Inch Cape

OFFSHORE LIMITED

Inch Cape Offshore Wind Farm
UXO Clearance

Marine Licence Application

Supporting Environmental Information (SEI) Report

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Acronyms & Abbreviations

Acronym	Term
AA	Appropriate Assessment
ADD	Acoustic Deterrent Device
AIS	Automatic Identification System
ALARP	As Low As Reasonably Practicable
AEZ	Archaeological Exclusion Zone
COLREGS	Collision Regulations
cUXO	Confirmed UXO
DDV	Drop down video
EC	European Commission
ECC	Export Cable Corridor
EIAR	Environmental Impact Assessment Report
EPS	European Protected Species
EPS-RA	European Protected Species Risk Assessment
ES	Environmental Statement
FLO	Fisheries Liaison Officer
HRA	Habitats Regulation Appraisal
ICES	International Council for the Exploitation of the Sea
ICOL	Inch Cape Offshore Limited

INNS	Invasive non-native species
MarLIN	Marine Life Information Network
MARPOL	Marine Pollution
MCA	Maritime and Coastguard Agency
MRCC	Maritime Rescue Co-ordination Centre
MMMP	Marine Mammal Mitigation Plan
NAS	Noise abatement system
NEQ	Net Explosive Quantities
NtM	Notice to Mariners
OfTI	Offshore Transmission Infrastructure
OSPAR	Oslo Paris Convention
OWF	Offshore Wind Farm
PAD	Protocol for Archaeological Discoveries
PMF	Priority Marine Feature
pUXO	Potential UXO
RA	Risk Assessment
RIAA	Report to Inform Appropriate Assessment
ROV	Remotely Operated Vehicle
SAC	Special Area of Conservation
SLVIA	Seascape, Landscape Visual Impact Assessment

SMT-ROV	Subsea Multi-Tool Remotely Operated Vehicle
SOLAS	Safety of lives at sea
SPA	Special Protection Area
SSC	Suspended Sediment Concentrations
SSSI	Site of Special Scientific Interest
UK-BAP	United Kingdom Biodiversity Action Plan
UK-HO	UK Hydrographic Office
USBL	Ultra-short baseline
UXO	Unexploded ordnance
WSI	Written Scheme of Investigation
WWI	World War I
WWII	World War II

Glossary

Defined Term	Meaning
The 2010 Act	Marine (Scotland) Act 2010.
The 2013 Application	The Environmental Statement, HRA Report and supporting documents submitted by the Company on 1st July 2013 to construct and operate an offshore generating station and transmission works.
The 2018 Application	The EIA Report, HRA Report and supporting documents submitted by the Company on 15 August 2018 to construct and operate an offshore generating station and transmission works.

Defined Term	Meaning
Development	The Inch Cape Offshore Wind Farm (the Wind Farm) and Offshore Transmission Works (OfTW) being developed by Inch Cape Offshore Limited (ICOL).
Development Area	The area for the Wind Farm, within which all Wind Turbine Generators, inter-array cables, interconnector cables, offshore substation platform(s) and the initial part of the Offshore Export Cable and any other associated works must be sited. As stipulated in the Crown Estate agreement for lease.
Inch Cape Offshore Transmission	Components of the Development which are permitted by the OfTI Marine Licence (MS-00010593).
Inch Cape Offshore Wind	A component of the Development, comprising wind turbines and their foundations and substructures, and inter-array cables.
Offshore Export Cables	The subsea, buried or protected electricity cables running from the offshore wind farm substation to the landfall and transmitting the electricity generated to the onshore cables for transmission onwards to the onshore substation and the electrical grid connection.
Offshore Export Cable Corridor/ Export Cable Corridor	The area within which the Offshore Export Cables will be laid from the OSP and up to Mean High Water Springs.
Offshore Transmission	The Offshore Export Cable and OSPs. This includes all permanent and temporary works required.
The Wind Farm	The Inch Cape Offshore Wind Farm.

Executive Summary

Inch Cape Offshore Limited (ICOL) is applying for a marine licence under Part 4 of the Marine (Scotland) Act 2010 ("the 2010 Act"). The marine licence is required for unexploded ordnance (UXO) clearance along the Offshore export Cable Corridor (ECC) and the Development Area for the Inch Cape Offshore Wind Farm (OWF).

As part of the pre-construction works, a number of activities are required in order for construction to proceed. These include UXO clearance. Boulder clearance and UXO identification activities will be covered by a separate marine licence application.

Although the activities involve an impulsive noise, the activities will be relatively and minimally invasive, will be localised, small scale and of short duration, taking place within the existing consented Project area i.e., the Development Area and the ECC and it can be concluded the UXO clearance activities will not result in significant effects on a range of environmental receptors.

This document has been prepared by competent experts (The Natural Power Consultants) to provide the supporting information to inform the marine licence application.

1 Introduction

1.1 Background

The Inch Cape Offshore Wind Farm (the Wind Farm) and Offshore Transmission Infrastructure (OfTI), hereafter referred to as the Development, is being developed by Inch Cape Offshore Limited (ICOL) (Figure 1.1).

In 2014, the Scottish Ministers granted ICOL Section 36 and marine licence consents, pursuant to the 2013 Application, for the construction and operation of an offshore wind farm and a marine licence for the construction and operation of offshore transmission infrastructure. The licences granted to ICOL in 2014 (along with those for other Forth and Tay projects, Seagreen Alpha and Bravo and Neart na Gaoithe) were subject to a petition for judicial review in early 2015. A decision was made by the UK Supreme Court in November 2017 to uphold the Scottish Ministers' decisions to grant the offshore consents.

In 2018 the original consent was updated, and a revised application was submitted to Scottish Minsters. In 2013 an Environmental Statement (ES) was produced to accompany the initial application based on the original design of the Wind Farm. This was also subsequently updated in 2018 with the production of an Environmental Impact Assessment Report (EIAR) to enable the use of progressions in technology following the original consent, through a reduction in turbine numbers (fewer turbines with larger generating capacity), and reduction in associated cabling (inter-array and export cables) in order to maximise efficiencies whilst minimising environmental impacts. The EIAR updated the 2013 ES and where impacts were predicted to be less than those already assessed, a new assessment was not undertaken as the conclusions drawn in the original 2013 ES remained valid.

Section 36 and marine licence consents for the revised design, were granted by Scottish Ministers in 2019. Since then, ICOL has successfully sought two variations to the Section 36 and Generation Station marine licence to optimise wind farm efficiency and both were granted consent in June 2023 (Section 36 Variation dated 14 June 2023 and Generation Marine Licence Variation MS-00010140 dated 15 June 2023).

In 2019 a revised marine licence was granted for the OfTI connecting the landfall location, near Cockenzie, East Lothian, and the Inch Cape Offshore Wind Farm. A varied Marine Licence (MS-00010593), to capture changes to deposit quantities and revision to the Offshore Export Cable Corridor coordinates, was granted 9th November 2023.

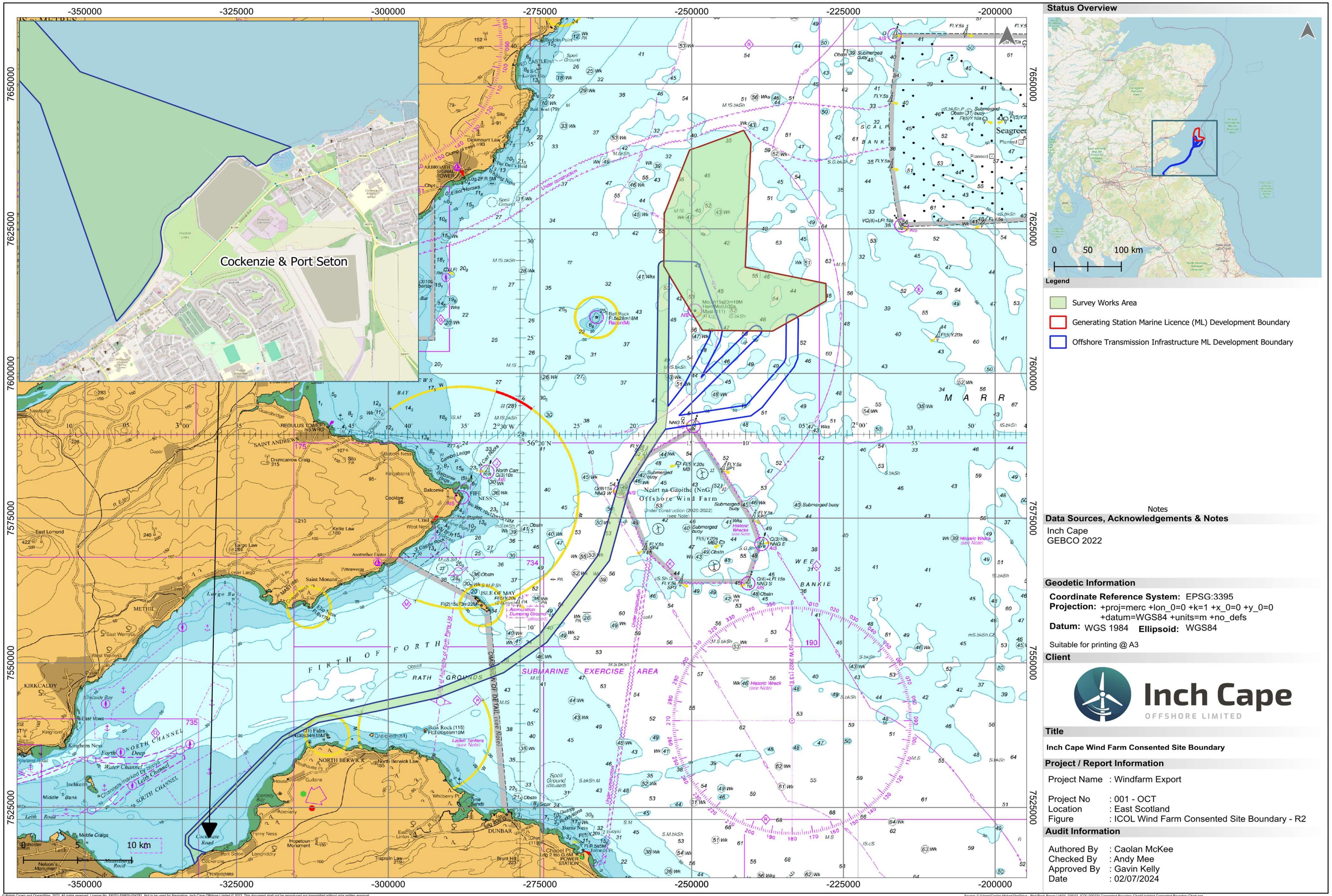

Figure 1.1: Inch Cape Offshore Wind Farm Development Area and Current Offshore Export Cable Corridor

1.2 Intention to Apply for a New Marine Licence

ICOL is applying for a marine licence for the unexploded ordnance (UXO) clearance activities for the whole Project, along the Export Cable Corridor (ECC) and within the Development Area (Figure 1.1)

Under the Marine (Scotland) Act 2010, and the Marine and Coastal Access Act 2009, a marine licence is required for UXO clearance activities. The requirement to considered European Protected Species (EPS) in developments in waters off Scotland derives from the Conservation of Offshore Marine Habitats and Species Regulations, 2017, which transpose the requirements of the Habitats Directive (Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora). ICOL intends to apply for a new marine licence under Part 4 of the Marine (Scotland) Act 2010 (“the 2010 Act”) for UXO clearance activities.

This document forms a suite of supporting application documents constituting the complete marine licence application, namely:

- Supporting Environmental Information (SEI) Report (This document -ICOL Ref: IC02-INT-EC-OFL-012-INC-RPT-003);
- Report to Inform Appropriate Assessment (RIAA)) (ICOL Ref: IC02-INT-EC-OFL-012-INC-RPT-004);
- European Protected Species (EPS) Risk Assessment (RA) (EPS RA) (NP Ref: 1355322, ICOL Ref: IC02-INT-EC-OFL-012-INC-RPT-006);
- Marine Mammal Mitigation Plan (MMMP) (NP Ref: 1655320, ICOL Ref: IC02-INT-EC-OFL-012-INC-PLA-001)

1.3 Scope of this Document

This document has been produced to provide the supporting information to inform the marine licence application, and contains the following:

- Description of the UXO clearance activities (Section 2);
- Scope of Assessment (Section 3);
- Environmental Appraisal (Section 4);
- Summary and Conclusions (Section 5); and
- References (Section 6).

The UXO clearance activities have been considered against whether they could result in significant impacts on a range of marine receptors.

