to high-order UXO disposal provide an option for substantially reducing the noise generated from UXO clearance, and these will be implemented as described in Sections 2.7 and 5.1.

5.3 UXO clearance mitigation procedures

The JNCC guidelines for minimising the risk of injury to marine mammals from using explosives (JNCC, 2010) provide the base from which the MMMP has been developed, with details of ADD use and soft-start charges tailored to the anticipated UXO sizes requiring clearance at the Seagreen site and the different methods of UXO disposal which may be applied. Consultation feedback and relevant experience from UXO clearance operations at other sites has also been incorporated.

A flow-chart for the proposed mitigation procedures is provided in Figure 2. Details of each stage are presented in the full MMMP in Appendix 3.

5.3.1 Mitigation zone and pre-detonation search

A mitigation zone of 1 km radius from the detonation location will be established, within which it will be ensured, through visual observations (trained MMOs), and PAM where required, that no marine mammals are present prior to the detonation event. Visual monitoring and PAM will be conducted in accordance with JNCC (2010) guidelines. Detonations will only occur during daylight and with a strong preference for calm sea conditions.

Ensuring that no marine mammals are present in the mitigation zone prior to detonation will reduce the risk of physical trauma to any species of marine mammal to negligible.

5.3.2 Acoustic Deterrence Device (ADD)

The risk assessment concluded that for some UXO clearance activities, there is a risk of auditory injury to harbour porpoise, minke whale and seals at a greater range than can be mitigated by monitoring of the 1 km mitigation zone alone. Therefore, an ADD will be operated for a pre-determined length of time, concurrent to the pre-detonation search, to deter marine mammals to a greater distance prior to any detonation. The ADD to be used is the Lofitech seal scarer. The ADD will be deployed from the RHIB as close to the UXO detonation site as possible and activated for a pre-determined length of time prior to any detonation, as outlined below and in the MMMP.

Evidence of the effectiveness of ADDs, and the Lofitech device in particular, is presented in Appendix 2. Overall, there is good evidence for the effective deterrence ranges of the Lofitech device on harbour porpoises and harbour seals, but less available for minke whales and none for dolphin species (McGarry et al., 2020). In summary, the evidence available suggests that the Lofitech is highly effective in deterring harbour porpoise to at least 7.5 km (i.e. near exclusion) with some deterrence observed to 15 km range (Brandt et al., 2013a; Brandt et al., 2013b). A recent study also showed strong deterrence from a single 15 min ADD exposure, including >50% chance of a porpoise response at distances up to 21.7 km within the 3 hours after exposure (Thompson et al., 2020). For minke whale, consistent avoidance to a 15 min exposure has been reported to >1 km, with several animals continuing to swim further away to a distance of between c. 3 km and 4.5 km (McGarry et al., 2017). Deterrence to ~1 km has been reported in harbour seals (Gordon et al., 2015; Gordon et al., 2019), with suggestions that this can also be applied to grey seals (Sparling et al., 2015).

For the Seagreen UXO clearance activities, it is planned to operate the ADD for different durations according to the UXO disposal method used, UXO/charge size, and associated predicted impact ranges. It has been suggested by some that a precautionary approach of tailoring mitigation to allows animals time to swim to twice the distance of the injury zone should be adopted (Herschel et al., 2013); however, considering the strong and far-reaching responses to relatively short exposures observed by some species, there is a need to carefully balance the need to remove animals from the impact area without causing large-scale disturbance (Brandt et al., 2013b; Thompson et al., 2020).

For all methods of UXO disposal that may be used and UXO/charge sizes that may be detonated, PTS impact ranges for harbour porpoise exceed the 1 km mitigation zone[10]. Furthermore, as noted by Sparling et al. (2015), even in good sighting/detection conditions, the probability of harbour porpoise detection by visual or acoustic means is likely to be lower than 100%. Therefore, the following ADD use is recommended (outlined in Table 5.1), based on the following assumptions:

- an instant response to ADD activation (all species)

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[10] The exception would be a successful low-order disposal; however, as there is a chance of a high-order detonation of the UXO from this approach, a high-order detonation is assumed for mitigation planning.

- a starting position of 500 m from the ADD (more precautionary than assuming 100% effectiveness of monitoring of the 1 km mitigation zone; more realistic than considering zero metres given some initial displacement from vessel activity associated with the UXO clearance set-up is highly likely) (all species)
- animals swim in a straight line away from the ADD at a speed of 1.5 m/s (harbour porpoise; minke whale – highly precautionary) or 1.15 m/s (seals; net swim speed reported for harbour seals in Gordon et al., 2019)

Table 5.1. Recommended ADD use for different UXO disposal scenarios and sizes, and associated justification

UXO disposal scenario	Minimum ADD duration prior to detonation	Justification
1. Low-yield disposal where combined donor charge of **up to 3.0 kg**	22 min	This is expected to displace harbour porpoise to 2.5 km range, which is sufficient for the maximum predicted PTS impact range of 2.3 km for a 3.0 kg charge. The PTS impact range for all other species of marine mammal for this disposal method is ≤ 500 m.
2. Low-order or high-order disposal where UXO + charge size is **up to 3.0 kg**	22 min	As above
3. Low-order or high-order disposal where UXO + charge size is **up to 6.5 kg**	30 min	This is expected to displace harbour porpoise to 3.2 km range, which is sufficient for the maximum predicted PTS impact range of 3.0 km for a combined UXO/charge size of 6.5 kg. The PTS impact range for all other species of marine mammal for this disposal method and UXO/charge is ≤ 600 m.
4. Low-order or high-order disposal where UXO + charge size is **up to 15 kg**	40 min	This is expected to displace harbour porpoise to 4.1 km range, which is sufficient for the maximum predicted PTS impact range of 3.9 km for a combined UXO/charge size of 15 kg. The PTS impact range for all other species of marine mammal for this disposal method and UXO/charge size is ≤ 800 m.
5. Low-order or high-order disposal where UXO + charge size is **up to 50 kg**	55-60 min (maximum of 60 min)	60 min of ADD use is expected to displace harbour porpoise to 5.9 km range, which is sufficient for the maximum predicted PTS impact range of 5.9 km for a combined UXO/charge size of 50 kg. This ADD use will also be expected to cause deterrence of minke whale and seals, which will contribute to reducing the likelihood that individuals of these species are within the 1 km and 1.2 km PTS impact ranges, respectively, for this disposal method and UXO/charge size.
6. Low-order or high-order disposal where UXO + charge size is **up to 300 kg**	55-60 min (maximum of 60 min) plus soft start charges (see Section 5.3.3)	As above. Additionally, soft-start charges required (see Section 5.3.3).

It is noted that, for all scenarios mentioned in Table 5.1 above, ADD activation can occur within the 60 min pre-detonation search, providing no marine mammals have been observed within the mitigation zone for a minimum of 20 minutes. Therefore, where 60 min of ADD use is required, the pre-detonation search will be a minimum of 80 min duration.

For scenarios 1-5, i.e. low-yield disposal and low-order or high-order disposal of UXOs with a combined UXO and donor charge size of up to 50 kg, the use of pre-detonation search and ADD measures are considered to reduce the risk of auditory injury (PTS) to negligible for all marine mammal species.

