Muir Mhòr Offshore Wind Farm

Environmental Impact Assessment Report

Volume 4, Appendix 10: In Principle Fish Mitigation Plan

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Glossary

Term	Definition
Array Area	The area in which the generation infrastructure (including Wind Turbine Generators and associated foundations and inter-array cables), Offshore Electrical Platform(s), and an interconnector cable will be located.
Developer	Muir Mhòr Offshore Wind Farm Limited
Floating Foundations	The floating structures on which the Wind Turbine Generators are installed.
Foundation anchors	The structures which anchor the Floating Foundations to the seabed, connected to the foundation mooring.
Foundation mooring	The mooring structures which connect the Floating Foundations to the anchors.
Inter-array cables	Cables which link the wind turbines generators to each other and the Offshore Electrical Platform(s).
Interconnector cable	Cable which links the Offshore Electrical Platform(s) to one another, allowing for power to be transferred between the platforms.
Offshore Electrical Platform (OEP)	Offshore platform consisting of High Voltage Alternating Current (HVAC) equipment, details depending on the final electrical set up of the Project.
Offshore Export Cable Corridor (ECC)	The area within which the offshore export cables will be installed.
Offshore export cables	The subsea electricity cable circuits running from the Offshore Electrical Platform(s) to the landfall which will transmit the electricity generated by the offshore wind farm to the onshore export cables for transmission onwards to the onshore substation and the national electrical transmission system along with auxiliary cables such as fibre optic cables.
Project	Muir Mhòr Offshore Wind Farm – comprises the wind farm and all associated offshore and onshore components.
Proposed Development	The offshore Muir Mhòr Offshore Wind Farm project elements to which this Offshore EIA Report relates.
Wind Turbine Generator (WTG)	The wind turbines that generate electricity consisting of tubular towers and blades attached to a nacelle housing mechanical and electrical generating equipment.

Acronyms

Term	Definition
BBC	Big Bubble Curtain
BSH	Bundesamt für Seeschifffahrt und Hydrographie
CaP	Cable Plan
CMS	Construction Method Statement
DBBC	Double Big Bubble Curtain
ECC	Export Cable Corridor
EIA	Environmental Impact Assessment
EIAR	Environmental Impact Assessment Report
EMP	Environmental Management Plan
HSD	Hydrosound Damper
IHLS	International Herring Larvae Survey
LSE	Likely Significant Effects
MD-LOT	Marine Directorate - Licensing Operations Team
MHWS	Mean High-Water Springs
NMPi	National Marine Plan Interactive
OEP	Offshore Electrical Platform
OWF	Offshore Wind Farm
PEMP	Project Environmental Monitoring Plan
PS	Piling Strategy
PSV	Platform Supply Vessel
PULSE	Pile Under Limited Stress
SEL	Sound Exposure Level
SPL	Sound Pressure Level
SSC	Suspended Sediment Concentration
TTS	Temporary Threshold Shift
ROV	Remotely Operated Vehicle
UWN	Underwater Noise
WTG	Wind Turbine Generator
ZoI	Zone of Influence

EXECUTIVE SUMMARY

Muir Mhòr Offshore Wind Farm Limited (hereafter referred to as 'the Developer') is proposing to develop the Muir Mhòr Offshore Wind Farm (hereafter 'the Project'). The Project is made up of both offshore and onshore components. The subject of this offshore Environmental Impact Assessment Report (EIAR) is the offshore infrastructure of the Project seaward of Mean High-Water Springs (MHWS) which is hereafter referred to as 'the Proposed Development'.

The Muir Mhòr Array Area covers an area of approximately 200 km^2 and is located approximately 63 km east of Peterhead on the east coast of Scotland. The offshore infrastructure of the Proposed Development includes Wind Turbine Generators (WTGs) and associated floating foundations, the Offshore Electrical Platforms (OEP(s)) and associated foundations, the inter-array cables, an interconnector cable, offshore export cables and landfall.

This In Principle Fish Mitigation Plan (hereafter referred to as the Plan) sets out the approach for the Developer to deliver potential mitigation measures in relation to the Proposed Development to ensure the avoidance of Likely Significant Effects (LSE) on spawning Buchan stock Atlantic herring (*Clupea harengus*).

The approach and measures provided within this Plan are in relation to the Proposed Development only and are in response to the conclusions of the EIAR, namely Volume 2, Chapter 10 (Fish and Shellfish Ecology).

The EIAR concluded that, subject to the final design of the Proposed Development, further mitigation measures may be necessary in relation to the LSE of the construction phase of the Proposed Development, in order to ensure there will be no LSE on spawning Buchan stock Atlantic herring.

This Plan has been produced to outline the principles and methodologies that will underpin the final In Principle Mitigation Plan (hereafter referred to as the Final Plan). The Final Plan will be finalised and adopted post-consent, ahead of construction, following approval by Scottish Ministers (in consultation with NatureScot and any other consultees as required at the discretion of the Scottish Ministers), in accordance with the relevant conditions of the Section 36 Consent and associated Marine Licences. The Final Plan will be based on the final design of the Proposed Development. At the time of writing, the mitigation measures are yet to be confirmed and, as such, this plan is considered 'in principle' until an optimised design for construction, and therefore clarity on the maximum parameters to be employed at the Proposed Development, is known.