2 Description of the UXO Clearance Activities

In order to undertake construction activities, a number of route preparation activities will be required to clear the area. This application considers the need for clearance of UXO, should they be present in the area affected by planned construction work. The UXO identification survey activities will be covered by a separate marine licence application.

A hierarchical approach to addressing confirmed UXO (cUXO) will be applied. This will be (in order of preference), avoidance, relocation, or clearance (deflagration or detonation).

2.1 Outline Programme

The UXO clearance work will be undertaken between the start of Q4 2024 and the end of Q2, 2025. However, there is potential that further UXO clearance may be required later in the construction programme of the Inch Cape OWF (July 2025 – August 2027) if any additional UXO are discovered.

2.2 Method Statement

2.2.1 UXO Clearance

A variety of options for managing UXOs on site are available and will be considered on a case-by-case basis:

- Micro-siting i.e., avoidance of UXO;
- Relocation ('lift and shift') of UXO (where deemed safe to do so); and
- Clearance of UXO using either low or high order clearance. Low order clearance (deflagration) will be attempted in the first instance wherever possible. Detonation by controlled explosion (high order clearance) will be used as a last resort.

It is anticipated that a maximum of 85 UXO targets may be present across the Development Area and ECC (westernmost corridor) (depths ranging between 40 – 59 m) and will require clearance. It is anticipated that 75 UXO targets will be cleared using low order clearance methods whilst up to 10 UXO may require high order clearance methods. These numbers are based on the findings of the UXO risk assessment (50028_UXOTARA_Inch Cape OWF Array_Vysus_V2.0) which is based on current published data on UXO presence in the project area. It is likely that different types of UXO will be present (small projectiles, mines, aerial bombs and torpedoes originating from WWI and WWII), many of which are likely to have been subject to degradation or burying over time. It is anticipated that the largest UXO may have a net explosive quantity (NEQ) of 254 kg in the Development Area and 1179 kg along the ECC.

Low order clearance is preferable to high order clearance as it avoids the high pressures associated with an explosion by using a small initiation explosive to 'burn away' the target explosive material within the UXO. Different sized initiation explosives may be required for different sized UXOs.

2.2.1.1 Micrositing

In some cases, it may be possible to somewhat micro-site some elements of the Project infrastructure so as to safely avoid identified UXO, thereby avoiding the need for any intrusive clearance. This will be considered for each UXO identified but for the purposes of this marine licence application it is assumed that clearance of up to 85 UXO will be required across the Development Area and the ECC.

2.2.1.2 Relocation of UXO

Relocation of a confirmed UXO target will be considered if the UXO is in close proximity to an area where construction work needs to be subsequently carried out, where a UXO item is located in close proximity to an existing asset (i.e. cables/pipelines) or where UXO are located within the wind turbine boxes and resulting detonation could impact the seabed and subsurface geology, resulting in impacts for pile installations. UXO will be relocated to an area within the Project Area and clear of any other known constraints (i.e. archaeological sensitivities, other assets etc).

Where it is identified that a UXO is to be relocated, and it has been confirmed that it is safe to move (following a threat and risk analysis), the relocation of UXO will be carried out using either a Remote Ordinance Lifting System or Enclosed Minution Lifting System.

2.2.1.3 UXO Clearance

The contractor that will undertake the UXO clearance activities is still to be selected. Consequently, the precise details of the methods to be used for UXO clearance (detonation) are not yet available and will depend on the outcome of the contract tendering process currently being undertaken. In the case where a target is confirmed as UXO, and it cannot either be avoided by micro-siting or cleared by re-location of the UXO, explosive detonation of the UXO will be required. For the purposes of this marine licence assessment, it is assumed that 75 UXO targets will be cleared using low order clearance methods whilst up to 10 UXO may require high order clearance methods. Low order deflagration solution as the primary method of UXO disposal due to being the most environmentally friendly solution. However, each UXO target must be individually assessed to determine its status and condition, to determine suitability for low order disposal. In the unlikely event that it is deemed necessary, a High Order disposal technique will be used. The most appropriate disposal tool will be prepared and an ROV deployed to place the tool in the optimum position adjacent to the UXO, the initiation float will be released and the ROV recovered to deck. The main vessel will step out to a safe stand-off distance, approximately 1000 m, and the Inch Cape MMMP (IC02-INT-EC-OFL-012-INC-PLA-001)) will be followed to ensure the area is clear of potential marine mammals. All relocation and clearance work will be undertaken during daylight hours, by specialists in accordance with the appropriate regulations and guidance.

2.2.2 Vessels

It has not yet been confirmed which vessels will be used for the UXO clearance work. It is anticipated that up to three vessels will be required:

- An 'ROV/dive support vessel' from which any charges will be set and on which the mitigation personnel will be based;
- A 'guard vessel' which will undertake preparation and implementation of the detonations and from which the Acoustic Deterrent Device (ADD) will be deployed; and
- A mitigation vessel for the deployment of a noise abatement system (NAS) if required.

The vessels will be on site for a limited duration (anticipated a maximum of nine months). The potential for impact on the designated sites from the use of vessels will mainly be related to indirect disturbance both in terms of noise and physical presence. Vessels will undertake 24/7 working, with clearance activities only being undertaken during daylight hours, and the UXO clearance strategy will be planned to minimise vessel transit lengths between targets.

2.3 Embedded Mitigation

There are a number of embedded mitigation measures which will be implemented to reduce the potential for certain impacts.:

- A hierarchical approach to addressing confirmed UXO (cUXO) will be applied. This will be (in order of preference), avoidance, relocation, or clearance (deflagration or detonation) to ensure the chances of high order detonation are reduced as low as possible;
- Compliance with IMO conventions including COLREGs and SOLAS to ensure standard levels of navigation and vessel safety are adhered to;
- Issue of Notice to Mariners (NtM) notifying of the type and location of the UXO clearance;
- Implementation of appropriate safety distances during UXO investigation;
- Waste management on board vessels is covered the Merchant Shipping (Prevention of Pollution by Sewage and Garbage from Ships) Regulations 2008. These regulations implement revised Annex IV of MARPOL 73/78 (Regulations for the Prevention of Pollution by Sewage from Ships), and Annex V of MARPOL 73/78 (including amendments) (Regulations for the Prevention of Pollution by Garbage from Ships);
- Appropriate biosecurity, aimed at preventing invasive non-native species (INNS); and
- Any work to be undertaken will avoid all designated Archaeological Exclusion Zones (AEZs) specified for the Development. A Protocol for Archaeological Discoveries (PAD) is currently being written, in line with current consents for the construction works1, and in the absence of an agreed PAD (and Written Scheme of Investigation (WSI)), ICOL has produced an Environmental Requirements Document (for the pre-construction activities) which will be provided to contractors, detailing the same information as that which would feature in the PAD/ WSI, for reference. Specific mitigation will include:

[1] Section 36 Consent (dated 14th June 2023); Generating Station Marine Licence (MS-00010140 dated 15th June 2023); and Offshore Transmission Infrastructure (OfTI) Marine Licence (MS-00010593 dated 9th November 2023)

  - Adherence to known Archaeological Exclusion Zones (AEZ); and
  - Implementation of an Environmental Requirements Document in the absence of an agreed PAD.

2.4 Licensible Marine Activities

The following activities associated with the UXO clearance are considered to be licensable under the Marine (Scotland) Act 2010:

- Deposits and use of explosives.

3 Scope of Assessment

This review and all subsequent assessments have been undertaken with particular regard to the environmental sensitivities of the geographical area that may be affected through a review of relevant designated sites (Special Areas of Conservation (SAC), Special Protection Areas (SPA) and Ramsar), specifically those closest to the location of UXO clearance activities (shortest straight-line distances provided) (Figure 3.1):

- Outer Firth of Forth and St Andrews Bay Complex SPA (direct overlap);
- Forth Islands SPA (direct overlap);
- Firth of Forth SPA (direct overlap);
- Isle of May SAC (4.3 km);
- River South Esk SAC (23.97 km);
- Firth of Tay and Eden Estuary SAC (24.53 km);
- Firth of Tay and Eden Estuary SPA (25.23 km);
- Berwickshire and North Northumberland Coast SAC (26.45 km);
- St Abb's Head to Fast Castle SPA (27.42 km);
- Fowlsheugh SPA (33.11 km);
- Ythan Estuary Sands of Forvie and Meikle Loch SPA (61.86 km); and
- Buchan Ness to Collieston Coast SPA (82.23 km)

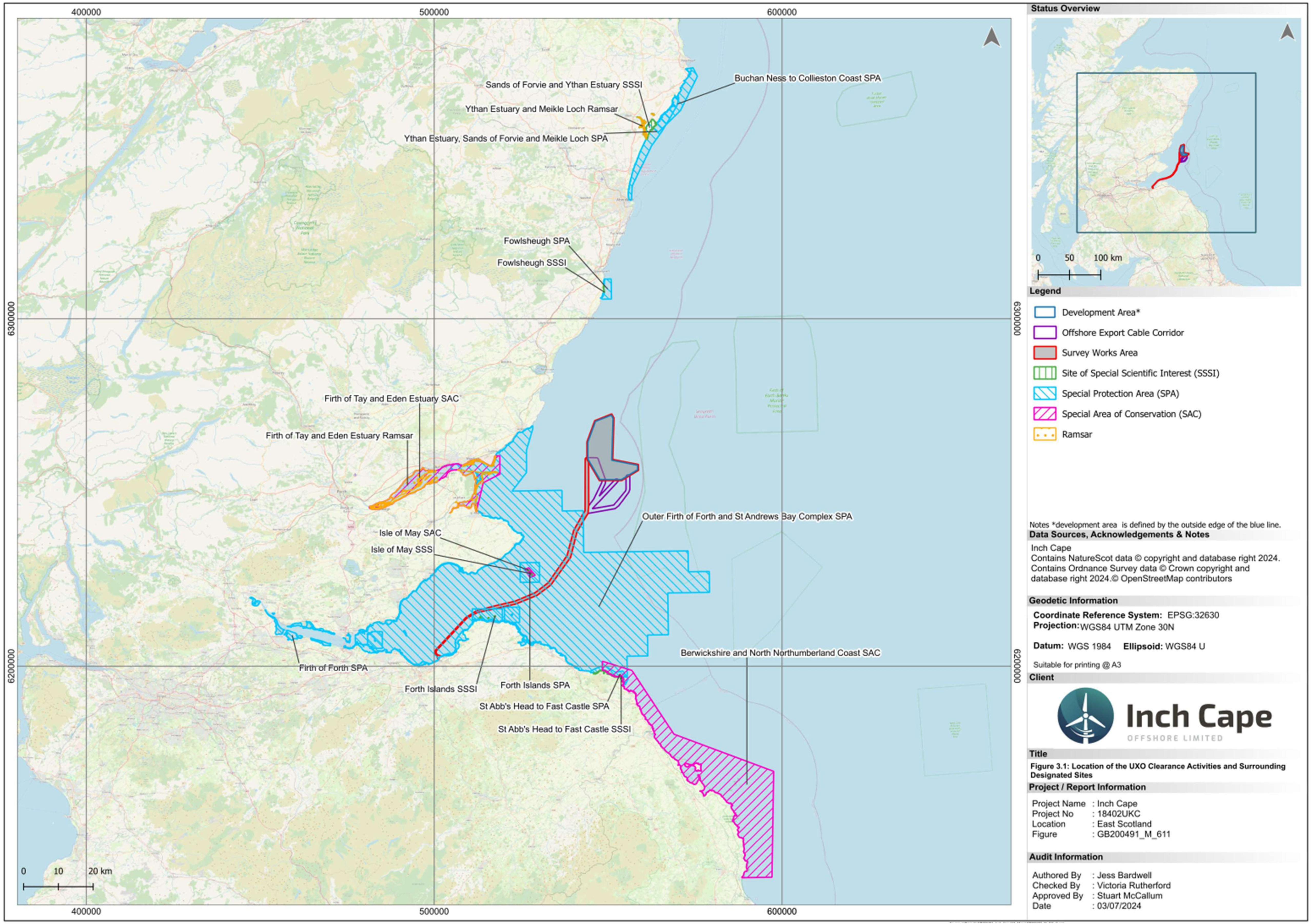

Figure 3.1: Location of the UXO clearance Activities and Surrounding Designated Sites

3.1 Evaluation of potential impacts

An evaluation of potential environmental impacts is provided in Table 3.1, below, with additional information provided in Section **Error! Reference source not found.** (Environmental Appraisal), where necessary. Where mitigation is considered to adequately be in place to minimise an impact to as low as reasonably practicable, e.g. pollution and INNS risk, these are not considered further.