5.3.3 Soft-start charges

For combined UXO/charge sizes > 50 kg and up to 300 kg, to reduce the risk of PTS to negligible, there is a need to deter harbour porpoise to > 6 km and up to 11 km, to deter seals to 1.2 to 2.1 km, and minke whale to 1.3 to 1.9 m. While evidence suggests that ADD use alone may be sufficient to deter minke whales to such a distance, there is less evidence that ADDs will be able to exclude harbour porpoise or seals to the necessary distance and therefore avoid some risk of an injury offence.

Therefore, for low-order or high-order disposal of UXO/charge sizes > 50 kg and up to 300 kg, following no less than 60 min of ADD use, additional mitigation in the form of soft-start detonations will be undertaken. While the effectiveness of soft-start charges for displacement of marine mammals is currently unknown, it is assumed that a series of small detonations of increasing size will induce avoidance behaviour and provide additional time for animals to move away prior to the main detonation. This practice has been widely adopted in recent UXO clearance operations.

Depending on the size of the UXO/charge, it is proposed to use between 2-4 soft-start charges between 50-200g each, spaced at 5 min intervals. While these relatively short intervals limit the time within which animals may move away, it was advised during consultation with NatureScot (see Section 1.4) that this was preferable as it reduced the likelihood of animals moving back towards the clearance area between consecutive detonations. For all species, the maximum predicted impact range for PTS from the soft-start charges is < 1 km (Table 5.2); therefore, these detonations, following ongoing ADD use and pre-detonation search, do not themselves pose a risk of injury.

Table 5.2. Predicted PTS and TTS impact ranges for soft-start charges, based on the functional hearing group-specific criteria for unweighted impulsive noise ($SPL_{0\text{-}peak}$) proposed by Southall et al. (2019).

Soft-start charge size (NEQ)	PTS (TTS) impact range (m) for each species			
	Minke whale	Dolphins	Harbour porpoise	Seals
50 g	104 (192)	34 (62)	588 (1 km)	115 (212)
100 g	131 (241)	43 (79)	741 (1.4 km)	145 (267)
150 g	150 (276)	49 (90)	848 (1.6 km)	166 (306)
200 g	165 (304)	54 (99)	933 (1.7 km)	183 (337)

The following soft-start configurations are proposed for low-order or high-order disposal of UXO/charge sizes > 50 kg:

- UXO/charge up to 100 kg: 50 g at 10 min prior to main detonation, 100 g at 5 min.
- UXO/charge up to 200 kg: 50 g at 15 min prior to main detonation, 100 g at 10 min, 150 g at 5 min.
- UXO/charge up to 300 kg: 50 g at 20 min prior to main detonation, 100 g at 15 min, 150 g at 10 min, 200 g at 5 min.

Low-order or high-order disposal of UXO > 300 kg

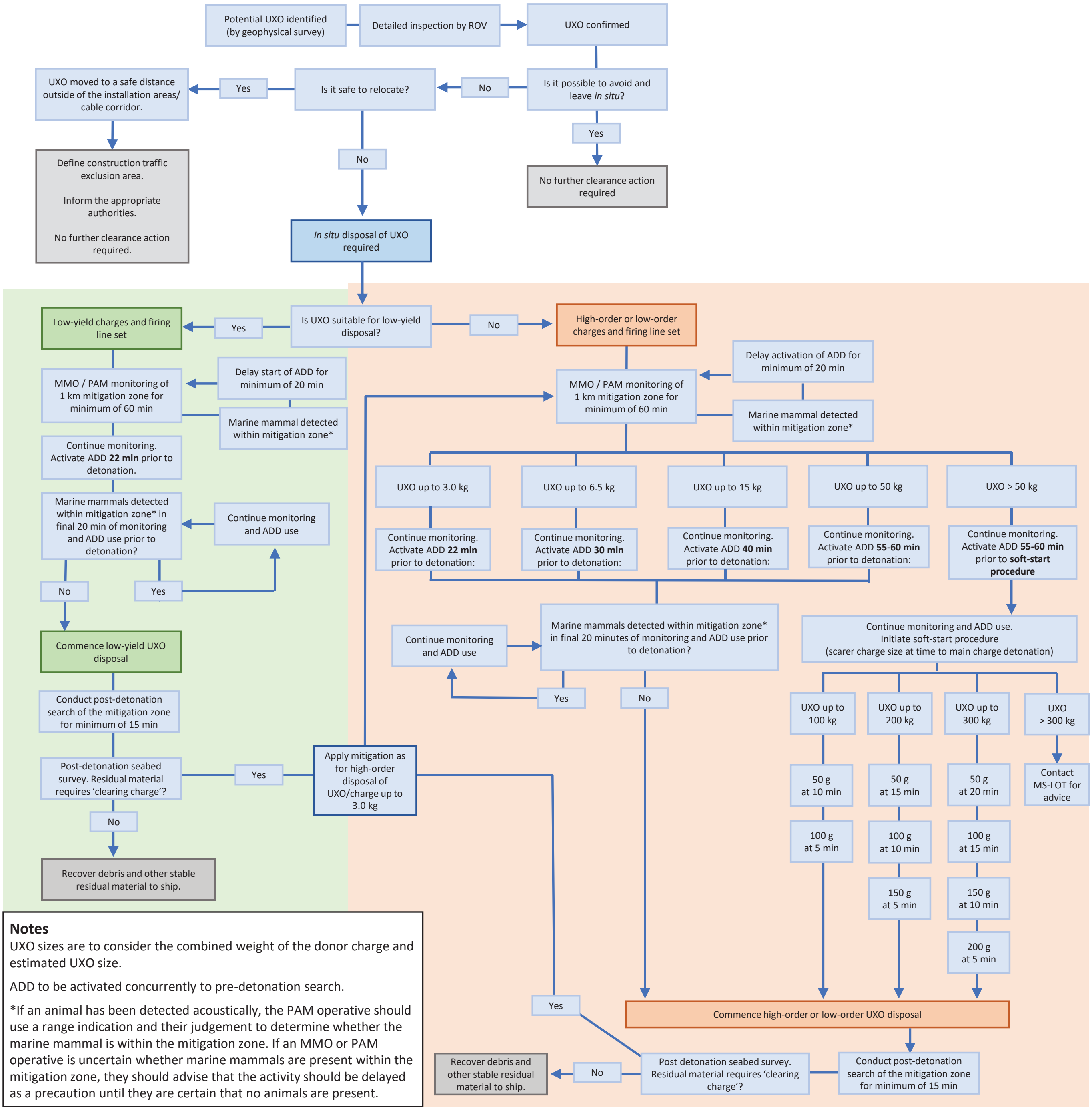
UXOs > 300 kg are unlikely or highly unlikely to be encountered in the Seagreen area, and less so to require low-order or high-order disposal. However, should a UXO of such size be identified, NS & MS-LOT will be contacted for a discussion on the preferred approach to disposal and proportional mitigation measures.

5.3.4 **Post-detonation search**

The MMO on the RHIB will undertake a post-detonation search of the mitigation zone for at least 15 minutes after the final detonation, to look for evidence of injury to marine life, including any fish kills. Any other unusual observations will be noted in the post-activity report.

5.3.5 **Other actions**

Appendix 3 outlines reporting procedures associated with the UXO clearance operations and implementation of the MMMP, along with details of the roles and responsibilities of personnel enacting the MMMP.