It is important to note that the Developer has provided detail on a suite of mitigation measures in the following sections that are both appropriate and sufficient to reduce the effects on spawning herring to non-significant levels (in EIA terms). These measures relate to the design of the Proposed Development, installation methodologies, or strategies and technologies to reduce impacts. These mitigation measures are intended to illustrate that mitigation options available to the Developer, which may be implemented as of suite of measures, or as a single measure in isolation. The specific mitigation measure (or suite of measures) that will be implemented during the construction of the Proposed Development will be determined, in consultation with the Marine Directorate – Licensing Operations Team (MD-LOT) and NatureScot (and other consultees as required at the discretion of the Scottish Ministers), following confirmation of the final project design, collection of additional survey data, and/or information on maturation of emerging technologies. This additional data and information will allow noise modelling and sediment plume modelling to be updated to feed into the Final Plan and discussions on the appropriate mitigation measure(s) to implement. This process will ensure that a conclusion of no LSE on spawning herring (in EIA terms) can be maintained.

1. INTRODUCTION

1.1. PROJECT BACKGROUND

1.1.1. Muir Mhòr Offshore Wind Farm Limited (hereafter referred to as 'the Developer') is proposing to develop the Muir Mhòr Offshore Wind Farm (hereafter 'the Project'). The Project is made up of both offshore and onshore components. The subject of this offshore Environmental Impact Assessment Report (EIAR) is the offshore infrastructure of the Project seaward of Mean High-Water Springs (MHWS) which is hereafter referred to as 'the Proposed Development'.

1.1.2. The Muir Mhòr Array Area covers an area of approximately 200 km^2 and is located approximately 63 km east of Peterhead on the east coast of Scotland. The offshore infrastructure of the Proposed Development includes Wind Turbine Generators (WTGs) and associated floating foundations, the Offshore Electrical Platforms (OEP(s)) and associated foundations, the inter-array cables, interconnector cable, offshore export cables and landfall. A full description of the Proposed Development is provided in Volume 1, Chapter 3 (Project Description).

1.2. PURPOSE OF THIS DOCUMENT

1.2.1. The primary aim of this In Principle Mitigation Plan (hereafter referred to as the Plan) is to set out the approaches and process for the Developer to agree works and mitigation measures associated with the Proposed Development, specifically in relation to the following activities that may impact spawning Buchan stock Atlantic herring (*Clupea harengus*):

- Offshore export cable installation; and
- Piling operations in the Array Area.

1.2.2. This Plan reflects the commitment from the Developer to undertake required measures to reduce the potential for any significant disturbance to spawning herring. The Plan sets out the necessary mitigation that will be secured through the relevant conditions of the Section 36 Consent and associated Marine Licences, whilst allowing scope for refinement of the precise mitigation measures to be adopted once the final design and construction methods for the Proposed Development have been confirmed. This will enable the most appropriate measures to be confirmed, based on best knowledge, evidence and proven technology available at the time of construction.

1.2.3. The need to provide scope for refinement arises, in part, due to the range of complex interdependencies common to all offshore wind farms (OWFs) in the early (pre-consent) development stages. These include the selection of specific infrastructure and equipment, coupled with the collection and analysis of more detailed site engineering data, which means that design work continues up until the immediate pre-construction period. As a result, it is not possible to provide final detailed method statements for construction prior to consent, and, as a result, the specific detail of required mitigation also cannot be finalised at this stage. Key outstanding areas of uncertainty that will be addressed post-consent therefore comprise:

- The precise extent and location of geotechnical constraints along the offshore Export Cable Corridor (ECC). This will be informed by pre-construction geotechnical surveys prior to cable route design;
- The properties and variability of seabed and subsurface geotechnical conditions across the Array Area, to inform selection of appropriate foundation technologies and their associated design. This will be informed by pre-construction geotechnical surveys;

- The detailed methodologies for foundation and export cable installation, as informed by pre-construction surveys; and
- The specifics of the technology available (and procured) at the time of construction.

1.2.4. It is important to note that the approach and measures listed in this Plan relate solely to the Plan and address assessment outcomes from the EIAR based on the worst-case design scenarios for the Proposed Development. The assessment of worst-case design scenarios concluded that further mitigation measures may be necessary to avoid LSE on spawning Buchan stock Atlantic herring. As the assessment outcomes are predicated on worst-case parameters which may not be brought forward in the final design, the measures presented herein are 'in-principle'. As such, this Plan should be considered as 'in principle' until completion of the pre-construction surveys and an optimised design for construction is known.

1.2.5. The Plan will be refined and developed on the basis of the additional pre-construction data, and as the design of the Proposed Development is optimised and finalised. This will ensure the in-principle provisions set out within this Plan are appropriate and relevant to the final design, and subsequently that the mitigation measures that will be implemented are effective in avoiding significant population level effects as a result of the Proposed Development on spawning Buchan stock herring.

1.2.6. The Final Plan will be finalised and adopted post-consent, ahead of construction, following approval by Scottish Ministers (in consultation with NatureScot and any other consultees as required at the discretion of the Scottish Ministers), in accordance with the relevant conditions of the Section 36 Consent and associated Marine Licences.