Table 3.1: Summary of Potential impacts Relating to the UXO clearance Activities

Receptor	Further information required	Reasoning
Metocean and Coastal Processes	No	The UXO clearance activities involve limited interaction with the seabed therefore it is considered there is no potential for any impact, other than negligible, highly localised effects. No further assessment required.
Benthic Ecology	Yes	Some minor temporary disturbance in areas where UXO clearance activities will be undertaken, may result in temporary benthic habitat disturbance. Further consideration is presented in Section 4.1
Natural Fish and Shellfish	Yes	Some minor temporary disturbance in areas where UXO clearance activities will be undertaken, may result in temporary fish and shellfish habitat disturbance. Further consideration is presented in Section 4.2.
Marine Mammals	Yes	The UXO clearance activities will result in increased vessel presence and use of survey equipment, therefore some minor temporary disturbance to marine mammals may occur. Further consideration is presented in Section 4.3.
Ornithology	Yes	The UXO clearance activities will result in increased vessel presence over a prolonged period of time, and indirect effects on prey species, therefore some minor temporary disturbance to ornithological receptors may occur. Further consideration is presented in Section 4.4.
Seascape, Landscape and Visual Impact Assessment (SLVIA)	No	No visual impact, other than localised and temporary vessel presence in an area of already high vessel traffic. No further assessment required.

Receptor	Further information required	Reasoning
Cultural Heritage and Marine Archaeology	Yes	Some minor temporary disturbance in areas where UXO clearance activities will be undertaken, may result in sediment disturbance potentially affecting cultural heritage assets. Further consideration is presented in Section 4.5.
Commercial Fish	Yes	The UXO clearance activities will result in up to three additional vessels. Additional vessels working in the area has the potential for effects on the commercial fishing community. Further consideration is presented in Section 4.6.
Shipping and Navigation	Yes	The UXO clearance activities will result in up to three additional vessels. Additional vessels working in the area have the potential for effects on shipping and navigation in the area. Further consideration is presented in Section 4.7.
Socio-Economics and Tourism	No	No potential for significant adverse effects to arise, and as such no requirement for further assessment.
Military and Civil Aviation	No	No potential for significant adverse effects to arise, and as such no requirement for further assessment.
Other Human Considerations	No	There may be very short periods of time during the works when there could be disruption to other human users of the environment. Short term and partial closures are not predicted to result in any significant effects on other users as large areas of sea will remain accessible. As such there is no potential for significant adverse effects to arise, and no requirement for further assessment.

Receptor	Further information required	Reasoning
Climate Change and Greenhouse Gases	No	It is recognised that some greenhouse gas emissions, arising from vehicular sources will be emitted as part of this proposed work. Due to the temporary and localised nature of the works, greenhouse gas emissions and waste materials are not considered to represent any potential for significant effects. It is considered that the works, as applied for, represent the lowest overall environmental effect. There is no potential for significant adverse effects to arise, and as such, no requirement for further assessment. Furthermore, the objective of the activities is to support the development of the Inch Cape Offshore Wind Farm which will generate a renewable source of electricity and contribute to a reduction in Scotland's greenhouse gas emissions. As per the Inch Cape 2021 Carbon Balance Assessment2, the Inch Cape Project's annual greenhouse gas emissions saving from displacing gas-fired generation is predicted to be 1.43 Metric tonnes of CO_2 per year. This is equivalent to a reduction of 3.1% of the annual total greenhouse gas emissions in Scotland (based on 2019 records).

[2] 4-ICOL-OnTW-EIA-Volume-3-Technical-Appendices.pdf (inchcapewind.com)

4 Environmental Appraisal

Where identified as required (Table 3.1), further information and consideration of environmental effects arising from the UXO clearance activities are provided in this section through a review of existing environmental assessment conclusions, followed by an updated assessment for the UXO clearance activities.

The UXO clearance activities are analogous to other construction phase work that may be undertaken for the installation of an offshore wind farm (i.e., short duration, localised, and utilised for facilitating the construction) and therefore it is considered that the baseline and relevant construction phase impacts from the existing ES and EIAR are relevant to the consideration of whether significant effects may arise from the proposed work.

4.1 Benthic Ecology

4.1.1 Baseline

The baseline investigations found the environment surrounding the project was relatively stable in sedimentary composition and contamination levels, with little change observed in the infaunal content for ten – 20 years. A total of ten biotopes were identified across the development area, and nine biotopes within the ECC (Table 4.1). The dominant biotope in the Development Area was found to be SS.SMx.CMx.MysThyMx.

Table 4.1: Biotopes Recorded at the Development Area and the Offshore Export Cable Corridor of the Inch Cape Offshore Wind Farm

Biotope Code	Name
Development Area	
SS.SSa	Sublittoral sands and muddy sands
SS.SCS.CCS	Circalittoral coarse sediment
SS.SCS.CCS.PomB	*Pomatoceros triqueter* with barnacles and bryozoan crusts on unstable circalittoral cobbles and pebbles
SS.SCS.CCS.MedLumVen	*Mediomastus fragilis*, *Lumbrineris* spp. and venerid bivalves in circalittoral coarse sand or gravel
SS.SCS.OCS	Offshore circalittoral coarse sediment
SS.SMx.CMx	Circalittoral mixed sediment
SS.SMx.CMx.MysThyMx	*Mysella bidentata* and *Thyasira* spp. in circalittoral muddy mixed sediment

SS.SMx.CMx.OphMx	*Ophiothrix fragilis* brittlestar beds on sublittoral mixed sediment
CR.HCR.Xfa	Mixed faunal turf communities.
Artica islandica	
Offshore Export Cable Corridor	
SS.SMu.CFiMu.SpnMeg	Circalittoral muddy sand with seapens and burrowing megafauna
SS.SMx.CMx **SS.SMx.CMx,** **SS.SSa.CMuSa,** **SS.SMx.CMx.MysThyMX** **SS.SMx.CMx.FluHyd**	Subtidal soft sediments
SSSMx.CMx **SS.SMx.CMx.FluHyd** **SS.SMx.CMx.OphMx** **CR.MCR.EcCr.FaAlCr** **CR.MCR.EcCr.FaAlCr.Bri** **CR.MCR.EcCr.FaAlCr.Pom** **CR.MCR.EcCr.FaAlCr.Adig** **SS.SCS.CCS**	Circalittoral and infralittoral coarse and mixed sediment, cobbles, boulders and rock with sessile epifaunal and algal communities

Preliminary observations of the drop down video (DDV) data indicated that the habitat and biota present in the survey area at the Development Area are typical of North Sea sedimentary communities. Although a wide range of sediment types were found to be present within the survey area as a whole – including coarse sand, shell and stone gravel, pebble, and cobble – the dominant substrate type recorded was rippled sand with shell gravel. No areas of bedrock or biogenic reef features were recorded.

The key species present in the survey area were found to be*: Alcyonium digitatum, Pomatoceros triqueter, Munida rugosa, Flustra foliacea*, and *Asterias rubens*. The brittlestar *Ophiothrix fragili*s was recorded in 2 locations at high densities, and the ocean quahog (*Artica islandica*) was recorded in the area (though only as small juvenile individuals).

Important habitats identified in the ECC area included "burrowed mud", a Scottish Priority Marine Feature

(PMF). This type of habitat (represented here by the SpnMeg biotope) covered extensive areas of the proposed Offshore Export Cable Corridor and is likely to occur widely throughout the region. Cobbles, boulders and rocky outcroppings around the Isle of May were regarded as having moderate to low resemblance to Annex I (EC Habitats Directive) stony and rocky geogenic reef.

4.1.2 Existing ES / EIAR conclusions

The effects of the construction of the Development on the benthic ecology of the area are set out in Chapter 12 of the 2013 Inch Cape Offshore ES. No further assessment was considered to be required for the revised design (2018) EIAR. The impact assessment concluded that there would be no significant impact on benthic ecology from the construction and operation of the Development.

4.1.3 Effect of the UXO Clearance Activities

Potential effects from the UXO clearance activities include:

- Seabed disturbance - temporary disturbance / loss of habitat; and
- Seabed disturbance - temporary increases in SSC leading to smothering.

4.1.3.1 Seabed Disturbance - Temporary Disturbance / Loss of Habitat

The UXO clearance activities may result in temporary habitat loss and disturbance. UXO clearance activities at other sites have predicted craters between 0.9 – 3 m deep and ranging from 2.8 – 15 m in radius giving a maximum predicted crater area of 0.0017 km^2 (Dogger Bank A & B, 2020 (MLA/2020/00581) and Triton Knoll, 2018 (MLA/2019/00475))[3]. Both the Development Area and the ECC are comprised of mainly sedimentary habitats (Table 4.1), and thus such relatively small scale displacement of sediment through UXO clearance works is not considered to represent any greater than a negligible impact on these habitats. Any areas of sediment disturbed through UXO clearance activities are predicted to recover in form and community in very short order, considering the lack of interruption of sedimentary and other physical processes in the area, and large area of equivalent habitat from which species are able to recolonise the affected area.

During the ES baseline surveys, no evidence of Annex I reef features were observed in the Development Area, and any potential reef features along the ECC were identified to have low resemblance to Annex I reef criteria. Depending on the location of UXO, some localised rock patches may be impacted by UXO detonations. Where fauna is lost, areas of exposed rock will recolonise quickly, with recovery evident in the short term.

4.1.3.2 Seabed Disturbance - Temporary Increase in SSC

The UXO clearance activities have the potential to physically disturb the seabed through detonation of UXO, resulting in an increase in SSC within the water column.

Bedrock and stony reef features are sensitive to smothering (> 5 cm is the benchmark used by the Marine Life Information Netwok (MarLIN)). The sediment arising from the activities will be limited in volume, being dispersed into a naturally dynamic system with cyclical changes in turbidity, and benthic features are largely adapted to such small fluctuations. The UXO clearance activities will be conducted over a small area and as such, limited arisings into the water column are expected. Given the small sediment arisings, there is no expectation that the sediment would travel a considerable distance, and no expectation that sufficient sediment will be disturbed that any fauna would be subject to smothering at a degree that could lead to mortality.

4.1.4 Conclusion

No significant effects are predicted to arise on the benthic ecology of the area as a result of the UXO clearance activities. The impacts which may occur are also considered to be lesser in scale and magnitude than those already consented (and assessed as not significant) for construction activities at the Inch Cape OWF.

4.2 Natural Fish and Shellfish

4.2.1 Baseline

A range of species are present in the Development Area and along the ECC, many of which have commercial importance and have spawning or nursery rounds in the immediate area. These include a number of fin fish, elasmobranchs and shellfish. Many of the fish species are highly mobile and widely distributed over both the Development Area and the ECC and have a high commercial value.

A number of species of conservation importance (PMF, UK-BAP and OSPAR) were found during EIA baseline surveys , including: Norway pout (*Trisopterus esmarkii*), whiting (*Merlangius merlangus*), sandeel (*Ammodytes tobianus*), mackerel (*Scomber scombrus*) herring (*Clupea harengus*), cod (*Gadus morhua*), saithe (*Pollachius virens*), ling (*Molva molva*), spurdog (*Squalus acanthias*), common skate (*Dipturus batis*), and anglerfish (*Lophius piscatorius*).

The Development Area was found to be largely suitable for sandeel, with discrete patches of prime and sub-prime sediment (Appendix 13B in ICOL, 2013). The site is also nestled between two large herring spawning grounds (north and south of the Firth of Forth), as defined by Coull *et al.* (1998). Herring in the North Sea spawn between August and October[4], and sandeel between September and MarchError! Bookmark not defined..

4.2.2 Existing ES / EIAR conclusions

The effects of the construction of the consented Inch Cape Offshore Export Cable works on natural fish and shellfish ecology were assessed the original application submitted in 2013 and the 2018 EIAR, both of which determined the construction and operation of the Development to be not significant.

4.2.3 Effect of the UXO Clearance Activities

Potential effects from the UXO clearance activities include:

- Seabed disturbance - direct and indirect temporary habitat disturbance; and
- Underwater noise – direct impacts on fish species.

4.2.3.1 Seabed Disturbance - Temporary Disturbance / Loss of Habitat

The UXO clearance activities may result in direct and indirect disturbance to fish habitat during the activities. Direct disturbance to the seafloor would occur during the activities, but also increases in SSC in the vicinity of the activities (see Section 4.1).

The proposed work will affect a negligibly small area of seabed, with small discreet locations disturbed in order to clear UXO. There is therefore no potential to adversely affect fish species at a population level in the area through seabed disturbance.