Notes

UXO sizes are to consider the combined weight of the donor charge and estimated UXO size.

ADD to be activated concurrently to pre-detonation search.

*If an animal has been detected acoustically, the PAM operative should use a range indication and their judgement to determine whether the marine mammal is within the mitigation zone. If an MMO or PAM operative is uncertain whether marine mammals are present within the mitigation zone, they should advise that the activity should be delayed as a precaution until they are certain that no animals are present.

Figure 2. Seagreen UXO clearance mitigation flow-chart

6. Residual effects and conclusions

6.1 Physical trauma

The assessment indicates that there is a very low risk of physical trauma to any EPS (or seals) even from high-order detonation of UXO of 1,000 kg, with impact ranges not exceeding 502 m. Therefore, the implementation and monitoring of a 1 km mitigation zone, as outlined in the MMMP, will reduce the risk of physical trauma to effectively zero.

6.2 Auditory injury (PTS)

For low-yield disposal and low-order or high-order disposal of UXOs with a combined UXO and donor charge size of up to 50 kg NEQ, the use of pre-detonation search and ADD measures as outlined in Section 5.3 and the MMMP (Appendix 3) are considered to reduce the risk of auditory injury (PTS) to negligible for all marine mammal species. These measures will also reduce the risk of PTS in white-beaked dolphin (and any other high-frequency cetacean) to negligible UXO/charge sizes of up to 300 kg (and to 1,000 kg).

For UXO/charge sizes of up to 300 kg NEQ, there is evidence to suggest that pre-detonation search and ADD use will also be sufficient to reduce the risk of PTS to minke whale to negligible, and will reduce the risk of PTS in harbour porpoise and seals to very low through strong displacement of animals to beyond the estimated impact range (see Section 5.3.2 and Appendix 2). To further reduce the risk of PTS to harbour porpoise and seals from UXO/charge sizes > 50 kg, it is proposed to also use soft-start charges to further deter animals from the area prior to the main detonation (Section 5.3.3). With these measures in place, and considering the precautionary approach to the risk assessment and anticipated over-estimation of impact ranges (e.g. likely degradation of UXO, seabed vs mid-water detonation, measurements from UXO clearance elsewhere, see Section 4.7), the risk of PTS to harbour porpoise is considered to be extremely low.

Nonetheless, the proposed mitigation measures cannot guarantee the complete exclusion of animals from the area over which PTS is predicted to occur (see Appendix 2); therefore, a very low residual risk remains that a small number of harbour porpoise may be exposed to noise levels from UXO at which the onset of PTS is expected. Such a scenario primarily relates to high-order detonations of UXO > 50 kg and, as such, is anticipated to only represent a subset of the maximum anticipated 20 detonations of UXO at the Seagreen site. This residual risk of PTS largely relates to offshore waters, where UXO clearance will occur; however, considering the predicted PTS impact ranges relative to the proximity to inshore waters, a very low residual risk of an injury offence to harbour porpoise also remains for inshore waters.

Therefore, it is proposed that an EPS licence is required for injury to harbour porpoise within both offshore and inshore waters to account for the low risk that mitigation measures result in the incomplete exclusion of animals from PTS impact areas. It is difficult to estimate the number of harbour porpoise which might be subject to PTS for this reason, but could be expected to be an order of magnitude lower than the number predicted to experience behavioural disturbance. Nominal values totalling 10 and 5 harbour porpoise are proposed for offshore and inshore waters, respectively.

The consequences of such noise-induced PTS at the individual level are considered to be small; mitigation measures are anticipated to displace animals to a large degree such that any animals exposed to noise levels that may result in PTS will be close to the onset of PTS (i.e. a small reduction in hearing sensitivity, and likely at a frequency below that used for echolocation). For example, expert elicitation exercises to inform the interim Population Consequences of Disturbance (iPCoD) model indicated that the effects of a 6 dB PTS in the 2-10 kHz band was unlikely to have a significant effect on survival or fertility of the species of interest, with effects considered to be smallest for harbour porpoises and seals and slightly larger in bottlenose dolphins (Booth and Heinis, 2018). For all species, experts indicated that the most likely predicted effect on survival or fertility as a result of 6 dB PTS was likely to be very small (i.e. predicted median decline in survival or fertility of 0.3%). When considering that the number of animals which might be subject to PTS represents < 0.001% of the North Sea Management Unit, such an effect is not significant from a population-perspective.

It is noted that the maximum predicted impact range of PTS to seals is 3.1 km, which is less than the 4.6 km minimum distance to inshore waters. **Therefore, it can be concluded that there is no risk of an injury offence to seals under the *Marine (Scotland) Act 2010*.**

6.3 Behavioural disturbance

As described in Section 4.6, there is a risk of behavioural disturbance to all species of EPS and seals from the UXO clearance activities, in particular for harbour porpoise where disturbance may occur to a range of approximately 20 km from high-order detonation of a 300 kg UXO. The avoidance or relocation of UXOs, and the use of UXO disposal methods other than high-order detonation, will reduce the potential for behavioural disturbance. However, operational measures such as ADD use and soft-start charges will not reduce the extent of disturbance effects; for minke whale and harbour porpoise, ADD and soft-start may actually increase the extent of disturbance effects, although these are considered necessary to sufficiently reduce the risk of auditory injury.

Even for the worst case UXO/charge sizes of several hundred kg NEQ, the number of minke whale or white-beaked dolphin predicted to be disturbed from a single detonation is < 5 individuals per species, representing < 0.001% of the relevant management unit. While the number of harbour porpoise disturbed could number 730 for a high-order detonation of a 300 kg NEQ UXO (1,627 animals for a 1,000 kg UXO), this represents 0.002% of the relevant management unit (0.005% for a 1,000 kg UXO).

The disturbance resulting from UXO detonation, soft-start charges or ADD use will likely represent a combination of startle responses, increased swimming speed, temporary displacement and potentially a temporary cessation of feeding activities while animals move away from the noise source. For the most sensitive and abundant species, harbour porpoise, evidence suggests that animals begin to return to areas within several hours of cessation of the noise source following exposure to ADDs (e.g. Brandt et al., 2013b; Thompson et al., 2020) and 24-48 hours following cessation of other high-amplitude impulsive noise sources such as pile-driving or seismic survey (e.g. Tougaard et al., 2006; Thompson et al., 2013; Pirotta et al., 2014).

While UXO clearance activities will take place over several months, disturbance will be temporally-discreet and limited to detonations on a maximum of 20 days. Furthermore, it is anticipated that only a single UXO will be disposed of in any one day, corresponding to up to two explosive disposal attempts should a clearing charge be required following the main disposal attempt. When considering the anticipated short return time of animals to the area, such disturbance effects would not be likely to impair the ability of an animal to survive or reproduce or result in any significant impacts to the local populations or distribution.

For other cetacean species, those potentially occurring, but unlikely to be present, are short-beaked common dolphin; white-sided dolphin; Risso's dolphin; killer whale; sperm whale; long-finned pilot whale; fin whale; humpback whale (Marine Scotland, 2014). A range of additional species, as listed in Marine Scotland (2020) EPS Guidance, may occur very rarely or as vagrants. It is probable that no individuals of these species will be present in the vicinity of the UXO clearance activities and therefore subject to disturbance; however, should they be present and be disturbed by elements of the planned activities, in particular the ADD use, the number of animals present and nature of the disturbance would not be considered significant. It is conservatively estimated that up to 10 individuals of less common species (total for all species) could be disturbed over the course of the UXO clearance activities.