1.2.7. The process that will be undertaken in finalising the Final Plan is outlined in the flowchart below (Figure 1-1):

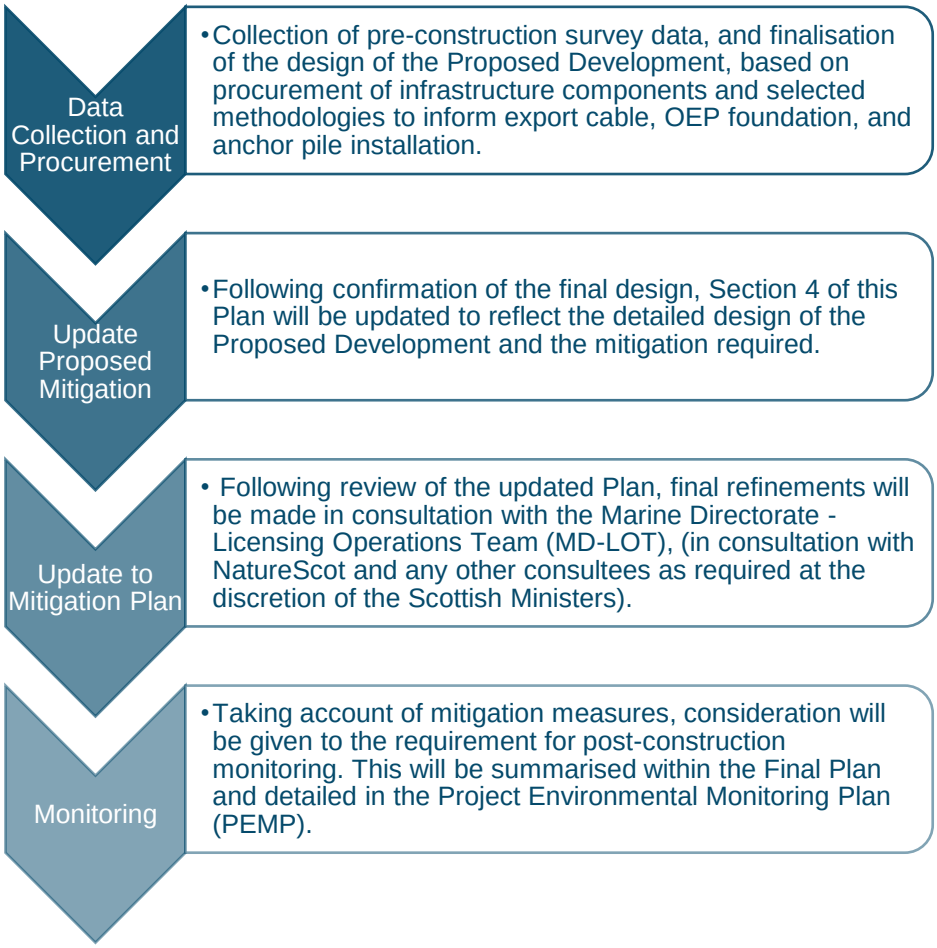


Figure 1-1 Piling and Sediment Mitigation Plan Process

1.2.8. Relevant information arising from the Final Plan will also be presented, as appropriate, in the following pre-construction plans:

- Cable Plan (CaP);
- Construction Method Statement (CMS)
- Piling Strategy (PS);
- Environmental Management Plan (EMP); and
- Project Environmental Monitoring Plan (PEMP).

1.3. DOCUMENT STRUCTURE

1.3.1. This Plan is structured as follows:

- Section 1: Introduction;
- Section 2: Sensitive Receptors;
- Section 3: Effects Requiring Mitigation;
- Section 4: Proposed Mitigation Measures;
- Section 5: Monitoring; and
- Section 6: References

1.3.2. The Plan should be read in conjunction with the following EIAR documents, which contain relevant detail which has been drawn upon and referred to throughout this document:

- Volume 1, Chapter 3 (Project Description);
- Volume 2, Chapter 10 (Fish and Shellfish Ecology);
- Volume 3, Appendix 3.1 (Subsea Noise Technical Report);
- Volume 3, Appendix 7.1 (Marine Processes Modelling Report); and
- Volume 3, Appendix 10.1 (Fish and Shellfish Technical Report).

2. SENSITIVE RECEPTORS

2.1.1. Within Volume 2, Chapter 10 (Fish and Shellfish Ecology), herring was identified as a key receptor, with this species being recognised to have an important spawning ground, within which the Proposed Development is located (Figure 2-1). This particular spawning ground forms part of the Buchan herring spawning ground which runs along the east coast of Scotland and extends offshore (National Marine Plan Interactive (NMPi), (2015), as categorised by Coull *et al*., 1988) (Figure 2-1). Spawning of the Buchan herring stock generally occurs between August and September.