With regards to spawning habitats, the majority of fish are pelagic spawners (releasing eggs into the water column) and therefore will not be directly affected by habitat disturbance. Some species, namely herring and sandeel, are demersal spawners, laying their eggs on the seabed, and requiring specific substrate. There is no direct overlap with herring spawning grounds and considering any sediment arisings will be small scale and localised, no potential for indirect effects. Though sandeel are potentially present in the area, suitable habitats for sandeel are common throughout the North Sea and are not restricted to the Development area and the ECC. Sandeel are also not considered sensitive to small increases in SSC, as are likely to arise from the works.

The area is also considered important for a range of commercially exploitable shellfish species (see also Commercial Fisheries, Section 4.6), however considering the small scale of the works, and limited seabed disturbance that will arise, the activities will have no more than a negligible effect on shellfish species, with no population level consequences.

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[4] https://www.ices.dk/about-ICES/projects/EU-RFP/EU%20Repository/ICES%20FIshMap/ICES%20FishMap%20species%20factsheet-herring.pdf

4.2.3.2 Underwater Noise – Direct Impacts on Sensitive Fish Species

The UXO clearance works have the potential to impact fish and shellfish receptors (including eggs and larvae) via underwater noise and vibration associated with low order deflagration, and high order detonation UXO clearance activities.

A review of hearing sensitivity in fish developed categories that can be used when assessing the effects of sound (Popper *et al*., 2014). The categories are based on the presence or absence of a swim bladder and the potential for the swim bladder to enhance hearing sensitivity. These include:

- Fish species with no swim bladder or another gas filled chamber (e.g., flatfish). These species generally only detect particle motion and are less sensitive to sound pressure. However, some physiological injury could result from exposure to sound.
- Fish species with swim bladders in which hearing is separate from the swim bladder or any other gas filled chamber (e.g., Atlantic salmon). While hearing only involves particle motion, not sound pressure, these species are sensitive to physiological effects.
- Fish species in which hearing involves a swim bladder or other gas filled chamber (e.g., herring and cod). These species are sensitive to physiological effects being able to detect sound pressure and particle velocity.
- Fish eggs and larvae: The limited available data (e.g., larvae displaying similar startle thresholds) suggests larvae have similar hearing frequency ranges to those of adults. It is thought swim bladders may develop at a larval stage meaning there may be a susceptibility to pressure related trauma (Popper *et al*., 2014).

In contrast, bioacoustics data (i.e., sound detection, acoustic behaviour, effects of anthropogenic sound) for shellfish is very limited which notably limits assessment of underwater noise on these species at this time.

In consideration of explosives and potential mortality, all species groups are considered equivalent and there is no frequency weighting to account for variations in hearing sensitivity. Two thresholds are provided; 229 dB SPLpeak and 234 dB SPLpeak which represent a lower and upper boundary, respectively for the potential impact. It is also considered that there is insufficient data for a quantitative calculation of impact ranges for recoverable injury or hearing impairment in respect of a blast.

Owing to the limited data available for the impact of different sized charges on fish species, calculated ranges for the risk of mortal injury to individuals have been provided. The upper limit (234 dB SPLpeak) of potential mortality or potential mortal injury is predicted to be within 640 m from source of the largest UXO devices (1, 179 kg) (lower limit of 229 dB SPLpeak is 1 km) (Table 4.2), however encountering UXO clearance with the largest charge is unlikely.

Table 4.2: Summary of the mortality and potential mortal injury impact ranges for UXO clearance using the unweighted Lp,pk explosion noise criteria from Popper *et al*. (2014) for fish (from Subacoustech, 2024)

Lp,pk	Mortality and potential mortal injury	
	234 dB (Upper limit)	229 dB (Lower limit)
0.25 kg	< 50 m	60 m
6 kg	110 m	180 m
15 kg	140 m	240 m
25 kg	170 m	290 m
49 kg	220 m	370 m
165 kg	330 m	550 m
227 kg	370 m	610 m
254 kg	380 m	640 m
354 kg	430 m	710 m
1,179 kg	640 m	1.0 km

Mitigation will include the use of low order detonation as a primary method for clearance, to reduce underwater noise generation.

It is considered fish have a high sensitivity to UXO clearance works, particularly high order explosions, however the receptor is mobile and are of impact is relatively small when compared to these species' natural ranges. Taking into consideration the mitigation options, and limited and temporary nature of the clearance activities, any potential effects are therefore predicted to be temporary, localised and not significant.

4.2.4 Conclusion

No significant effects are predicted to arise on the fish and shellfish ecology of the area as a result of the UXO clearance activities. The impacts which may occur are also considered to be lesser in scale and magnitude than those already consented (and assessed as not significant) for constructions activities at the Inch Cape OWF.

4.3 Marine Mammals

4.3.1 Baseline

The most common species recorded in the Firths of Forth and Tay, identified as key receptors, are as follows:

- Bottlenose dolphin (*Tursiops truncatus*);

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

Of the marine mammals listed above, grey seal, harbour seal and bottlenose dolphin are of particular relevance with regards to the inshore UXO clearance activities. Other cetaceans such as minke whales and white-beaked dolphins are more likely to be present further offshore.

Generally, the populations are in favourable conservation status. This is true of cetaceans, however while the overall status of harbour seal is favourable, the local population in the Firth of Tay and Eden Estuary SAC is predicted to be in overall decline.

The Offshore Export Cable Corridor passes relatively close to the south-west of the Isle of May (approximately 5.5 km at the nearest point), an area designated as an SAC for grey seal. Around 2,000 pups are born each year on the island, with lower numbers recorded on smaller islands in the southern half of the Firth of Forth. A fast-growing colony can also be found at Fast Castle, on the southern outer reaches of the Forth.

Bottlenose dolphins (*Tursiops truncatus*) are primarily coastal, generally in waters less than 25 m deep, and whilst there appears to be no reports of bottlenose dolphins near to Cockenzie they have been recorded along the Northumberland coast, suggesting they occur across the Offshore Export Cable Corridor.

4.3.2 Existing Assessment

The effects of construction of the consented Inch Cape OWF works on marine mammals were assessed as part of the revised application in 2018 (EIAR, Chapter 10) and determined to not be significant.

4.3.3 Effect of the UXO Clearance Activities

The potential effects of the UXO clearance activities on EPS have been assessed within a separate EPS-RA document. An MMMP has also been prepared to complement the application.

Mitigation required as identified through the Risk Assessment Process is summarised in Table 4.3.

Table 4.3: Mitigation as Identified through the Risk Assessment Process

Approach	Mitigation Measure
Micro-siting	Locations within the development area and offshore export cable corridor will be 'micro-sited' to avoid the UXO and prevent the need for a detonation where deemed safe to do so.
Lift and shift	The 'lift and shift' approach (to move the UXO to another location) will be considered on a case-by-case basis where deemed safe to do so.

Low order clearance	• Pre-work search (min. 60 mins) • Use of an ADD • Low order clearance • Post-detonation search (min. 15 mins)
High order clearance	• Use of an ADD (see Table 7.2) • Use of a NAS (UXO >49 kg) • High order clearance • Post-detonation search (min. 15 mins)

The following impacts were assessed for marine mammal receptors, the conclusions for which are presented below:

- Lethal Effects
- Auditory Injury
- Behavioural responses

4.3.3.1 Lethal Effects and Physical Injury

It is likely that the visual and passive acoustic pre-work search of the 1 km radius mitigation zone alone will be sufficient to negate the potential for lethal effects and physical injury. With this, in combination with the other mitigation procedures outlined, individuals will not be present in close proximity to the proposed UXO clearance work and the potential for lethal effects and physical injury is nil.

4.3.3.2 Auditory Injury

It is likely that pre-work searches (1 km radius zone) alone will be sufficient to negate the potential for auditory injury as a result of low order clearance work using a 0.05 kg or 0.25 kg initiation explosive. For all high order UXO clearance, and low order UXO clearance using a 10 kg initiation explosive, ADD use will be required to ensure no individuals will be present in the zone of potential effect for auditory injury.

The clearance ranges for very high frequency cetaceans (i.e. harbour porpoises) for each of the different mitigation methods (pre-work search, use of an ADD, and use of a NAS for high order clearance >49 kg) for all low order initiation explosive weights and all high order UXO charge weights is presented in the MMMP (IC02-INT-EC-OFL-012-INC-PLA-001). Using these ranges, no harbour porpoise will be present within the zones of potential effect for auditory injury for either low order or high order clearance. With these mitigations, the potential for auditory injury is nil for harbour porpoise.

The mitigation was designed around the greatest (i.e., worst case) potential impact ranges which are those for very high frequency cetaceans (i.e., harbour porpoise). Therefore, with mitigation (pre-work search, use of an ADD and use of a NAS for high order clearance >49 kg), high frequency cetaceans (bottlenose dolphins and white-beaked dolphins), low frequency cetaceans (minke whales) and phocid carnivores in water (seals), will not be present within the zones of potential effect for auditory injury. Therefore, the potential for auditory injury is nil for all species.

4.3.3.3 Behavioural Responses

Behavioural responses will likely be short term; Thompson *et al*. (2020) showed that the minimum time to the first porpoise detection following a 15 minute ADD playback was 133 minutes for all C-PODs within 1 km of the playbacks. Suitable local alternative habitat is likely to be available in the meantime therefore the energetic costs of fleeing should be able to be met relatively quickly. Because each piece of clearance work will only take a few hours, it is unlikely that animals will be excluded from key areas for significant periods of time.

4.3.4 Conclusion

Following the mitigation listed, no significant effects are predicted to arise on marine mammals as a result of the UXO clearance activities. The impacts which may occur are also considered to be lesser in scale and magnitude than those already consented (and assessed as not significant) for constructions activities at the Inch Cape OWF.

4.4 Ornithology

4.4.1 Baseline

The Development Area and the EEC are situated within / pass through or are in close proximity to a number of European designated sites for ornithological features. The Offshore Export Cable Corridor passes through the intertidal area of the Firth of Forth, passing near to the Firth of Forth SPA, Ramsar site and Site of Special Scientific Interest (SSSI), and through the Outer Firth of Forth and St Andrews Bay Complex SPA. This shoreline contains a variety of coastal and estuarine habitats which attract large numbers, and a wide variety, of over-winter and passage wetland birds (waders and waterfowl) to the area. many of the sites are designated for breeding seabird features, with the breeding season for most seabird species falling between April and September. Outside the breeding season the wider area is used for foraging, resting and roosting by seabirds. Adult seabirds with active nests are likely to be constrained by foraging distance in order to maintain energy.

4.4.2 Existing Assessment

The effects of construction of the consented Inch Cape Offshore Export Cable works on ornithology have been assessed as part of Chapter 15 of the 2013 ES (ICOL, 2013) and determined to be not significant. This was not reassessed for the revised design as the design changes were deemed to fall within the existing worst case assessed.

4.4.3 Effect of the UXO Clearance Activities

Potential effects from the UXO clearance activities include:

- Visual and noise related disturbance; and
- Indirect effects through impacts on prey species.

4.4.3.1 Visual and noise related disturbance

The UXO clearance vessels will be present within the context of existing sources of disturbance such as commercial shipping, recreational boating etc. up to 85 pUXO are expected across the whole Project.

There will be increased vessel presence within the SAC due to the boulder clearance and UXO identification activities with a maximum of four vessels working concurrently. Although these have the potential to disturb bird species, temporarily displacing them or affecting foraging behaviour, the area of the Firth of Forth experiences very high shipping densities on a daily basis (an average of 22 and 37 unique vessel movements per day across the Development Area and Offshore Export Cable Corridor respectively (ICOL, 2018)) and thus it is expected that all birds who regularly utilise the area will have an increased tolerance for vessel presence in region. The duration of work in any one location will be temporary, with any effects highly localised around the working vessel. Vessels will be moving slowly and in a predictable manner, and any visual or noise related disturbance will therefore be minimal. In addition, the SPA covers a large area and there is an abundance of available and equivalent feeding and loafing habitats in the immediate and wider area.

Accordingly, it is not considered this work will significantly disturb or displace ornithological species. Ornithological features are already acclimated to the high level of vessel traffic in the area which will not be materially altered by the proposed work. The work will be undertaken from vessels moving in a predictable and slow manner, and there is an abundance of equivalent habitat available. As such, it is considered there is no potential for the work to result in significant effects as a result of vessel disturbance.

4.4.3.2 Indirect Effects through Impacts on Prey

Bird species have the potential to show distributional changes due to impacts on prey species. Prey availability has been correlated with breeding success (Bustnes *et al*., 2013). Fish such as herring and sandeel are a key prey resource, which both have the potential to be impacted by disturbance to the specific sediment, essential for successful spawning and completion of the lifecycle. Long term studies in the Firth of Forth highlighted a long-term decline in the overall prevalence of sandeel in kittiwake chick diet, concomitant with an increase in the relative prevalence of clupeids in Scottish waters (Wanless *et al*., 2018) indicating adaptable diet. Disruption to the prey habitat at any one location is anticipated to be temporary and of short duration. In addition, there is extensive adjacent equivalent prey habitat in the surrounding area whereby prey availability will not be affected by the UXO clearance activities. As such, it is considered there is no potential for the work to result in significant effects as a result of indirect impacts to prey species.