Therefore, it is proposed that an EPS licence is not required for disturbance within offshore waters.

6.4 Estimated extent of disturbance in Scottish inshore waters

UXO clearance activities will be restricted to the Seagreen wind farm site, which is located entirely within offshore (> 12 nm) waters. The minimum distance between clearance areas and the limit of inshore waters is 4.6 km; therefore, for some species and charge sizes, there is the potential for disturbance to individual cetaceans to occur within inshore waters, necessitating an EPS licence for disturbance under *The Conservation (Natural Habitats, &c.) Regulations 1994 (as amended)*.

No disturbance to any cetacean species is anticipated in inshore waters from low-yield disposal, or successful low-order disposal; however, use of ADDs or soft start charges in advance of these techniques may result in some disturbance in inshore waters, where the extent of induced displacement extends beyond 4.6 km.

The maximum predicted impact range for behavioural disturbance to white-beaked dolphin is 1.7 km; therefore, no disturbance to individuals of white-beaked dolphin (or any other dolphin or high-frequency cetacean species) within inshore waters.

Behavioural disturbance to minke whale in inshore waters may occur for high-order detonations of UXOs > 500 kg. A maximum impact range of 5.2 km is predicted for minke whale for a 1,000 kg UXO; this would result in disturbance over a maximum of 1.9 km^2 of inshore waters, corresponding to an estimated < 1 minke whale disturbed. The minimum distance between the site clearance areas and inshore waters also exceeds the maximum reported deterrence range to minke whales from ADD use of 4.5 km, reducing the likelihood of disturbance to individuals from ADD use as mitigation; however, it is noted that this also corresponded to the visual limit of observations reported in McGarry et al. (2017), and that animals exposed to ADD at an initial distance of c. 1 km may have continued to exhibit behavioural responses ranges beyond 4.5 km.

Behavioural disturbance to harbour porpoise in inshore waters may occur for UXOs of > 3.5 kg. For high-order detonation of a 1,000 kg UXO resulting in a disturbance impact range of 29.4 km, disturbance to harbour porpoise may occur over up to 966 km^2 of inshore waters, corresponding to an estimated 579 harbour porpoise disturbed (0.002% of MU). This is greater than the predicted impact range for disturbance which might occur from ADD use as a mitigation measure.

In all the above scenarios, the potential for behavioural disturbance in inshore waters is dependent on the location of the UXO being cleared, with values presented assuming clearance at a point in the site closest to the 12 nm limit. As such, estimates of the maximum number of animals disturbed in inshore waters are highly precautionary.

Therefore, it is proposed that an EPS licence is applied for to account for potential disturbance of individuals of harbour porpoise and minke whale in inshore waters.

6.5 Potential effects of other acoustic sources: USBL and MBES

The MBES on the ROV will operate with main energy in high frequencies (200-700 kHz) which are outside the hearing range of all cetaceans and seals and therefore will not result in any behavioural disturbance. While indicative the MBES source level (230 dB re 1 µPa SPL_{rms}) is above the PTS threshold of all species, this will be transmitted in a narrow beam close to the seafloor and be rapidly attenuated due to the high operating frequency. Therefore, the MBES is not considered to pose a potential risk of auditory injury to any EPS or seals.

The USBL will operate at a sufficiently low source level (200 dB re 1 µPa SPL_{rms}) that there is no risk of injury to any species of marine mammal. The noise from the USBL will be detectable to all species of EPS and seal, and so may elicit behavioural responses such as avoidance. However, considering the nature of this source, disturbance is likely to be short-term, temporary, of a spatial extent unlikely to exceed a few hundred metres of the source, and of a lesser extent than other activities within the UXO clearance campaign (i.e. ADD use, detonations).

6.1 Consideration of cumulative effects

Other impulsive noise-generating activities may be occurring in the Seagreen area during the UXO clearance campaign:

- Geophysical surveys for UXO, boulder and debris identification are taking place from March to June (assessed under previous risk assessment - LF000009-CST-OF-SUR-REP-0005).
- Pile-driving of the offshore substation platform (OSP) is scheduled to occur in June.

Appropriate mitigation will be in place to reduce the risk of injury from the geophysical survey and OSP pile-driving activities (specified in the piling strategy (LF000009-CST-OF-PLN-0003) and to be assessed in a forthcoming EPS Risk Assessment). Additionally, no UXO detonation will take place on days where pile-driving occurs. While these activities will result in some disturbance of animals within the Seagreen site and adjacent area, such disturbance will be transient and/or temporary and of limited spatial extent.

Considering the predicted extent of disturbance resulting from UXO activities, including the very small proportion of management units impacted, cumulative effects are not expected in association with other impulsive noise generation at the Seagreen site or other activities in the wider region.

6.2 Assessment of potential impact on favourable conservation status

The planned UXO clearance activities will not result in impacts which might damage the status of any EPS in the long-term, and therefore there will be no impact on the favourable conservation status of any EPS.

7. Protected sites

7.1 Special Areas of Conservation

A number of SACs supporting certain marine mammal species that are potentially sensitive to underwater noise were identified during the 2012 ES (Seagreen, 2012) and these remained unchanged in the 2018 EIAR (Seagreen, 2018); these sites are detailed in Table 7.1.

Table 7.1 Special Areas of Conservation considered in EPS Risk Assessment

SAC	Qualifying features of relevance to this risk assessment	Minimum distance to site
Isle of May	Grey Seal	51 km
Berwickshire and North Northumberland Coast	Grey seal	65 km
Firth of Tay and Eden Estuary	Harbour seal	46 km
Moray Firth	Bottlenose Dolphin	~ 200 km (22 km and 26 km to coastal 30 m and 20 m depth contours, respectively)

While cetaceans and seals are wide-ranging and frequently occur beyond the boundaries of protected sites, these sites encompass areas of favourable habitat supporting higher densities of the species than other areas of UK waters and, in the case of seals, key breeding sites. Harbour seals exhibit strong site fidelity throughout the year, foraging within approximately 50 km of their breeding colony (Jones et al., 2015). Grey seals forage more widely, and may move between haul-out sites outside of the breeding season (Russell et al., 2013; Jones et al., 2015), but are considered to remain relatively close to colonies during the breeding season[11].

Under the *Conservation (Natural Habitats, &c.) Regulations 1994* (the ‘Habitats Regulations’), all competent authorities must consider whether any plan or project, either alone or in combination with other plans or proposal, will have a ‘likely significant effect’ on a European site (including SACs and SPAs). If so, they must carry out carry out an ‘appropriate assessment’ (AA). This process is known as Habitats Regulations

[11] NatureScot advice received on previous EPS applications for the Seagreen site is that grey seals tend to stay within 20km of the breeding colony during the breeding season.

Appraisal (HRA)[12]. Here, information is provided to assist the competent authority (Marine Scotland) and their advisors (NatureScot) in undertaking HRA of the proposed UXO clearance activities.

The LSE (likely significant effect) test is a high-level assessment of whether the proposed activities: a) clearly have no ecological connectivity to the a site's qualifying interests OR b) obviously won't undermine the conservation objectives for the qualifying interests to which it has a connection. Unless a significant effect can be objectively ruled out with certainty, it is considered 'likely'. NatureScot advice is that the LSE test should be a relatively quick and straightforward decision, and include plans and projects at any distance beyond the European site's boundaries.