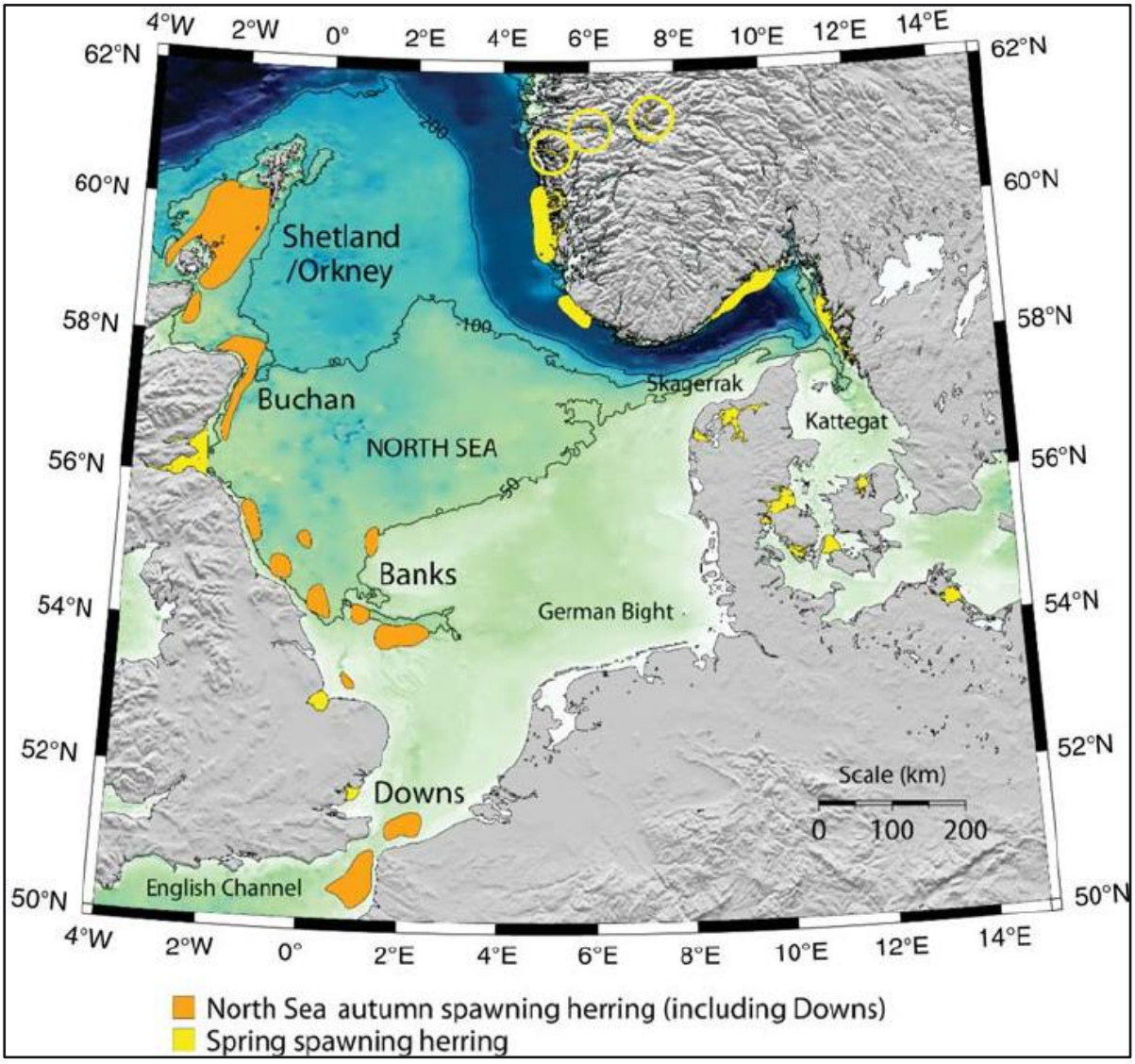


Figure 2-1 Spawning grounds of autumn- and spring-spawning herring in the North Sea and adjacent waters (Dickey-Collas et al., 2010)

2.1.2. Herring are demersal spawners, meaning they lay their eggs on the seafloor or other submerged surfaces. A key concern for herring eggs and larvae is the impact of increased suspended sediment concentrations (SSCs) and sediment deposition, which can smother the eggs and disrupt the development of the larvae. Furthermore, herring have a swim bladder that is involved in hearing, and therefore are also known to be sensitive to underwater noise (UWN).