4.4.4 Conclusion

No significant effects are predicted to arise on the ornithology receptors as a result of the UXO clearance activities. The impacts which may occur are also considered to be lesser in scale and magnitude than those already consented (and assessed as not significant) for constructions activities at the Inch Cape OWF.

4.5 Cultural Heritage and Marine Archaeology

4.5.1 Baseline

During baseline surveys, a number (135) of marine geophysical anomalies were identified within the Development Area including four recorded wrecks / obstructions, four wrecks, 37 counts of debris, two seafloor disturbances, 78 dark reflectors and 10 magnetic anomalies. The ECC returned a total of 378 geophysical anomalies including two recorded wrecks / obstructions, two wrecks, 47 counts of debris, three seafloor disturbances, one depression, 79 dark reflectors, and 244 magnetic anomalies.

Archaeological features are sporadic and not concentrated in any one area within the Development Area or the ECC and the potential exists for further unknown cultural heritage features to be identified including prehistoric, maritime and aviation features.

4.5.2 Existing Assessment

The effects of construction of the consented Inch Cape OWF on cultural heritage assets have been assessed in Chapter 17 of the original ES (2013) and determined to be not significant.

4.5.3 Effect of the UXO Clearance Activities

Potential effects from the UXO clearance activities include:

- Seabed disturbance -damage to or removal of heritage features resulting from direct physical impacts.

4.5.3.1 Seabed Disturbance - Damage to or Removal of Heritage Features Resulting from Direct Physical Impacts

Both high order (detonation) and low order (deflagration) UXO clearance activities have the potential to directly affect marine cultural heritage and marine archaeology (partial or total destruction) through direct impacts to the seabed.

There are a number of known archaeological features within the Development Area and along the ECC, and there is the possibility that un-recorded assets will be identified during the works, despite the activities being minimally invasive. It is not expected that there will be many features which have not been identified, however owing to the dynamic nature of the North Sea, it is possible assets could have moved and therefore this cannot be ruled out.

Any work to be undertaken will avoid all designated Archaeological Exclusion Zones (AEZs) specified for the Development. A Protocol for Archaeological Discoveries (PAD) is currently being written, in line with current consents for the construction works[5], and in the absence of an agreed PAD (and Written Scheme of Investigation (WSI)), ICOL has produced an Environmental Requirements Document (for the pre-construction activities) which will be provided to contractors, detailing the same information as that which would feature in the PAD/ WSI, for reference.

Specific mitigation will include:

- Adherence to known Archaeological Exclusion Zones (AEZ); and

[5] Section 36 Consent (dated 14th June 2023); Generating Station Marine Licence (MS-00010140 dated 15th June 2023); and Offshore Transmission Infrastructure (OfTI) Marine Licence (MS-00010593 dated 9th November 2023)

- Implementation of an Environmental Requirements Document in the absence of an agreed PAD.

It is currently anticipated the work will involve up to three vessels working concurrently across the Development Area and the ECC and the activities taking place will be intermittent, of short duration and limited in scale and it is therefore considered that there is no potential for the work to result in significant effects as a result of the UXO clearance activities.

4.5.4 Conclusion

With appropriate mitigation, no significant effects are predicted to arise on the cultural heritage receptors as a result of the UXO clearance activities. The impacts which may occur are also considered to be lesser in scale and magnitude than those already consented (and assessed as not significant) for constructions activities at the Inch Cape OWF.

4.6 Commercial Fisheries

4.6.1 Baseline

The Firth of Forth is an important area for commercial fisheries. Key fisheries in the area include the scallop fishery, the creel fishery, the squid fishery and the *Nephrops* fishery. Other fisheries of potential growing importance include both whelk and mackerel.

The Development Area and Offshore Export Cable Corridor are located in ICES rectangles 41E7 and 42E7 and these two rectangles contain valuable Scottish fishing grounds.

Over the five-year period considered in the EIAR between 2011 and 2016, the majority of landings in 41E7 were made up of *Nephrops* which accounted for 53% of all landings (by value) which equates to an annual average of £4,093,313. Landings of lobster were the second highest in this rectangle (34% - £2,602,308), with smaller quantities of crabs (edible and velvet crabs 5%), scallops (3%), razor clams (1%) and squid (1%). Other notable species captured in this rectangle include mackerel and whelks, although together they account for less than 1.2% of the average annual landings.

In rectangle 42E7 lobsters made up almost half the landings in the study period (49% which equates to an annual average £1,264,203), followed by scallops (21% - £529,645) and crabs (edible 10% and velvet swimming crabs 6%), squid (6%), Nephrops (6%) and mackerel (1%) and other species.

4.6.2 Existing Assessment

The effects of construction of the consented Inch Cape OWF works on the commercial fisheries of the area is set out in Chapter 14 of the 2018 Inch Cape Offshore EIA Report and were assessed as not significant.

4.6.3 Effect of the UXO Clearance Activities

Potential effects from the UXO clearance activities include:

- Vessel Presence - disruption to existing fishing activities from temporary loss or restricted access to fishing grounds, increased steaming times to fishing grounds, and displacement of fishing vessels into other areas.

4.6.3.1 Vessel Presence - Disruption to Existing Fishing Activities

The work will be undertaken over a large area within the Development Area and along the ECC, however in any given area the work will be relatively short term, localised and small scale. Additionally, the vessels will work in an area with a high presence of vessel traffic and the work undertaken will have predictable and slow vessel movements. Vessel presence (along with the requirement to keep a safe distance during UXO clearance works) from the planned UXO clearance activities therefore have the potential to result in temporary, short term (estimated campaign of nine months (with vessels potentially being on site 24/7), and localised disruption of fishing activities within the vicinity of detonation activities.

The Inch Cape project has a Project Fisheries Liaison Officer (FLO) who will ensure effective, ongoing communication between ICOL and the fisheries stakeholders, which will include communication surrounding these activities. The FLO will ensure key information surrounding the work, including timings and location, is communicated on an ongoing basis. Prior to any work being undertaken, and during the work, all appropriate notices and communications will be shared via the Kingfisher Bulletin updates and via Notice to Mariners (NtMs).

Through good communication and cooperation, there will be no significant disruption to commercial fishery receptors, and no significant impact on this receptor group.

4.6.4 Conclusion

Considering the mitigation in place, no significant effects are predicted to arise on the commercial fisheries receptors of the area as a result of the UXO clearance activities. The impacts which may occur are also considered to be lesser in scale and magnitude than those already consented (and assessed as not significant) for constructions activities at the Inch Cape OWF.

4.7 Shipping and Navigation

4.7.1 Baseline

The Firth of Forth is an area with busy shipping, fishing and recreational vessel use. Automatic Identification System (AIS) data revealed approximately three to four vessels pass through the Development Area per day (mostly fishing vessels) and an average of 20 vessels use the ECC each day (33% fishing vessels, and 28% tankers).

4.7.2 Existing Assessment

The effects of the OfTW on shipping and navigation of the area is set out in the 2013 and 2018 ES and EIAR which concluded impacts were not significant.

4.7.3 Effect of the UXO Clearance Activities

Potential effects from the UXO clearance activities include:

- Vessel presence - increased vessels in the area.

4.7.3.1 Vessel Presence – Increased Vessels in the Area

The planned UXO clearance activities have the potential for short term, localised disruption to shipping activities within the vicinity of the detonation activities. Ongoing communication would be shared via all the

Kingfisher Bulletin updates and issue of NtMs. It is anticipated the UXO vessel will use VHF radio to transmit warnings advising any transient shipping that clearance works are taking place.it will be necessary for the vessel to communicate the exact locations, including exclusion zones, to all vessels throughout the UXO clearance activities. Vessels will display lights and signals in accordance with the requirements of the International Regulations for the Prevention of Collisions at Sea. The project will consult with and actively maintain communications about the proposed works with the Northern Lighthouse Board (NLB), the Maritime and Coastguard Agency (MCA), the UK Hydrographic Office (UKHO) and the relevant Maritime Rescue Co-ordination Centre (MRCC).

Standard mitigation measures will be implemented to ensure impacts to shipping and navigation is kept to a minimum, including NtM and Kingfisher Bulletin notices will be issued in advance of the planned activities.

The work will be temporary in nature, localised and covering a small spatial scale. The Firth of Forth is, a naturally busy shipping area and the presence of the three anticipated vessels associated with this work would not materially contribute to an increase in overall vessel traffic giving rise to potential significant effects.

4.7.4 Conclusion

Given the mitigation to be implemented, no significant effects are predicted to arise on the shipping and navigation of the area as a result of the UXO clearance activities. The impacts which may occur are also considered to be lesser in scale and magnitude than those already consented (and assessed as not significant) for constructions activities at the Inch Cape OWF.

4.8 Cumulative Considerations

As the UXO clearance activities are very localised in extent and will not result in any significant adverse effects on any receptor, it is considered that there is no potential for significant cumulative effects to arise.

The only other plans or projects that could be considered to act cumulatively are the other Inch Cape OWF construction and pre-construction related activities, Neart na Gaoithe construction, and EGL-1 construction, as this work could be undertaken during the same timeframe and at the same spatial location.

All effects of the Inch Cape OWF construction were considered to be not-significant, as are any effects that may result from the UXO clearance activities. As such, it is therefore considered that all effects at a cumulative level will not be significant, due to the short duration of works, and limited spatial scale over which all will act.

5 Summary and Conclusion

The UXO clearance activities will take place within the existing consented Inch Cape Development Area and the ECC. Based on the above considerations of impacts on all potential environmental receptors, it can be concluded that the UXO clearance activities (described in Section 2) will not result in any potential significant effects, taking into consideration appropriate mitigation as detailed.

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Predictions of underwater noise impacts from UXO clearance, Inch Cape Offshore Wind Farm

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Executive Summary

Subacoustech Environmental Ltd., on behalf of Inch Cape Wind, has undertaken a study to assess the potential underwater noise caused by UXO clearance in the vicinity of the Inch Cape Offshore Wind Farm site and its effects on local marine fauna.

The modelling results were analysed in terms of relevant noise metrics and criteria to assess the effects of impact piling noise on marine mammals and fish. For marine mammals, maximum permanent threshold shift (PTS) impact ranges were predicted out to 17 km for species in the Very High Frequency (VHF) cetacean category when considering the largest anticipated charge weight (1,179 kg), for fish, the largest injury ranges were predicted out to 1.0 km for the same scenario.

It should be stressed that, due to the nature of modelling, while the results present specific ranges at which each impact threshold is met, the ranges should be taken as indicative and worst case in determining where environmental effects may occur in receptors during the proposed operations.

The outputs of this modelling have been used to inform analysis of the impacts of underwater noise on marine mammals and fish in their respective reports.

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Terminology

Decibel (dB)	A customary scale commonly used (in various ways) for reporting levels of sound. The dB represents a ratio/comparison of a sound measurement (e.g., sound pressure) over a fixed reference level. The dB symbol is followed by a second symbol identifying the specific reference value (e.g., re 1 µPa).
Peak pressure	The highest pressure above or below ambient that is associated with a sound wave.
Peak-to-peak pressure	The sum of the highest positive and negative pressures that are associated with a sound wave.
Permanent Threshold Shift (PTS)	Onset of permanent total or partial loss of hearing caused by acoustic trauma. PTS results in irreversible damage to the sensory hair cells of the ear, and thus a permanent impairment of hearing acuity.
Root Mean Square (RMS)	The square root of the arithmetic average of a set of squared instantaneous values. Used for presentation of an average sound pressure level.
Sound Exposure Level (SEL or $L_{E,p}$)	The constant sound level acting for one second, which has the same amount of acoustic energy, as indicated by the square of the sound pressure, as the original sound. It is the time-integrated, sound-pressure-squared level. SEL is typically used to compare transient sound events having different time durations, pressure levels, and temporal characteristics.
Sound Exposure Level, cumulative (SEL_{cum} or $L_{E,p,t}$)	Single value for the collected, combined total of sound exposure over a specified time or multiple instances of a noise source.
Sound Pressure Level (SPL or L_p)	The sound pressure level is an expression of sound pressure using the decibel (dB) scale; the standard frequency pressures of which are 1 µPa for water and 20 µPa for air.
Sound Pressure Level Peak (SPL_{peak} or $L_{p,pk}$)	The highest (zero-peak) positive or negative sound pressure, in decibels.
Temporary Threshold Shift (TTS)	Onset of a temporary reduction of hearing acuity because of exposure to sound over time. The mechanisms underlying TTS are not well understood, but there may be some temporary damage to the sensory cells. The duration of TTS varies depending on the nature of the stimulus.
Unweighted sound level	Sound levels which are “raw” or have not been adjusted in any way, for example to account for the hearing ability of a species.
Weighted sound level	A sound level which has been adjusted with respect to a “weighting envelope” in the frequency domain, typically to make an unweighted level relevant to a particular species.