While there is some level of potential connectivity between the UXO clearance area and qualifying features of several European sites (as described above), based on: (i) the proximity of the Seagreen area to sites; (ii) the ranging patterns of qualifying features; and, (iii) advice received on previous EPS applications for the Seagreen site, it is proposed that LSE cannot be ruled for the following site:

- Firth of Tay and Eden Estuary SAC (harbour seal qualifying feature)

Therefore, an appropriate assessment is required to determine if the proposed UXO clearance activities will have an adverse effect on site integrity, in terms of its conservation objectives. The conservation objectives relate to the long-term maintenance of the quality of the site such that it continues to make an appropriate contribution to the qualifying features achieving or maintaining a favourable conservation status. Therefore, for the UXO clearance activities to have an adverse effect on the integrity of an SAC, they would need to result in a long-term deterioration of the qualifying feature(s) and its habitats.

Considering:

- the location of the area of operations relative to the SAC (Table 7.1);
- the nature of what is considered an adverse effect on site integrity (in terms of site conservation objectives);
- the estimated very low presence of the qualifying features within the area of operations (Section 3); and,
- that any disturbance arising from the UXO clearance activities will be relatively localised (within a few kilometres radius), short-term and transient and to a limited number of individuals (Section 4.6),

it is suggested that there will be no adverse effects on the integrity of the Firth of Tay and Eden Estuary SAC.

7.2 Designated seal haul-outs

It is also noted that under Section 117 of the *Marine (Scotland) Act 2010*, it is also an offence to harass seals at haul-out sites in Scotland designated under *The Protection of Seals (Designated Sea Haul-out Sites)*

[12] Further information is available at: https://www.nature.scot/professional-advice/planning-and-development/environmental-assessment/habitats-regulations-appraisal-hra

(Scotland) Order 2014. However, considering the location of the planned UXO clearance activities relative to the shore (≥ 27 km) and nearest designated haul-out site (≥ 67 km, Fast Castle), there is no potential for harassment of seals at designated haul-out sites and such effects are not considered further.

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9. Appendix 1 – Unweighted SEL at range from UXO detonations of different sizes

Early consultation feedback on the proposed UXO risk assessment methodology requested the use of unweighted sound exposure level (SEL) in addition to sound pressure level (Table 1.2). In Table 9.1, below, the model for SEL estimation presented in Soloway and Dahl (2014) is used to estimate the ranges at which different unweighted SEL values might occur, given different charge sizes. The SEL values used correspond to the range of thresholds presented in von Benda-Beckmann et al. (2015), drawing on experiments conducted by Ketten (2004), Lucke et al. (2009) and expert judgement. These suggested thresholds for unweighted SEL relate to permanent hearing loss caused by a single underwater explosion in shallow water (< 50 m depth), and include:

- > 203 dB re 1 μPa^2·s: Blast wave-induced ear trauma very likely (all cetaceans)
- 190-203 dB re 1 μPa^2·s: Blast wave-induced ear trauma increasingly likely; noise-induced PTS very likely (all cetaceans)
- < 190 dB re 1 μPa^2·s: Blast wave-induced ear trauma unlikely (all cetaceans)
- 179-190 dB re 1 μPa^2·s: Noise-induced PTS increasingly likely (harbour porpoise; extrapolated from TTS experiments). Note: Noise-induced hearing loss is that upon which the thresholds for SPL and cumulative SEL presented in Southall et al. (2019) are based.

Table 9.1. Estimated ranges (km) to unweighted SEL values based on Soloway and Dahl (2014).

Charge/UXO size (NEQ)	Estimated ranges (km) to unweighted SEL values (dB re 1 μPa^2·s)					
	205 dB	203 dB	195 dB	190 dB	185 dB	179 dB
Low-order and Low-yield donor charge configurations						
80 g	< 0.1	< 0.1	< 0.1	< 0.1	0.1	0.3
1.5 kg	< 0.1	< 0.1	0.1	0.2	0.5	1.4
3 kg	< 0.1	< 0.1	0.1	0.3	0.7	2.0
High-order donor charge options						
1.2 kg	< 0.1	< 0.1	0.1	0.2	0.4	1.3
3.5 kg	< 0.1	< 0.1	0.1	0.3	0.8	2.2
Potential UXOs (assuming full high-order detonation)						
6.5 kg	< 0.1	< 0.1	0.2	0.4	1.0	3.0
15 kg	< 0.1	0.1	0.3	0.6	1.5	4.5
25 kg	0.1	0.1	0.3	0.8	2.0	5.7
36 kg	0.1	0.1	0.4	1.0	2.4	6.9
50 kg	0.1	0.1	0.5	1.2	2.8	8.1
100 kg	0.1	0.2	0.7	1.6	3.9	11.3
227 kg	0.2	0.2	1.0	2.4	5.9	16.9
300 kg	0.2	0.3	1.1	2.8	6.7	19.4
500 kg	0.3	0.4	1.5	3.6	8.6	24.9
800 kg	0.3	0.5	1.9	4.5	10.9	31.4
1,000 kg	0.4	0.5	2.1	5.0	12.1	35.0

10. Appendix 2 – Evidence for the effects of the Lofitech seal scarer acoustic deterrent device (ADDs) as mitigation for the effects of noise on marine mammals

A review of the characteristics of different ADDs and the evidence base for their application as marine mammals mitigation is provided by McGarry et al. (2020). Seagreen proposes to use the Lofitech seal scarer; this device is among those for which the greatest evidence base exists for harbour porpoise and minke whale deterrence and has reported some of the largest deterrence distances, and which has been used for marine mammal mitigation purposes at a number of offshore wind farm construction projects across Europe.

10.1 Technical details on the Lofitech seal scarer ADD

The Lofitech ADD produces signals of ~ 50 ms pulse length (with pauses between signals of variable length) in the range 10-20 kHz, with a nominal source SPL (assumed SPL_{rms}) of 189 dB re 1 µPa[13]. Field measurements have indicated a fundamental frequency of 14.6 kHz with harmonics at higher frequencies up to 72.8 kHz (McGarry et al 2017), while source level estimates based on field measurements vary (e.g. $SPL_{peak\text{-}peak}$ 187.2 dB re 1 µPa (Thompson et al., 2020); SPL_{rms} 193 dB re 1 µPa (Gordon et al., 2015); SPL_{peak} 204 dB re 1 µPa (McGarry et al., 2017)). Based on these characteristics, the potential for the Lofitech ADD to cause injury (PTS) to marine mammals is considered to be zero or negligible (i.e. animals would need to remain within close proximity for an extended period.

10.2 Summary of evidence for deterrence

Overall, there is good evidence for the effective deterrence ranges of the Lofitech device on harbour porpoises and harbour seals, but less available for minke whales and none for dolphin species (McGarry et al., 2020). Evidence of deterrence among dolphins from other types of ADD is mixed, with a review by Sparling et al. (2015) concluding that they are not currently useful for mitigation for piling at offshore wind farms (i.e. a static impulsive noise source).