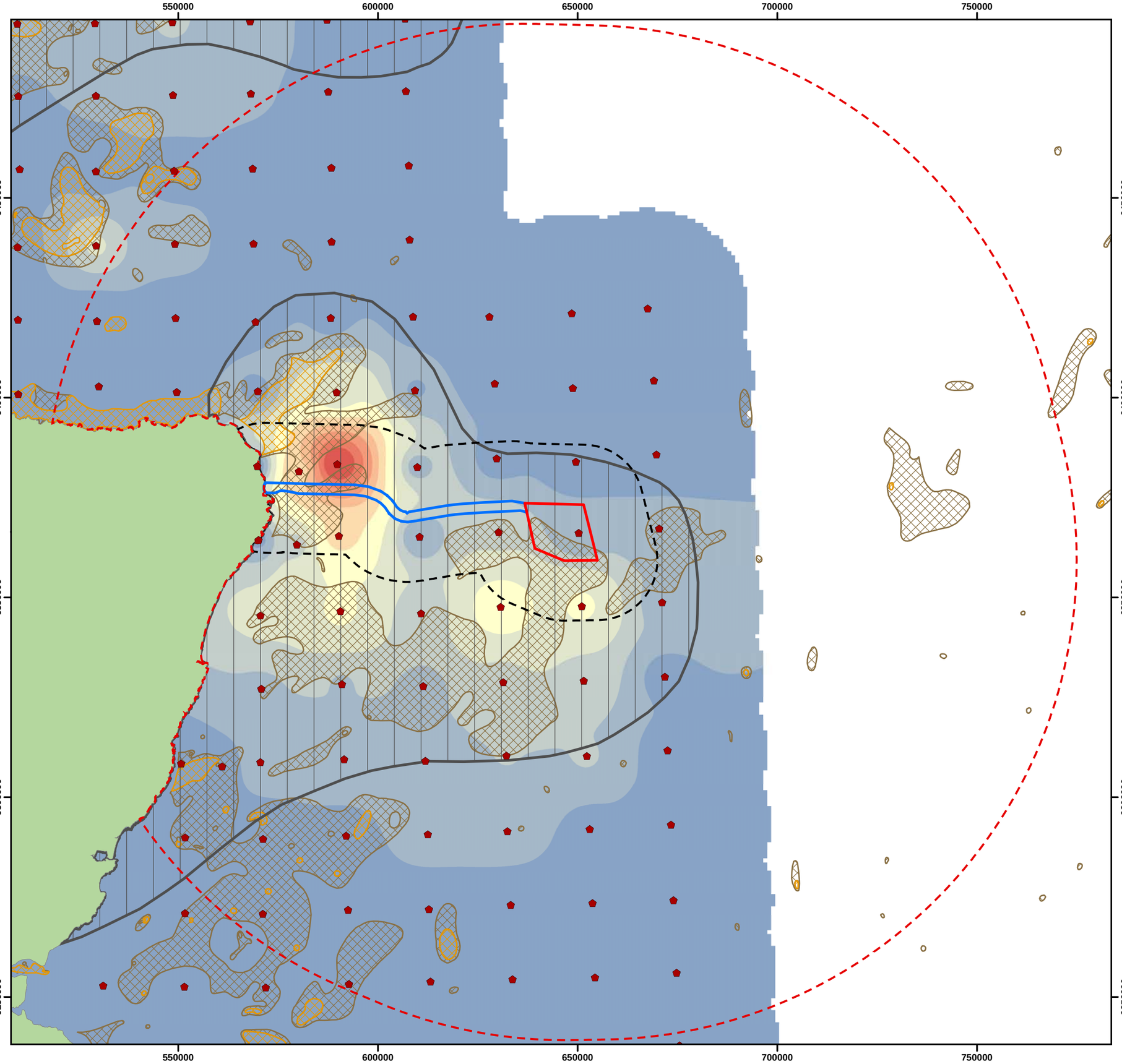
2.1.3. Volume 2, Chapter 10 (Fish and Shellfish Ecology) refers to the following three study areas to inform the assessments:

- **Primary study area:** comprises the footprint of the Array Area and offshore ECC of the Proposed Development. The term "primary impacts" refers to the direct impacts on fish and shellfish species within the Array Area and offshore ECC boundaries including factors such habitat disturbance and habitat loss.
- **Secondary Zone of Influence (ZoI):** comprises a 15 km buffer around the Proposed Development defined by the mean spring tidal excursion to represent the area over which suspended sediment might travel following disturbance. The term “secondary impacts” refers to the indirect impacts on fish and shellfish that arise from changes to the physical environment, particularly increased suspended sediment and sediment deposition.
- **UWN ZoI:** relates to UWN from piling in the Array Area. UWN modelling for the Proposed Development (the outputs of which are detailed in Volume 3, Appendix 3.1 (Subsea Noise Technical Report)) have been utilised to inform the 120 km ZoI for UWN impacts (centred around Array Area), which is considered suitably precautionary for the Proposed Development.

2.1.4. The primary source of information for the current status of herring spawning is the International Herring Larval Survey (IHLS) data, which is collected under the auspices of International Council for the Exploration of the Sea (ICES). Previous analyses (Boyle & New, 2018) have demonstrated the suitability of the IHLS data to be used to aid in informing the location and extent of active herring spawning grounds as an update to the historical spawning grounds as defined by Coull *et al*. (1998). This method has been broadly accepted for use in EIAs, including for Hornsea Four.

2.1.5. This IHLS data provides a proxy for actively spawning herring (based on distribution and density of larvae). As evident in Figure 2-2, areas of peak herring larval density lie within the secondary ZoI and UWN ZoI, and interact with the offshore ECC. Densities of up to 35,000 larvae per m^2 are present within the offshore ECC, with peak densities of up to 59,000 larvae per m^2 evident immediately north of the offshore ECC. Herring larvae densities are comparatively lower in the Array Area, with densities of up to 3,500 larvae per m^2 present in the southern portion of the Array Area. To the south of the Array Area, and within the secondary ZoI, larvae densities reach up to 14,500 larvae per m^2 (Volume 3, Appendix 10.1 (Fish and Shellfish Technical Report)).

2.1.6. The herring spawning potential heat map (Figure 2-3) indicates there are areas of ‘high’ spawning potential within south and southeast extent of the Array Area, with the remainder of the Array Area classified as having ‘medium’ spawning potential. The majority of the offshore ECC is also classified as having ‘medium’ spawning potential. Within the secondary ZoI and wider UWN ZoI, areas of ‘very high’ spawning potential are present, to the south, southwest and southeast of the Array Area. Please see Volume 3, Appendix 10.1 (Fish and Shellfish Technical Report) for further detail on the heat map process and methodology.