Units

dB	Decibel (sound pressure)
G	Gram (mass)
Hz	Hertz (frequency)
kg	Kilogram (mass)
kHz	Kilohertz (frequency)
km	Kilometre (distance)
m	Metre (distance)
mm/s	Millimetres per second (particle velocity)
m/s	Metres per second (speed)
Pa	Pascal (pressure)
Pa^2s	Pascal squared seconds (acoustic energy)
µPa	Micropascal (pressure)

Acronyms

HF	High-Frequency Cetaceans
ISO	International Organisation for Standardisation
LF	Low-Frequency Cetaceans
MTD	Marine Technology Directorate
NEQ	Net Explosive Quantity
PCW	Phocid Carnivores in Water
PTS	Permanent Threshold Shift
RMS	Root Mean Square
SE	Sound Exposure
SEL	Sound Exposure Level
SPL	Sound Pressure Level
TNT	Trinitrotoluene (Explosive)
TTS	Temporary Threshold Shift
UXO	Unexploded Ordnance
VHF	Very High-Frequency Cetaceans

1 Introduction

The risk associated with the clearance of unexploded ordnance (UXO) associated with the construction of the Inch Cape Offshore Wind Farm located in the North Sea off the Angus Coast, Scotland, has been investigated by Subacoustech Environmental Ltd., in respect of the underwater noise produced. The ranges of impact in relation to marine mammals and fish injury from UXO clearance has been estimated.

Within the array area and export cable corridor route, several UXO devices with a range of charge weights (or quantity of contained explosives) are anticipated to be or could be present. These may need to be removed before construction can begin.

There are expected to be a variety of explosive types, many of which are likely to have been subject to degradation or burying over time. Two otherwise identical explosive devices are likely to produce different blasts in the case where one has spent an extended period on the seabed. A selection of explosive sizes has been considered based on site surveys, and in each case, it has been assumed that the maximum explosive charge in each device is present and detonates with the clearance.

2 Background to underwater noise metrics

Sound travels much faster in water (approximately 1,500 m/s) than in air (340 m/s). Since water is a relatively incompressible, dense medium, the pressure associated with underwater sound tends to be much higher than in air. It should be noted that stated underwater noise levels are different to those stated for airborne noise levels, as a different scale is used between in water and in air measurements. Therefore, noise measurements in air are generally incomparable to noise measurements underwater.

2.1 Units of measurement

Sound measurements underwater are usually expressed using the decibel (dB) scale, which is a logarithmic measure of sound. A logarithmic scale is used, as this better reflects how sound is perceived. For example, equal increments of sound levels do not have an equal increase in the perceived sound. Instead, each doubling of sound level will cause a roughly equal increase of loudness. Any quantity expressed in this dB scale is termed a "level." For example, if the unit is sound pressure, it will be termed a "sound pressure level" on the dB scale.

The fundamental definition of the dB scale is given by:

$$Level = 10 \times \log_{10}\left(\frac{Q}{Q_{ref}}\right)$$

where Q is the quantity being expressed on the scale, and Q_{ref} is the reference quantity.

The dB scale represents a ratio. It is therefore used with a reference unit, which expresses the base from which the ratio is expressed. The reference quantity is conventionally smaller than the smallest value to be expressed on the scale so that any level quoted is positive. For example, a reference quantity of 20 µPa is used for sound in air since that is the lower threshold of human hearing.

When used with sound pressure, the pressure value is squared. So that variations in the units agree, the sound pressure must be specified as units of Root Mean Square (RMS) pressure squared. This is equivalent to expressing the sound as:

$$Sound\ pressure\ level\ (L_p) = 20 \times \log_{10}\left(\frac{P_{RMS}}{P_{ref}}\right)$$

For underwater sound a unit of 1 µPa is typically used as the reference unit (P_{ref}). One Pascal (Pa) is equal to the pressure exerted by one Newton over one square metre, one micropascal (µPa) equals one millionth of this.

2.2 Sound pressure level (L_p or SPL)

The Sound Pressure Level (SPL or L_p) is normally used to characterise noise of a continuous nature, such as drilling, boring, continuous wave sonar, or background sea and river noise levels. To calculate the SPL, the variation in sound pressure is measured over a specific period to determine the RMS level of the time-varying sound. The SPL ($L_{p,RMS}$) can therefore be considered a measure of the average unweighted level of sound over the measurement period.

Where SPL is used to characterise transient pressure waves, such as that from impact piling, seismic airgun or underwater blasting, it is critical that the period over which the RMS level is calculated is quoted e.g., $L_{p,125ms}$. For instance, in the case of a pile strike lasting a tenth of a second, the mean taken over a tenth of a second will be ten times higher than the mean averaged over one second. Often, transient sounds such as these are quantified using "peak" SPLs ($L_{p,pk}$) or Sound Exposure Levels (SELs, L_E).

Unless otherwise defined, all L_p noise levels in this report are referenced to 1 µPa.

2.3 Peak sound pressure level ($L_{p,pk}$ or SPL_{peak})

The peak SPL, or $L_{p,pk}$, is often used to characterise transient sound from impulsive sources, such as percussive impact piling. $L_{p,pk}$ is calculated using the maximum variation of the pressure from positive to zero within the wave. This represents the maximum change in positive pressure (differential pressure from positive to zero) as the transient pressure wave propagates.

A further variation of this is the peak-to-peak SPL ($L_{p,pk\text{-}pk}$) where the maximum variation of the pressure from positive to negative is considered. Where the wave is symmetrically distributed in positive and negative pressure, the peak-to-peak pressure will be twice the peak level, or 6 dB higher.

2.4 Sound exposure level ($L_{E,p,t}$ or SEL)

When considering the noise from transient sources, the issue of the duration of the pressure wave is often addressed by measuring the total acoustic energy (energy flux density) of the wave. This form of analysis was used by Bebb and Wright (1953, 1954a, 1954b, 1955), and later by Rawlins (1987), to explain the apparent discrepancies in the biological effect of short and long-range blast waves on human divers. More recently, this form of analysis has been used to develop criteria for assessing injury ranges for fish and marine mammals from various noise sources (Popper *et al.,* 2014; Southall *et al.,* 2019).

The SEL ($L_{E,p}$) sums the acoustic energy over a measurement period (t), and effectively takes account of both the SPL of the sound and the duration it is present in the acoustic environment. Sound Exposure (SE) is defined by the equation:

$$SE = \int_0^T p^2(t)dt$$

where p is the acoustic pressure in Pa, T is the total duration of sound in seconds, and t is time in seconds. The SE is a measurement of acoustic energy and has units of Pascal squared seconds (Pa^{2}s).

To express the SE on a logarithmic scale, by means of a dB, it must be compared with a reference acoustic energy (${p^2}_{ref}$) and a reference time (T_{ref}). The $L_{E,p,t}$ is then defined by:

$$L_{E,p} = 10 \times \log_{10}\left(\frac{\int_0^T p^2(t)dt}{{P^2}_{ref}T_{ref}}\right)$$

By using a common reference pressure (p_{ref}) of 1 µPa for assessments of underwater noise, the $L_{E,p}$ and L_p can be compared using the expression:

$$L_{E,p} = L_p + 10 \times \log_{10} T$$

where L_p is a measure of the average level of broadband noise and the $L_{E,p}$ sums the cumulative broadband noise energy.

This means that, for continuous sounds of less than (i.e., fractions of) one second, the $L_{E,p,1s}$ will be lower than the L_p. For periods greater than one second, the $L_{E,p}$ will be numerically greater than the L_p (i.e., for a continuous sound of 10 seconds duration, the $L_{E,p,10s}$ will be 10 dB higher than the L_p; for a sound of 100 seconds duration the $L_{E,p,100s}$ will be 20 dB higher than the L_p, and so on).

Where a single impulse noise such as the soundwave from UXO clearance is considered in isolation, this can be represented by a "single pulse" $L_{E,p}$. A cumulative $L_{E,p,t}$, or SEL_{cum}, accounts for the exposure from multiple impulses over time, where the number of impulses replaces the T in the equation above, leading to:

$$L_{E.p.t} = L_E + 10 \times \log_{10} X$$

where $L_{E,p,t}$ is the sound exposure level of one impulse and X is the total number of impulses. Unless otherwise defined, all $L_{E,p,t}$ noise levels in this report are references to 1 $\mu Pa^2 s$. Only single impulses have been considered in this report.

2.5 Analysis of environmental effects

Over the last 20 years it has become increasingly evident that noise from human activities in and around underwater environments can have an impact on the marine species in the area. The extent to which intense underwater sound might cause adverse impacts in species is dependent upon the incident sound level, source frequency, duration of exposure, and/or repetition rate of an impulsive sound (see, for example, Hastings and Popper, 2005). As a result, scientific interest in the hearing abilities of aquatic species has increased. Studies are primarily based on evidence from high level sources of underwater noise such as seismic airguns, impact piling and blasting as these sources are likely to have the greatest immediate environmental impact and therefore the clearest observable effects, although interest in chronic noise exposure is increasing.

The impacts of underwater sound on marine species can be broadly summarised as follows:

- Physical traumatic injury and fatality,
- Auditory injury (either permanent or temporary), or
- Disturbance and behavioural responses.

The following sections discuss the underwater noise criteria used in this study with respect to species of marine mammals and fish that may be present around the Inch Cape site.

The main metrics and criteria that have been used in this study to aid assessment of environmental effects come from three key papers covering underwater noise and its effects:

- Southall *et al*. (2019) marine mammal exposure criteria, and
- Popper *et al*. (2014) sound exposure guidelines for fishes and sea turtles.

At the time of writing these include the most up-to-date and authoritative criteria for assessing environmental effects for use in impact assessments.

2.5.1 Marine mammals

The Southall *et al*. (2019) paper is the most used and recognised reference for marine mammal hearing thresholds. The guidance categorises marine mammals into groups of similar species and applies filters to the unweighted noise to approximate the hearing sensitivities of the receptor in question. The hearing groups given by Southall *et al*. (2019) are summarised in Table 2-1 and Figure 2-1. Further groups for sirenians and other marine carnivores in water are given, but these have not been included in this study as those species are not commonly found in the North Sea.

It should be noted that despite Southall *et al*. (2019) referring to peak SPL as SPL_{peak}, this notation has since been deprecated (ISO 18405:2017) and will be referred to as $L_{p,pk}$ in the rest of this report.

Table 2-1 Marine mammal hearing groups (from Southall et al., 2019).

Hearing group	Generalised hearing range	Example species
Low-frequency cetaceans (LF)	7 Hz to 35 kHz	Baleen whales
High-frequency cetaceans (HF)	150 Hz to 160 kHz	Dolphins, toothed whales, beaked whales, bottlenose whales (including bottlenose dolphin)
Very high-frequency cetaceans (VHF)	275 Hz to 160 kHz	True porpoises (including harbour porpoise)
Phocid carnivores in water (PCW)	50 Hz to 86 kHz	True seals (including harbour seals)

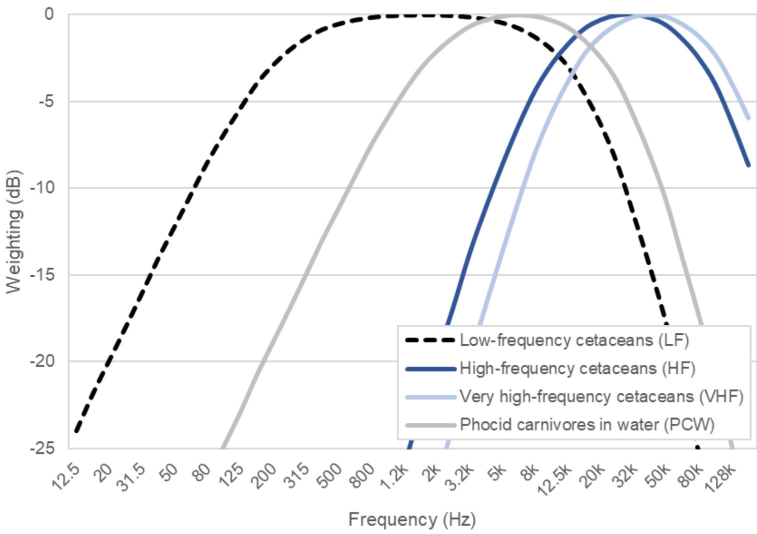

Figure 2-1 Auditory weighting functions for low-frequency cetaceans (LF), high-frequency cetaceans (HF), very high-frequency cetaceans (VHF), and phocid carnivores in water (PCW) (from Southall et al., 2019).