The evidence available suggests that the Lofitech ADD is effective to at least 7.5 km for harbour porpoise (Brandt et al., 2013a; Brandt et al., 2013b), >1 km in minke whales (McGarry et al., 2017) and ~1 km in seals (Gordon et al., 2015; Sparling et al., 2015; Gordon et al., 2019). Further details are provided below.

10.2.1 **Harbour porpoise**

Of key relevance is the study by Brandt et al. (2013b), where passive acoustic monitoring (CPODs) was conducted at ranges of zero to 7.5 km from a Lofitech ADD source over ten ADD broadcast trials in the German North Sea. The ADD was activated for 4 hr; data for the first hour of activation were excluded due to potential confounding effects of vessel disturbance. Subsequently, changes in porpoise activity (porpoise detection positive minutes, PPM) over 3 hr blocks were compared pre- and during the ADD activation. Porpoise detections were reduced at all distances, with only those were detections pre-activation were already low being non-significant. At 7.5 km range, PPM during exposure was reduced by an average 96%

[13] https://www.lofitech.no/information

compared to pre-activation. An aerial surveys concurrent with one ADD broadcast across an area of 30 x 30 km centred on the ADD location revealed a significant decrease in porpoise density from 2.4 porpoises km^2 before to 0.3 porpoises km^2 during ADD operation; there were only 4 porpoise sightings following activation of the ADD (closest to ADD was 6.3 km) compared to 38 sightings prior to activation. Combined, these results suggested a near-exclusion of animals to 7.5 km, with strong deterrence to at least 15 km. Significant deterrence was no longer reported during the 7-9 hr block after ADD activation.

More recently, ADD playback experiments[14] in the Moray Firth confirmed a strong behavioural response from harbour porpoise (Thompson et al., 2020). Changes in porpoise occurrence at various CPOD locations were investigated in the 3, 6 and 12 hr periods after a 15 min Lofitech ADD exposure, relative to the baseline occurrence. Porpoises were considered to have responded to the ADD when the proportional decrease in occurrence (detection positive hours) was greater than 0.5 (the 99th percentile of the baseline distribution). The probability that porpoise occurrence did (1) or did not (0) show a response to ADD was then modelled in relation to distance from the ADD as a binomial response. Within the 3 hr period following the ADD playback, there was a >50% chance of porpoise response at distances up to 21.7 km (13.8 km in the 6 hr period after ADD exposure and 3.9 km in the 12 hr period after ADD exposure). Close inspection of results for the 3 hr period indicates that the closest data point classified as no response was at approximately 10 km distance to the ADD source (see Figure S7 in Thompson et al., 2020).

10.2.2 Minke whale

In controlled exposure experiments on minke whale in Icelandic coastal waters, 15 animals were tracked from a research vessel upon activation of a Lofitech ADD for a 15 min exposure (McGarry et al., 2017). The tracked animal moved away from the ADD deployment site in all cases. A significant increase in net swim speed during the treatment phase was observed, with whales increasing their speed by an average of 7.4 km/h, and a significant increase in speed during the second half of the treatment phase, indicating that animals both increase their speed and the directness of their path in relation to exposure to the ADD signal. Most animals were exposed from an initial distance of 1 km. Animals exposed at ≥1 km range and tracked for the full duration of the 15 min exposure (n = 7) had moved to distances of between c. 1.8 km and c. 3.3 km of the source after 15 min and continued to move away. While two whales showed a net movement back toward the source site approximately 10-15 min after the end of the ADD exposure, 5 whales tracked for c. 45 minutes in total reached distance of between c. 3 km and c. 4.5 km of the source site.

10.2.3 Seals

In controlled exposure experiments of tagged harbour seals to 15 min of Lofitech ADD activation, all 38 animals exposed at ranges of c. 1 km or less moved away from the source, with aversion responses also observed when exposed to a maximum range of c. 3 km; however, in a small number of cases the net movement was only a few tens of metres (Gordon et al., 2019). The mean change in distance for animals showing a clear response was + 625 m, up to a maximum of c. 1.9 km. Sparling et al. (2015) note that while there is evidence for basic deterrence for grey seals, studies showing the extent of animal movements and deterrence ranges at offshore sites have not been conducted; the authors suggest that, for the purposes of using ADDs for the mitigation of injury from piling noise, evidence gathered for each species (grey or harbour seals) would be assumed to apply for the other.

11. Appendix 3 – Marine Mammal Mitigation Plan

The purpose of the Marine Mammal Mitigation Plan (MMMP) is to mitigate the risk of physical trauma or auditory injury, in the form of PTS, to marine mammals by the proposed UXO clearance activities at the Seagreen offshore wind farm site, as described in Section 5. In the sections below, measures are specified which correspond to the assessment of potential effects presented in Section 4, to ensure that, as far as practicable, no marine mammals are present within the area where either physical trauma or PTS could arise.

In the first instance, mitigation will take the form of avoiding the need for the use of explosives, either by leaving the confirmed UXO in situ and micro-siting construction work and infrastructure around it, or by relocating the UXO to a safe place and leaving in situ. However, avoidance or relocation may not be possible for some UXO and, therefore, as a worst-case scenario up to 20 UXO detonations may be required.

High-order disposal of UXO, where an attempt is made to fully detonate the contents of the UXO, represents the highest potential for impacts to marine mammals. Therefore, low-yield and low-order disposal will be preferentially applied where it is suitable to do so. The donor charge sizes for low-order disposal are the smallest of all disposal approaches and therefore, where successful, low-order disposal represents the lowest potential impact. However, as a risk remains that a low-order disposal attempt may result in a high-order detonation of the UXO, low-yield disposal is the preferred approach for UXO clearance at the Seagreen site. As identified in Section 4, the potential for physical trauma, PTS or behavioural disturbance is much reduced for low-yield disposal, corresponding only to the size of the donor charges to be used.

In the sections below (including Figure 3), where relevant, a distinction is made between the different disposal approaches when outlining mitigation measures. Due to the potential risk of low-order disposal resulting in a high-order detonation, mitigation measures for low-order disposal assume the worst-case scenario of full high-order detonation of the UXO.

11.1 UXO clearance mitigation procedures

The JNCC guidelines for minimising the risk of injury to marine mammals from using explosives (JNCC, 2010) provide base from which this MMMP has been developed, with details of ADD use and soft-start charges tailored to the anticipated UXO sizes requiring clearance at the Seagreen site and the different methods of UXO disposal which may be applied. Consultation feedback and relevant experience from UXO clearance operations at other sites has also been incorporated.

A flow-chart for the proposed mitigation procedures is provided in Figure 3, with further details of each stage provided in the sections below. For ease of reading, Figure 3 is also provided as a separate .pdf document.

11.1.1 Mitigation zone and pre-detonation search

A mitigation zone of 1 km radius from the detonation location will be established, within which it will be ensured (through visual observations, and potentially PAM), that no marine mammals are present prior to the detonation event. Visual monitoring and PAM will be conducted in accordance with JNCC (2010) guidelines.

Detonations will only occur during daylight and with a strong preference for calm sea conditions (noting the RHIB can only be deployed in wind speed conditions less than 25 knots and that detection of marine mammals is best in sea state 2 or below).