Legend:

- Array Area
- Offshore Export Cable Corridor
- Secondary Zone of Influence
- Underwater Noise Zone of Influence
- Herring Spawning Grounds (Coull et al., 1998)

International Herring Larvae Survey

- Sample Location (2011 - 2024)

EMODnet Sediment Class
Herring Habitat Suitability

- Marginal Sediment
- Preferred Sediment

IHLS Season 2011-12 to Season 2023-24
Larval abundance per m^2

- 0
- 0.1 - 1,500
- 1,500.1 - 3,500
- 3,500.1 - 5,500
- 5,500.1 - 9,500
- 9,500.1 - 14,500
- 14,500.1 - 20,000
- 20,000.1 - 26,000
- 26,000.1 - 35,000
- 35,000.1 - 45,000
- 45,000.1 - 59,000

Project:	Report:
Muir Mhòr	In Principal Mitigation Plan

Herring Spawning Data

Figure: 2-2	Drawing No: GoBe-0197		
Revision:	Date:	Drawn:	Checked:
01	06/11/24	EV	BPHB

Map scale 1:950,000 @ A3

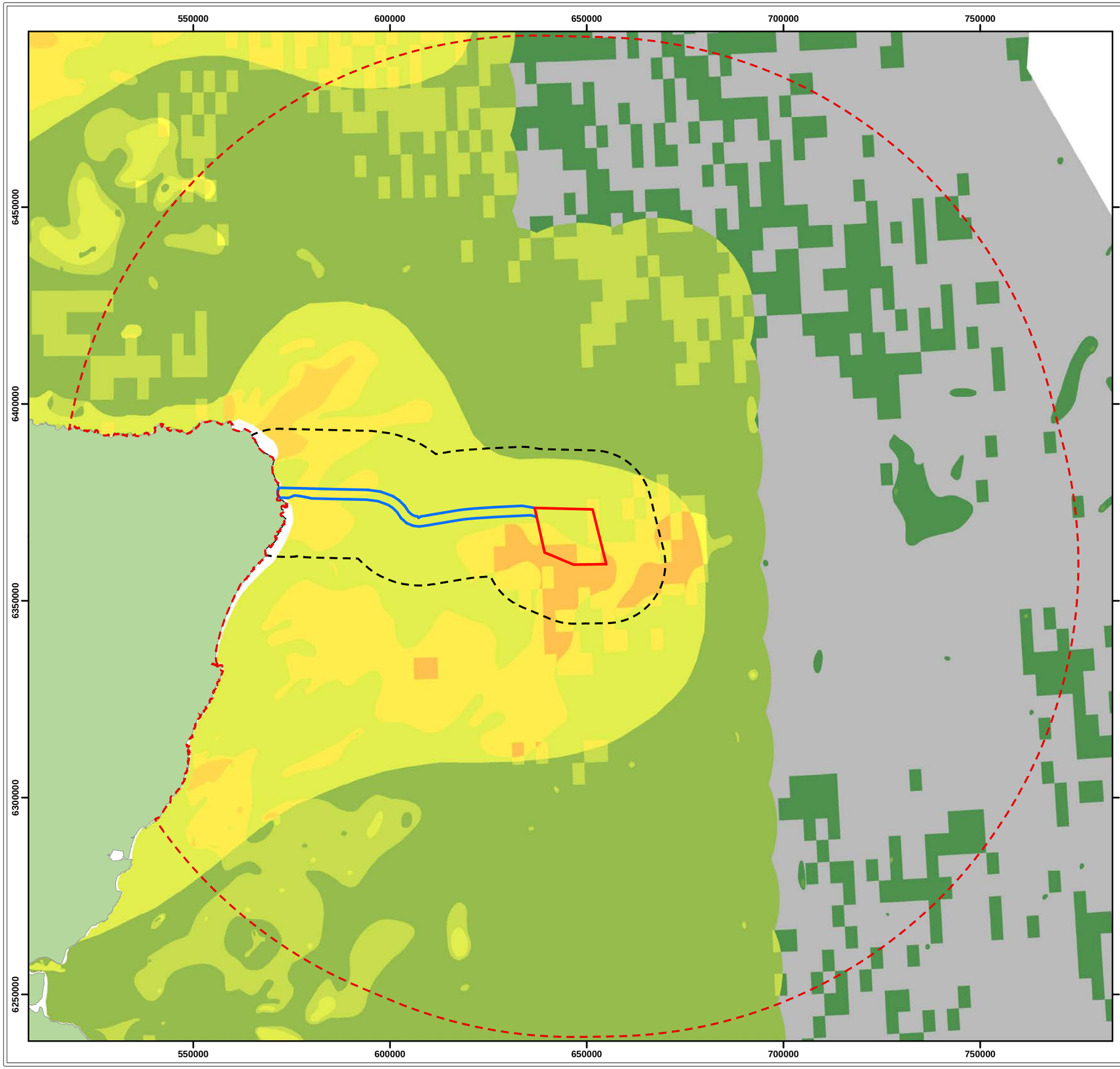
0 10 20 km

N

Co-ordinate system: ETRS 1989 UTM Zone 30N **EPSG:** 25830

MUIR MHÒR
OFFSHORE WIND FARM
A joint venture between Fred. Olsen Seawind & Vattenfall

Service Layer Credits: Esri, Garmin, GEBCO, NOAA NGDC, and other contributors



Legend:

- Array Area
- Offshore Export Cable Corridor
- Secondary Zone of Influence
- Underwater Noise Zone of Influence

Herring Spawning Habitat Confidence

- 0
- 2 (Low)
- 3 (Low)
- 4 (Low)
- 5 (Medium)
- 6 (Medium)
- 7 (Medium)
- 8 (Medium)
- 9 (High)
- 10 (High)
- 11 (High)
- 12 (High)
- 13 (Very High)
- 14 (Very High)
- 15 (Very High)
- 16 (Very High)