Southall *et al*. (2019) considers the nature of the sound in the context of whether it is an impulsive or non-impulsive noise source.

Although the use of impact ranges derived using the impulsive criteria are recommended for all but clearly defined non-impulsive sources, it should be recognised that where calculated ranges are beyond 3.5 km, the impact range is likely to be somewhere between the impulsive and non-impulsive impact criteria (Hastie *et al.*, 2019). Therefore, if the modelled impact range of an impulsive noise has been predicted to be greater than 3.5 km, the non-impulsive impact range should also be considered relevant. Both impulsive and non-impulsive criteria have been presented in this study.

Within each of the impulsive and non-impulsive noise criteria set out by Southall *et al.* (2019), different impact thresholds are presented depending on the potential of different levels of auditory injury at different noise levels of that sound. Auditory injury is grouped into the following two types:

- Permanent Threshold Shift (PTS) – unrecoverable (but incremental) hearing damage, and
- Temporary Threshold Shift (TTS) – a temporary reduction in hearing sensitivity.

It should be noted that the greatest calculated impact range is usually associated with TTS. However, the effects from PTS represent permanent (but only incremental, not total) impairment, and thus, PTS is usually quoted as the most important impact threshold.

In summary, when using Southall *et al*. (2019) assessment criteria to calculate impacts, three variables are considered:

- The marine mammal receptors within the area
- The nature of the sound (and subsequently, the appropriate metrics), and
- The type of auditory injury.

Table 2-2 and Table 2-3 present the impulsive and non-impulsive criteria set out by Southall *et al*. (2019) for PTS and TTS in marine mammals used in this study.

Table 2-2 $L_{p,pk}$ criteria for PTS and TTS in marine mammals (Southall et al., 2019).

Southall *et al.* (2019)	$L_{p,pk}$ (dB re 1 µPa)	
	Impulsive	
	PTS	TTS
Low-frequency cetaceans (LF)	219	213
High frequency-cetaceans (HF)	230	224
Very high-frequency cetaceans (VHF)	202	196
Phocid carnivores in water (PCW)	218	212

Table 2-3 $L_{E,p,24h,wtd}$ criteria for PTS and TTS in marine mammals (Southall et al., 2019).

Southall *et al.* (2019)	$L_{E,p,24h,wtd}$ (dB re 1 µPa²s)			
	Impulsive		Non-impulsive	
	PTS	TTS	PTS	TTS
Low-frequency cetaceans (LF)	183	168	199	179
High frequency-cetaceans (HF)	185	170	198	178
Very high-frequency cetaceans (VHF)	155	140	173	153
Phocid carnivores in water (PCW)	185	170	201	181

2.5.2 Fish

The Popper *et al*. (2014) guidelines are recognised as a suitable reference for underwater noise impacts on marine fauna (aside from marine mammals) in UK waters. While previous studies have applied broad criteria based on limited studies of fish that are not present in UK waters (McCauley *et al*. 2000), or measurement data not intended to be used as criteria (Hawkins *et al*., 2014), Popper *et al*. (2014) provides a summary of the latest research and guidelines for fish (and other marine fauna) exposure to sound and uses categories for fish that are representative of the species present around the Inch Cape site.

The Popper *et al*. (2014) guidelines present criteria dependent on the type of noise source, species of marine fauna and their hearing capabilities, and impact type. Noise sources considered in the guidance include explosions, pile driving, seismic airguns, sonar, and shipping and continuous noise. For this study, the criteria for explosions have been used.

Popper *et al*. (2014) categorises the marine fauna into groups of fish, sea turtles, and eggs and larvae. Due to their diversity and quantity, fish are categorised further into three groups depending on their hearing capabilities, which can be indicated by whether they possess a swim bladder or not, and whether the swim bladder is involved in hearing. For each group, criteria are given for mortality and potential mortal injury, impairment (split into recoverable injury, TTS, and masking), and behavioural effects.

Depending on the noise source, quantitative criteria are given in appropriate metrics ($L_{p,pk}$, $L_{E,p,24h}$, etc.), which can then be used as thresholds for the onsets of listed impacts. Where insufficient data is available, Popper *et al.* (2014) also gives a qualitative description. This summarises the effect of the noise as having either a high, moderate or low relative risk of an effect on an individual in either near (tens of meters), intermediate (hundreds of meters) or far (thousands of meters) from the source.

The quantitative and qualitative thresholds from the Popper *et al*. (2014) used in this study are reproduced in Table 2-4 for explosions. Similar to the Southall *et al*. (2019) criteria in section 2.5.1, the Popper *et al*. (2014) criteria use the deprecated SPL_{peak}, SPL_{RMS} and SEL_{cum} notation, and this report will use respectively the $L_{p,pk}$, L_p, and $L_{E,p,t}$ notation from ISO 18405:2017 from hereon.

Table 2-4 Recommended guidelines for explosions according to Popper et al. (2014) for species of fish, sea turtles, and eggs and larvae (N = near-field; I = intermediate-field, F = far-field).

Popper *et al*. (2014) criteria for explosions					
Receptor	**Mortality and potential mortal injury**	**Impairment**			**Behaviour**
		Recoverable injury	**TTS**	**Masking**	
Fish: no swim bladder	229 – 234 dB $L_{p,pk}$	(N) High (I) Low (F) Low	(N) High (I) Moderate (F) Low	N/A	(N) High (I) Moderate (F) Low
Fish: swim bladder not involved in hearing	229 – 234 dB $L_{p,pk}$	(N) High (I) Low (F) Low	(N) High (I) Moderate (F) Low	N/A	(N) High (I) Low (F) Low
Fish: swim bladder involved in hearing	229 – 234 dB $L_{p,pk}$	(N) High (I) Low (F) Low	(N) High (I) Low (F) Low	N/A	(N) High (I) Low (F) Low
Sea turtles	229 – 234 dB $L_{p,pk}$	(N) High (I) Low (F) Low	(N) High (I) Low (F) Low	N/A	(N) High (I) Low (F) Low
Eggs and larvae	> 13 mm/s peak velocity	(N) High (I) Low (F) Low	(N) High (I) Low (F) Low	N/A	(N) High (I) Low (F) Low

It is important to note that despite the emerging evidence that fish are sensitive to particle motion, the Popper *et al*. (2014) guidance defines noise impacts in terms of sound pressure or sound pressure-associated functions (i.e., $L_{E,p,t}$).

It has been suggested that the criteria set out by Popper *et al.* (2014) could have been derived from unmeasured particle motion, as well as sound pressure. Whilst this may be true, sound pressure remains the preferred metric in the criteria due to a lack of data surrounding particle motion (Popper and Hawkins, 2018), particularly in regarding the ability to predict the consequences of the particle motion of a noise source, and the sensitivity of fish to a specific particle motion value. Therefore, as stated by Popper and Hawkins (2019): “since there is an immediate need for updated criteria and guidelines on potential effects of anthropogenic sound on fishes, we recommend, as do our colleagues in Sweden (Andersson *et al*., 2017), that the criteria proposed by Popper *et al*. (2014) should be used.”

2.5.3 Marine invertebrates

A review by Solé *et al.* (2023) highlights the increasing evidence that some types of anthropogenic noise can negatively impact a variety of marine invertebrate taxa. These impacts include changes in behaviour, physiology, and rate of mortality, as well as physical impairment, at the individual, population, or ecosystem level. Much of the damage from exposure to noise comes from vibration of the invertebrate body (André *et al.,* 2016) caused by the passage of sound.

Comparatively, the studies described by Solé *et al.* (2023) show a general inconsistency in the way noise impacts have been quantified for marine invertebrates. For example, Hubert *et al*. (2021) notes behavioural changes in blue mussels to 150 and 300 Hz tones, whereas Spiga *et al.* (2016) describes behavioural changes in the same species at $L_{E,p}$ (single pulse) 153.47 dB re 1 µPa. These inconsistencies make it difficult to generate accurate thresholds for the onset of any impact for species. A notable exception is the cephalopods group, in which several studies, mainly by Solé *et al.* (2013, 2018, and 2019) and André *et al.* (2011) show a consistent threshold for auditory damage on various species of cephalopod at 157 dB re 1 µPa. While further research is needed even on this group to ensure accurate thresholds which are satisfactory to regulators, the current state of research on cephalopods sets a goal for the research required for other marine invertebrate groups, if they are to be used usefully as impact thresholds.

The meta-analysis conducted by Solé *et al.* (2023) also reveals inconsistencies in the responses of taxonomically near species of marine invertebrates to the effect of anthropogenic noise. For example, Fields *et al.* (2019) demonstrates low mortality of zooplankton during seismic airguns, whereas for the same noise source, McCauley *et al.* (2017) showed mass mortality of krill larvae. Clearly, the effect of noise on one species may not necessarily be applicable on another species despite being taxonomically near, which again makes it difficult to generate a generalised impact threshold that can confidently be applied to different taxonomic groups of marine invertebrates.

In its current state, research on the effects of anthropogenic noise on marine invertebrates is emerging, but more slowly than for marine mammals and fish. At this time, this research is in too early a stage to be used to accurately generate impact thresholds which would be satisfactory to regulators. However, it cannot be ignored that convincing evidence of noise impacts to marine invertebrates does exist. The data available could potentially be referenced for some species but with caution, as there are still considerable gaps in the knowledge that would enable reliable conclusions for the impact of noise for most species.

3 Estimation of underwater noise levels

3.1 High order clearance

The noise produced by the detonation of explosives is affected by several different elements, only one of which, the charge weight, can easily be factored into a calculation. In this case, the charge weight used for calculations is based on the equivalent weight of TNT contained within the device. Many other elements relating to its situation (e.g., its design, composition, age, position, orientation, whether it is covered by sediment) and exactly how they will affect the sound produced by detonation are usually unknown and cannot be directly considered in this type of assessment. This leads to a high degree of uncertainty in the estimation of the source noise level (i.e., the noise level at the position of the UXO). A worst-case estimation has therefore been used for calculations, assuming the UXO to be detonated is not buried, degraded or subject to any other significant attenuation from its 'as new' condition. A high-order clearance assumes that the UXO detonates fully, as opposed to low-order, where the explosive material in the UXO does not detonate (see below).

The consequence of this is that the noise levels produced, particularly by the larger explosives under consideration, are likely to be over-estimated as some degree of degradation would be expected.

The range of equivalent charge weights of the potential UXO devices that could be present have been estimated as between 6 kg to 1,179 kg (see Table 3-1). This is not intended to be a comprehensive list of all devices that could be found, although it includes a broad range of sizes of device which is unlikely to be exceeded. All devices will be detonated using a smaller donor explosive device, and the charge weight of has been added onto the UXO charge weight for calculation.

Estimation of the source noise level for each combined charge weight was carried out in accordance with the methodology of Soloway and Dahl (2014), which follows Arons (1954) and the Marine Technical Directorate (MTD) (1996).

3.2 Low order clearance

A low order clearance technique is being considered to reduce the impact of noise impacts from high order UXO clearance, that is, the detonation of the main charge of the UXO. Deflagration is such an alternative technique, intended to result in a 'low order' burn of the explosive material in a UXO, which destroys, but does not detonate, the internal explosive.

Deflagration is a safer technique for UXO disposal as it is intended to avoid the high pressures associated with an explosion, which would lead to an increased risk of adverse effects to marine life. Where the UXO device cannot be moved, deflagration represents a significant improvement over high-order clearance in respect to environmental effects.

Where the technique proceeds as intended, it is still not without noise impact. The process requires an initial shaped explosive donor charge, typically less than 250 g, to breach the casing and ignite the internal explosive material without full detonation. The shaped charge and burn will both produce noise, although it will be significantly less than the high order detonation of the much larger UXO. It may not destroy all of the explosive, necessitating further deflagration events or collection of the remnants. The deflagration may produce an unintentional high order event.

For calculation of the scenario of total destruction of the explosive material using deflagration, it is anticipated that the initial shaped charge is the greatest source of noise (Cheong *et al*., 2020). The shaped charge is treated as a bulk charge with NEQ determined according to the size of UXO on which it is placed. A prediction of this impact is based on a charge weight of 250 g. The worst-case scenario would of course be a high order detonation with maximum pressures from complete detonation of the UXO, and this has also been used in the calculation of impact for comparison.