The pre-detonation search will commence at least 1 hour prior to any detonation event (including soft-start charges where required) with at least 2 trained MMOs to observe from two different viewing platforms at the closest location possible to the detonation site. **It is anticipated that one MMO will be located on the RHIB and one will remain on the main vessel**. This will ensure that the entire mitigation zone can be monitored at all times. One of the MMOs should be dedicated to this purpose throughout the campaign, while a second can be a trained member of the wider crew, although they should be dedicated to MMO duties throughout the pre-detonation search. The MMOs will be in close contact with each other and the relevant explosive ordnance disposal (EOD) supervisor (or a designated liaison) to ensure any sighting of a marine mammal within the mitigation zone is communicated. MMOs will utilise binoculars and suitable equipment (e.g. reticule, range-finding stick, laser range-finder) to assess the location of any animals observed relative to the mitigation zone. The surface support vessel will remain within 1 km of the UXO clearance operations, but with a minimum standoff distance of 200 m. Exact standoff distances will be dependent on the scale of ordinance to be cleared.

During periods of low visibility (due to adverse weather and/or sea states of 3 or higher), PAM will be used as an additional measure to monitor the mitigation zone. It is anticipated that the PAM equipment and operator will be located on the RHIB to ensure that it is deployed as close as possible to the detonation site.

A detonation will only commence once the pre-detonation search has lasted for a minimum on one hour, and no marine mammal detections have been made in the 20 min prior to detonation. If a marine mammal is detected within the mitigation zone during the pre-detonation search, the following procedures will be applied:

- EOD supervisor notified
- Animal(s) monitored until it is clear of the mitigation zone. EOD supervisor notified
- If animal(s) remains clear of the mitigation zone for at least 20 min, and the one-hour pre-detonation search has also been completed, then a detonation can commence.

If a marine mammal detection is made, visually and/or by PAM, and there is uncertainty in the location of the animal(s) relative to the mitigation zone, a precautionary approach should be taken and operations should be delayed until there is certainty that the animal(s) is no longer in the mitigation zone.

11.1.2 Acoustic Deterrence Device (ADD)

The risk assessment concluded that for some UXO clearance activities, there is a risk of potential auditory injury to harbour porpoise, minke whale and seals at a greater range than can be mitigated by monitoring of the 1 km mitigation zone alone. Therefore, an ADD will be operated for a pre-determined length of time, concurrent to the pre-detonation search, to deter marine mammals to a greater distance prior to any detonation. The ADD to be used is the Lofitech seal scarer. The ADD will be deployed from the RHIB as close to the UXO detonation site as possible and activated for a pre-determined minimum length of time prior to any detonation, as outlined below and in the MMMP. The ADD will be deployed and operated by a specialised contractor, experienced in the use of ADD during UXO clearance.

Evidence of the effectiveness of ADDs, and the Lofitech device in particular, is presented in Appendix 2.

For the Seagreen UXO clearance activities, it is planned to operate the ADD for different durations according to the UXO disposal method used, UXO/charge size, and associated predicted impact ranges.

For all methods of UXO disposal that may be used and UXO/charge sizes that may be detonated, PTS impact ranges for harbour porpoise exceed the 1 km mitigation zone[15]. Furthermore, as noted by Sparling et al. (2015) even in good sighting/detection conditions, the probability of harbour porpoise detection by visual or acoustic means is likely to be lower than 100%. Therefore, the following ADD use is recommended:

- *Low-yield disposal:* ADD to be activated for a minimum of **22 min** prior to detonation for a combined donor charge weight of up to 3.0 kg.
- *Low-order or high-order disposal where UXO + charge size is up to 3.0 kg:* Follow procedures for (1) low-yield disposal as outlined above.
- *Low-order or high-order disposal where UXO + charge size is up to 6.5 kg:* ADD to be activated for a minimum of **30 min** prior to detonation.
- *Low-order or high-order disposal where UXO + charge size is up to 15 kg:* ADD to be activated for a minimum of **40 min** prior to detonation.
- *Low-order or high-order disposal where UXO + charge size is up to 50 kg:* ADD to be activated for **55-60 min** (maximum of 60 min) prior to detonation.
- *Low-order or high-order disposal where UXO + charge size is up to 300 kg:* For UXO/charge sizes > 50 kg, **55-60 min** (maximum of 60 min) of ADD use will be followed by detonation of **soft-start charges** before the main detonation (see Section 11.1.3, below).

It is noted that, for all scenarios mentioned above, ADD activation will occur within the 60 min pre-detonation search, providing no marine mammals have been observed within the mitigation zone for a minimum of 20 minutes. If marine mammals are observed in the mitigation zone prior to activating the ADD, the ADD activation must be delayed until marine mammals have moved out of the mitigation zone and no further sightings within the zone are reported for a minimum of 20 min. Therefore, where 60 min of ADD use is required, the pre-detonation search will be a minimum of 80 min duration.

11.1.3 Soft-start charges

For low-order or high-order disposal of UXO/charge sizes > 50 kg and up to 300 kg, following 60 min of ADD use, additional mitigation in the form of soft-start detonations will be undertaken.

[15] The exception would be a successful low-order disposal; however, as there is a chance of a high-order detonation of the UXO from this approach, a high-order detonation is assumed for mitigation planning.

Depending on the size of the UXO/charge, it is proposed to use between 2-4 soft-start charges between 50-200 g each, spaced at 5 min intervals. The following soft-start configurations are proposed for low-order or high-order disposal of UXO/charge sizes > 50 kg:

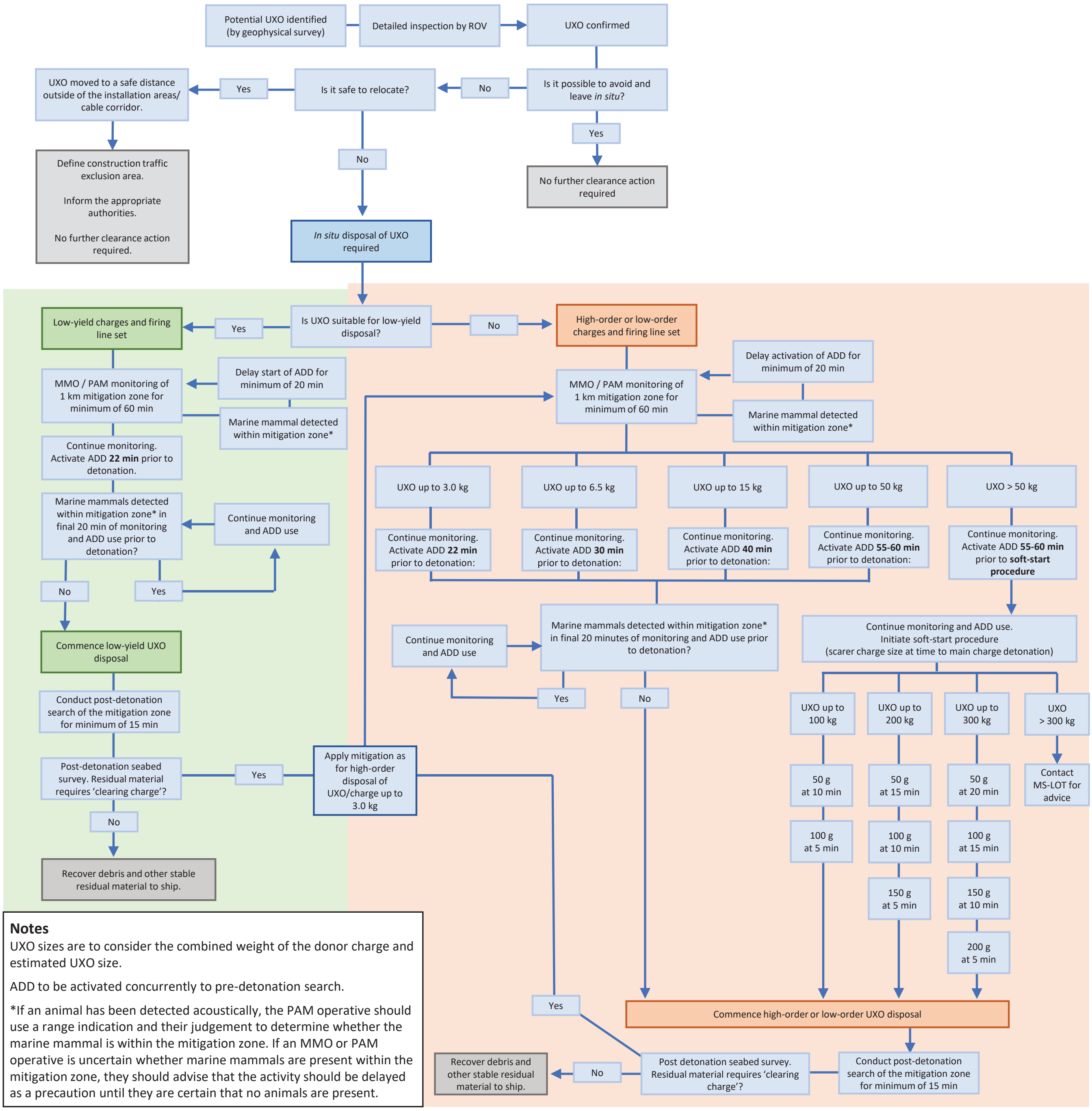
- UXO/charge up to 100 kg: 50 g at 10 min prior to main detonation, 100 g at 5 min.
- UXO/charge up to 200 kg: 50 g at 15 min prior to main detonation, 100 g at 10 min, 150 g at 5 min.
- UXO/charge up to 300 kg: 50 g at 20 min prior to main detonation, 100 g at 15 min, 150 g at 10 min, 200 g at 5 min.

Low-order or high-order disposal of UXO > 300 kg

Should a UXO of > 300 kg be identified, MS-LOT will be contacted for a discussion on the preferred approach to disposal and proportional mitigation measures.

11.1.4 **Post-detonation search**

The MMO on the RHIB will undertake a post-detonation search of the mitigation zone for at least 15 minutes after the final detonation, to look for evidence of injury to marine life, including any fish kills. Any other unusual observations will be noted in the post-activity report.



Notes

UXO sizes are to consider the combined weight of the donor charge and estimated UXO size.

ADD to be activated concurrently to pre-detonation search.

*If an animal has been detected acoustically, the PAM operative should use a range indication and their judgement to determine whether the marine mammal is within the mitigation zone. If an MMO or PAM operative is uncertain whether marine mammals are present within the mitigation zone, they should advise that the activity should be delayed as a precaution until they are certain that no animals are present.

Figure 3. Seagreen UXO clearance mitigation flow-chart

11.2 Reporting

Monitoring of the UXO clearance operations and implementation of the MMMP will be undertaken by Seagreen to keep a detailed record of UXO clearance operations, mitigation procedures and marine mammal sightings. These will be prepared and submitted in compliance with consent conditions, and will include completion and submission of JNCC Marine Mammal Recording Forms and details of operations.

Reporting will include a record of:

- All confirmed UXO identified, including estimated size, type, location and water depth.
- The approach taken for each confirmed UXO, including the dates, times, disposal method attempted, size, type and number of donor charge(s) used.
- Vessel presence, location and activity during UXO clearance operations.
- The outcome of each UXO disposal, including evidence of high-order detonation, any clearing charges required and method of debris and residue recovery.
- The mitigation procedures followed for each UXO disposal, including details of visual observations, PAM operations, ADD duration and size and timing of soft-start charges where required.
- All marine mammal sightings and completed marine mammal recording forms.
- Any problems encountered and instances of non-compliance with the JNCC guidelines, MMMP and variations from agreed procedures.

11.3 Roles and responsibilities

Persons involved in implementing, and ensuring compliance with, the MMMP for UXO clearance activities include:

- Lead consents manager
- Marine Mammal Observers (MMOs);
- Passive Acoustic Monitoring Operator (PAM-Op);
- Acoustic Deterrent Device Operator (ADD-Op); and
- Explosive Ordnance Disposal (EOD) supervisor.

Clear lines of communication between these persons must be maintained throughout UXO clearance operations. Information on the specific responsibilities of each of the above is provided in

Table 11.1.

Table 11.1. Responsibilities of key personnel involved in implementing the MMMP

Key personnel	Responsibilities
Lead consents manager	• Overall responsibility for ensuing compliance documents such as the MMMP are included in construction contract documents • Reporting marine mammal monitoring and UXO clearance activities via field and written reports. • Notification to the regulator of any issues with the UXO clearance activities, such as incidences of non-compliance or discussion of any modification to operations and MMMP (e.g. if UXOs > 300 kg are identified) • Notifying relevant parties of any relocated UXO
Explosive Ordnance Disposal (EOD) Supervisor	• Take responsibility for ensuring that the requirements of the MMMP are met offshore. • Responsibility for decisions on initiating, delaying or pausing detonation activities, including ensuring no UXO detonations occur without explicit consent from the EOD Supervisor. • Main point of communication between the Vessel Master, wider EOD team and mitigation team (Lead Consents Manager, MMOs and other personnel as required). • Ensure clear lines of communication between the Vessel Master, members of the crew, MMOs, PAM and ADD operators to ensure no miscommunications occur. • Inform the Vessel Master of the environmental considerations relevant to the vessel's activities.
Marine Mammal Observers (MMOs)	• Report to EOD supervisor and Lead Consents Manager. • Monitor the mitigation zone and conducting the pre-detonation search as described in the MMMP. • Communicate with other MMO and PAM operator. • Communicate all sightings to the EOD supervisor to ensure compliance with the MMMP. • Initiate PAM (via the PAM operator) where conditions are such that PAM is required to supplement visual monitoring. • Conduct the post-detonation search as outlined in the MMMP. • Complete marine mammal reporting requirements in the field and report to the Lead Consents Manager as appropriate.

Key personnel	Responsibilities
Passive Acoustic Monitoring (PAM) Operator	• Report to EOD supervisor and Lead Consents Manager. • Deploy, maintain and operate PAM equipment, including spares. • Liaise with the ADD operator to ensure the ADD is tested appropriately. • Monitor the mitigation zone and conducting the pre-detonation search as described in the MMMP. • Communicate with the MMOs. • Communicate all detections to the MMO(s) and EOD supervisor to ensure compliance with the MMMP. • Liaise with the MMOs to meet marine mammal reporting requirements in the field and report to the Lead Consents Manager as appropriate.
Acoustic Deterrent Device Operator	• Report to EOD supervisor and Lead Consents Manager. • Ensure that the ADD is tested and fully functional prior to use. • Operate the ADD in line with the requirements set out in the MMMP. • Liaise with other members of the mitigation team as appropriate. • Provide final report(s) on the use of ADD during the UXO clearance campaign.