Project:	Report:
Muir Mhòr	In Principal Mitigation Plan

Herring Spawning Potential Heat Map

Figure: 2-3	Drawing No: GoBe-0198		
Revision:	Date:	Drawn:	Checked:
01	06/11/24	EV	BPHB

Map scale 1:950,000 @ A3

0 10 20 km

N

Co-ordinate system: ETRS 1989 UTM Zone 30N **EPSG:** 25830

MUIR MHÒR OFFSHORE WIND FARM

A joint venture between Fred. Olsen Seawind & Vattenfall

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3. EFFECTS REQUIRING MITIGATION

3.1. OVERVIEW

3.1.1. The following section provides an overview of the relevant impact sources and sensitive features for the Plan. The mitigation measures that have been identified and set out in Section 4, are based on worst case design scenarios as informed by the design envelope for the Proposed Development (set out in Volume 1, Chapter 3 (Project Description)). The associated topic-specific worst case design scenarios and potential impacts on spawning herring are detailed in full within Volume 2, Chapter 10 (Fish and Shellfish Ecology), Table 10-16 and Section 10.7, respectively.

3.1.2. As set out in Volume 2, Chapter 10 (Fish and Shellfish Ecology), the following impacts from the Proposed Development could result in LSE on spawning Buchan stock herring in the absence of further mitigation:

- Increases in SSCs and deposition of disturbed sediments to the seabed, resulting from the installation of the export cable using jetting tools; and
- Recoverable injury, temporary threshold shift (TTS) and behavioural impacts arising from UWN, from piling of foundations in the Array Area.

3.2. INCREASES IN SSC AND DEPOSITION OF DISTURBED SEDIMENTS TO THE SEABED, RESULTING FROM THE INSTALLATION OF THE EXPORT CABLE USING JET TRENCHING

3.2.1. As detailed above, herring are demersal spawners, meaning they lay their eggs on the seafloor or other submerged surfaces. A key concern for herring eggs and larvae is the impact of increased SSC and sediment deposition, which can smother the eggs and disrupt the development of the larvae. The Proposed Development (the Array Area and the offshore ECC) lies within the Buchan herring spawning ground ((NMPi, 2015), as categorised by Coull *et al*., 1998)). Further, the offshore ECC transits an area of high importance for herring spawning (Figure 2-2). Taking into account the presence of areas of importance to spawning herring, and the demersal nature of spawning herring, there is the potential for LSE on the Buchan herring spawning stock from changes in SSCs and sediment deposition from cable installation activities using jet trenching in the offshore ECC.

3.3. RECOVERABLE INJURY, TTS AND BEHAVIOURAL IMPACTS ARISING FROM UWN, FROM PILING OF FOUNDATIONS IN THE ARRAY AREA

3.3.1. Herring are sensitive to noise impacts as they possess swim bladders which are linked to the inner ear and are therefore involved in hearing (Popper *et al*., 2014). Furthermore, herring are demersal spawners and are therefore considered static receptors during the spawning season, increasing their theoretical exposure to UWN from the construction phase of the development. Taking into consideration the high intensity spawning occurring to the north of the offshore ECC (Figure 2-2 - as informed by the presence of high densities of larvae, used as a proxy for active spawning), and the sensitivity of herring to UWN, there is the potential for LSE on the Buchan herring spawning stock from UWN.

3.3.2. As set out within Volume 2, Chapter 10 (Fish and Shellfish Ecology), the full range of noise impacts (mortality and potential mortal injury, recoverable injury, TTS and behavioural impacts) have been assessed, however ranges of mortality and potential mortal injury are predicted to be very localised, even with unmitigated piling scenarios, and not found to represent an impact on Buchan stock herring at a population scale. As concluded in Volume 2, Chapter 10 (Fish and Shellfish Ecology), there is the potential for LSE on the Buchan herring stock from recoverable injury, TTS and behavioural effects.

4. PROPOSED MITIGATION MEASURES

4.1. INTRODUCTION

4.1.1. This section of the Plan outlines the measures currently available or likely to be available within the development timeframe for the Proposed Development, which may be applicable to construction activities at the Proposed Development, pending final post-consent project design.

4.1.2. It is important to note that the Developer has provided detail on a suite of mitigation measures in the following sections that are considered both appropriate and sufficient to reduce the effects on spawning herring to non-significant levels (in EIA terms). These measures relate to the design of the Proposed Development, installation methodologies, or strategies and technologies to reduce impacts. These mitigation measures are intended to illustrate the mitigation options available to the Developer, which may be implemented as of suite of measures, or as a single measure in isolation. The specific mitigation measure (or suite of measures) that will be implemented during the construction of the Proposed Development will be determined, in consultation with MD-LOT and NatureScot, following confirmation of the final project design, collection of additional survey data, and/or information on maturation of emerging technologies. This additional data and information will allow noise and sediment modelling to be updated to feed into the Final Plan, and discussions on the appropriate mitigation measure(s) to take place. This process will ensure that a conclusion of no LSE on spawning herring (in EIA terms) can be maintained.