Table 3-1 Range of charge weights for the potential UXO present across the Inch Cape site.

Description	Net Explosive Quantity (NEQ)
Low order	0.05 kg
Low order	0.25 kg
Small WWII Naval Projectile	6 kg
Artillery Projectile	15 kg
Small WWI Aerial Bomb	25 kg
Naval Projectile	49 kg
WWI Mine	165 kg
British WWII Mine	227 kg
WWI Torpedo	254 kg
WWII Aerial Torpedo	354 kg
German WWII Mine	1,179 kg

The calculation of the source noise levels is described in the following section.

3.3 UXO noise propagation

For this assessment, the attenuation of the noise from UXO detonation has been accounted for in calculations using geometric spreading and a sound absorption coefficient based on methodologies cited in Soloway and Dahl (2014). These establish a trend based on measurements of underwater blast in open water given by, for $L_{p,pk}$:

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

and for $L_{E,p}$:

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

These equations provide a relatively simple calculation which has been used to give an indication of the range of effect. Detailed modelling is not intended in this assessment. The equation does not take into account variable bathymetry or seabed type around the site, and thus calculation results will be the same regardless of where it is used.

Despite this attenuation correction, the resulting noise levels still need to be considered carefully. For example, $L_{p,pk}$ noise levels over larger distances are difficult to predict accurately (von Benda-Beckmann *et al.*, 2015). Soloway and Dahl (2014) only verify results from the equation above for small charges at ranges of less than 1 km, although the results are similar to the measurements presented by von Benda-Beckmann *et al*. (2015). At longer ranges, greater confidence is expected with the $L_{E,p}$ calculations.

A further limitation in the Soloway and Dahl (2014) equations are that variations in noise levels at different depths are not considered. Where animals are swimming near the surface, the acoustics can cause the noise level, and hence the exposure, to be lower (MTD, 1996). The risk to animals near the surface may therefore be lower than indicated by the impact ranges and therefore the results presented can be considered conservative in respect of the impact at different depths.

Additionally, an impulsive wave tends to be smoothed (i.e., the pulse becomes longer) over distance (Cudahy and Parvin, 2001), meaning the injurious potential of a wave at greater range can be even lower than just a reduction in the absolute noise level. An assessment in respect of $L_{E,p}$ is considered preferential at long range as it considers the overall energy, and the degree of smoothing of the peak with increasing distance is less critical.

The selection of assessment criteria must also be considered in light of this. The smoothing of the pulse at range means that a pulse may be considered non-impulsive at distance, suggesting that, at greater ranges, it may be more appropriate to use the non-impulsive criteria. This consideration may begin at 3.5 km (Hastie *et al*., 2019).

A summary of the unweighted source levels calculated using this method for modelling are given in Table 3-2.

Table 3-2 Summary of the unweighted $L_{p,pk}$ and $L_{E,p}$ source levels used for modelling

Device	NEQ	Source level ($L_{p,pk}$)	Source level ($L_{E,p}$)
Low order	0.05 kg	264.5 dB re 1 µPa @ 1 m	210.7 dB re 1 µPa^{2}s @ 1 m
Low order	0.25 kg	269.8 dB re 1 µPa @ 1 m	215.2 dB re 1 µPa^{2}s @ 1 m
Small WWII Naval Projectile	6 kg	280.2 dB re 1 µPa @ 1 m	224.0 dB re 1 µPa^{2}s @ 1 m
Artillery Projectile	15 kg	283.2 dB re 1 µPa @ 1 m	226.5 dB re 1 µPa^{2}s @ 1 m
Small WWI Aerial Bomb	25 kg	284.9 dB re 1 µPa @ 1 m	227.9 dB re 1 µPa^{2}s @ 1 m
Naval Projectile	49 kg	287.1 dB re 1 µPa @ 1 m	229.8 dB re 1 µPa^{2}s @ 1 m
WWI Mine	165 kg	291.0 dB re 1 µPa @ 1 m	233.1 dB re 1 µPa^{2}s @ 1 m
British WWII Mine	227 kg	292.1 dB re 1 µPa @ 1 m	234.0 dB re 1 µPa^{2}s @ 1 m
WWI Torpedo	254 kg	292.4 dB re 1 µPa @ 1 m	234.3 dB re 1 µPa^{2}s @ 1 m
WWII Aerial Torpedo	354 kg	293.5 dB re 1 µPa @ 1 m	235.3 dB re 1 µPa^{2}s @ 1 m
German WWII Mine	1,179 kg	297.5 dB re 1 µPa @ 1 m	238.6 dB re 1 µPa^{2}s @ 1 m

4 Impact ranges

Table 4-1 to Table 4-4 present the impact ranges for UXO clearance, considering various charge weights and impact criteria. Ranges smaller than 50 m have not been presented.

Although the impact ranges presented in the following tables are large, the duration the noise is present must also be considered. For detonation of UXO each explosion is only a single noise event, so there is no continued exposure nor the need to calculate cumulative effects.

Table 4-1 Summary of the PTS and TTS impact ranges for UXO clearance using the unweighted, impulsive $L_{p,pk}$ noise criteria from Southall et al (2019) for marine mammals.

$L_{p,pk}$	PTS (Impulsive)				TTS (Impulsive)			
	LF 219 dB	HF 230 dB	VHF 202 dB	PCW 218 dB	LF 213 dB	HF 224 dB	VHF 196 dB	PCW 212 dB
0.05 kg	100 m	< 50 m	580 m	110 m	190 m	65 m	1.0 km	210 m
0.25 kg	170 m	60 m	990 m	190 m	320 m	100 m	1.8 km	360 m
6 kg	500 m	160 m	2.8 km	560 m	930 m	300 m	5.2 km	1.0 km
15 kg	690 m	220 m	3.9 km	760 m	1.2 km	410 m	7.1 km	1.4 km
25 kg	810 m	260 m	4.6 km	900 m	1.5 km	490 m	8.5 km	1.6 km
49 kg	1.0 km	330 m	5.7 km	1.1 km	1.8 km	610 m	11 km	2.0 km
165 kg	1.5 km	500 m	8.6 km	1.7 km	2.8 km	920 m	16 km	3.1 km
227 kg	1.7 km	550 m	9.6 km	1.8 km	3.1 km	1.0 km	18 km	3.4 km
254 kg	1.7 km	570 m	10 km	1.9 km	3.2 km	1.0 km	18 km	3.6 km
354 kg	1.9 km	640 m	11 km	2.1 km	3.6 km	1.1 km	21 km	4.0 km
1,179 kg	2.9 km	960 m	17 km	3.2 km	5.4 km	1.7 km	31 km	6.0 km

Table 4-2 Summary of the PTS and TTS impact ranges for UXO clearance using the weighted, impulsive $L_{E,p}$ noise criteria from Southall et al (2019) for marine mammals.

$L_{E,p}$	PTS (Impulsive)				TTS (Impulsive)			
	LF 183 dB	HF 185 dB	VHF 155 dB	PCW 185 dB	LF 168 dB	HF 170 dB	VHF 140 dB	PCW 170 dB
0.05 kg	100 m	< 50 m	< 50 m	< 50 m	1.4 km	< 50 m	420 m	260 m
0.25 kg	230 m	< 50 m	80 m	< 50 m	3.2 km	< 50 m	750 m	570 m
6 kg	1.0 km	< 50 m	320 m	190 m	15 km	80 m	1.8 km	2.6 km
15 kg	1.7 km	< 50 m	470 m	300 m	23 km	120 m	2.2 km	4.1 km
25 kg	2.1 km	< 50 m	560 m	380 m	29 km	150 m	2.4 km	5.2 km
49 kg	3.0 km	< 50 m	710 m	530 m	39 km	200 m	2.7 km	7.1 km
165 kg	5.4 km	< 50 m	1.0 km	970 m	66 km	340 m	3.3 km	12 km
227 kg	6.3 km	< 50 m	1.1 km	1.1 km	75 km	380 m	3.5 km	14 km
254 kg	6.7 km	< 50 m	1.1 km	1.1 km	78 km	400 m	3.6 km	15 km
354 kg	7.8 km	< 50 m	1.3 km	1.4 km	89 km	460 m	3.7 km	17 km
1,179 kg	14 km	80 m	1.7 km	2.5 km	139 km	710 m	4.4 km	27 km

Table 4-3 Summary of the PTS and TTS impact ranges for UXO clearance using the weighted, non-impulsive $L_{E,p}$ noise criteria from Southall et al (2019) for marine mammals.

$L_{E,p}$	PTS (Non-impulsive)				TTS (Non-impulsive)			
	LF 199 dB	HF 198 dB	VHF 173 dB	PCW 201 dB	LF 179 dB	HF 178 dB	VHF 153 dB	PCW 181 dB
0.05 kg	< 50 m	< 50 m	< 50 m	< 50 m	210 m	< 50 m	50 m	< 50 m
0.25 kg	< 50 m	< 50 m	< 50 m	< 50 m	460 m	< 50 m	110 m	80 m
6 kg	70 m	< 50 m	< 50 m	< 50 m	2.2 km	< 50 m	430 m	390 m
15 kg	100 m	< 50 m	< 50 m	< 50 m	3.4 km	< 50 m	610 m	610 m
25 kg	120 m	< 50 m	< 50 m	< 50 m	4.4 km	< 50 m	730 m	780 m
49 kg	180 m	< 50 m	< 50 m	< 50 m	6.1 km	60 m	900 m	1.0 km
165 kg	320 m	< 50 m	80 m	60 m	11 km	100 m	1.2 km	1.9 km
227 kg	380 m	< 50 m	90 m	70 m	13 km	110 m	1.4 km	2.2 km
254 kg	400 m	< 50 m	100 m	70 m	13 km	110 m	1.4 km	2.3 km
354 kg	470 m	< 50 m	110 m	80 m	16 km	130 m	1.5 km	2.8 km
1,179 kg	850 m	< 50 m	190 m	150 m	27 km	230 m	2.0 km	4.9 km

The maximum PTS ranges calculated for UXO clearance is 17 km for the VHF cetacean category when considering the $L_{p,pk}$ criteria for the largest high-order clearance. For $L_{E,p}$ criteria, the largest PTS range is calculated for LF cetaceans with a predicted impact range of 14 km using the impulsive noise criteria. As explained earlier, this assumes no degradation of the UXO and no smoothing of the pulse over distance, which is very precautionary. Although an assumption of non-pulse could underestimate the potential impact (Martin *et al*., 2020) (the equivalent range based on LF cetacean non-pulse criteria is 850 m), it is likely that the long-range smoothing of the pulse peak would reduce its potential harm and the maximum 'impulsive' range for all species is very precautionary.

Table 4-4 Summary of the mortality and potential mortal injury impact ranges for UXO clearance using the unweighted $L_{p,pk}$ explosion noise criteria from Popper et al. (2014) for fish.

$L_{p,pk}$	Mortality and potential mortal injury	
	234 dB (Upper limit)	229 dB (Lower limit)
0.05 kg	< 50 m	< 50 m
0.25 kg	< 50 m	60 m
6 kg	110 m	180 m
15 kg	140 m	240 m
25 kg	170 m	290 m
49 kg	220 m	370 m
165 kg	330 m	550 m
227 kg	370 m	610 m
254 kg	380 m	640 m
354 kg	430 m	710 m
1,179 kg	640 m	1.0 km

There is a potential for mortal injury in fish out to a maximum range of 1.0 km from the largest UXO devices.

5 Summary and conclusions

Subacoustech Environmental has undertaken a study to assess the potential underwater noise and its effects during UXO clearance at the Inch Cape Offshore Wind Farm, located in the North Sea off the Angus Coast, Scotland.

The level of underwater noise from UXO clearance has been estimated using noise modelling equations from Soloway and Dahl (2014), the modelling results were then analysed in terms of relevant noise metrics and criteria in order to assess the effects of the noise on marine mammals (Southall *et al*., 2019) and fish (Popper *et al.*, 2014), which has been used to inform biological assessments.

For marine mammals maximum PTS ranges were predicted out to 17 km for VHF cetaceans based on the $L_{p,pk}$ criteria and largest considered charge weight. For $L_{E,p}$ criteria, the largest PTS range is calculated for LF cetaceans with a predicted impact range of 14 km using the impulsive noise criteria.

There is little data available for the impact of different sized charges on fish species. However, calculated ranges for the risk of mortal injury to individuals have been provided. The upper limit of potential mortal injury to fish is predicted to be within 1.0 km of the UXO location, for the largest anticipated charge weight.

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