4.1.3. The process for updating this Plan post-consent also allows other relevant technologies or methodologies that may arise in the future to be considered and assessed. This will allow any new, currently unforeseen technologies or methods that may arise prior to construction to be considered. Due to the time lag between the granting of a consent for an OWF and the start of offshore construction (which will typically be several years), together with the rapid rate of technological development in the market, it is possible that new measures may become available. The Final Plan should not be restricted to measures only available at the time of consent, provided that the emerging measures do not have other effects/parameters that would fall outside of the design envelope of the consent. Inevitably no efficacy information is currently available for any such measures and their use and impact on spawning herring will need to be considered within the Final Plan and be subject to consultation with MD-LOT and NatureScot.

4.1.4. Before implementation of any mitigation measures determined as necessary during the drafting of the Final Plan, the efficacy of each measure (alone or in-combination with other measures) will need to be considered to ensure that the proposed measure can be relied upon to achieve any required reduction in impact magnitude and the associated conclusion of no LSE.

4.1.5. MD-LOT and NatureScot would be consulted during this process to ensure that the mitigation measures and the assessment of their efficacy are appropriately robust. Following the consideration and selection of any mitigation measures considered necessary to avoid LSE on spawning Buchan stock Atlantic herring, a Final Plan would be submitted to MD-LOT for consideration (in consultation with NatureScot) and, subject to any amendments required, would be submitted for approval by the Scottish Ministers prior to the start of the relevant licensed activities.

4.1.6. The approach to developing the mitigations for export cable installation and impact piling are presented separately in the sections below. Illustrative scenarios are provided to demonstrate and evidence that the implementation of these measures would be sufficient to reduce the effects on spawning herring to no LSE (in EIA terms) and that the reduction in the magnitude of impact predicted is appropriate and achievable.

4.2. DEFINING THE PEAK HERRING SPAWNING PERIOD

4.2.1. Before consideration can be given to the mitigation measures that may be required to minimise impacts on spawning herring, the peak spawning period must be defined as this will inform any potential seasonal restriction dates. The Developer considers that mitigating this 'peak' will be sufficient to mitigate population level impacts (the purpose of the EIA) on the Buchan herring spawning stock. This peak spawning period will be defined post-consent through the analysis of the most recent ten years of IHLS data alongside a back-calculation to identify the most likely date for when spawning commenced for the majority of the larvae captured within the IHLS data. This back-calculation will use variables such as:

- IHLS survey timings;
- Larval length in survey sample data;
- Larval length at hatching;
- Egg development duration;
- Yolk absorption duration; and
- Growth rate.

4.3. MITIGATION MEASURES FOR EXPORT CABLE INSTALLATION WITHIN THE OFFSHORE EXPORT CABLE CORRIDOR

4.3.1. This section sets out the approaches and methodologies proposed to be employed to provide mitigation of the following impact identified in Volume 2, Chapter 10 (Fish and Shellfish Ecology), that could lead to LSE on spawning herring:

- Increases in suspended sediment concentrations (SSC) and deposition of disturbed sediments to the seabed, resulting from the installation of the export cable using jet trenching.

4.3.2. The Plan draws upon information available on the export cable route (or that will be available prior to construction) and examples of the types of equipment that may be used for export cable installation. The importance of the latter aspect is to demonstrate that such methods and techniques are deliverable for the proposed export cable installation works within the offshore ECC and can therefore be relied upon to deliver the mitigation of LSE that may arise in the absence of such.

4.3.3. The principles underpinning the export cable installation mitigation comprise the following:

- A seasonal restriction (during the peak herring spawning period) on the use of jet trenching for export cable installation works in the nearshore portion of the offshore ECC (Mitigation Option A);
  - This aims to minimise the direct and indirect (secondary) seabed disturbance footprint to reduce impacts during the peak spawning period in the nearshore portion of the ECC, which will provide mitigation of impacts to Buchan herring stock eggs and larvae.

OR

- A seasonal restriction (during the peak herring spawning period) for export cable installation works in the nearshore portion of the offshore ECC (Mitigation Option B);
  - This will ensure offshore export cable installation activities within the nearshore portion of the offshore ECC are undertaken outside the Buchan stock peak

spawning period to avoid any effects from sediment deposition on herring eggs and larvae.

4.3.4. These principles will be applied in a staged approach as set out below (and illustrated in Figure 4-1):

- **Step 1:** The Developer will define the peak herring spawning period (and therefore the associated potential seasonal restriction dates) using the process set out in Section 4.2.
- **Step 2:** Following pre-construction surveys (geophysical and geotechnical surveys), a Cable Burial Risk Assessment will be produced, in accordance with the survey outputs and preliminary project design. Revised sediment plume modelling will be undertaken in accordance with the survey outputs and proposed preliminary project design and analysed relative to the most recent herring eggs and larvae survey data. In the event that no LSE is concluded, the revised sediment plume modelling will be added to the Final Plan, which will be submitted to MD-LOT for approval, in consultation with NatureScot. If it is considered that LSE on spawning herring could still occur, then the Developer will progress to Step 3.
- **Step 3:** The Developer will look to commit to either Mitigation Option A (seasonal restriction (during the peak herring spawning period) on the use of jet trenching for export cable installation works in the nearshore portion of the offshore ECC), or Mitigation Option B (seasonal restriction (during the peak herring spawning period) for export cable installation works in the nearshore portion of the offshore ECC).
- **Step 4:** Mitigation Option presented in the Final Plan which will be submitted to MD-LOT for approval, in consultation with NatureScot.

4.3.5. Further detail on each of these mitigation options is set out in the sections below.

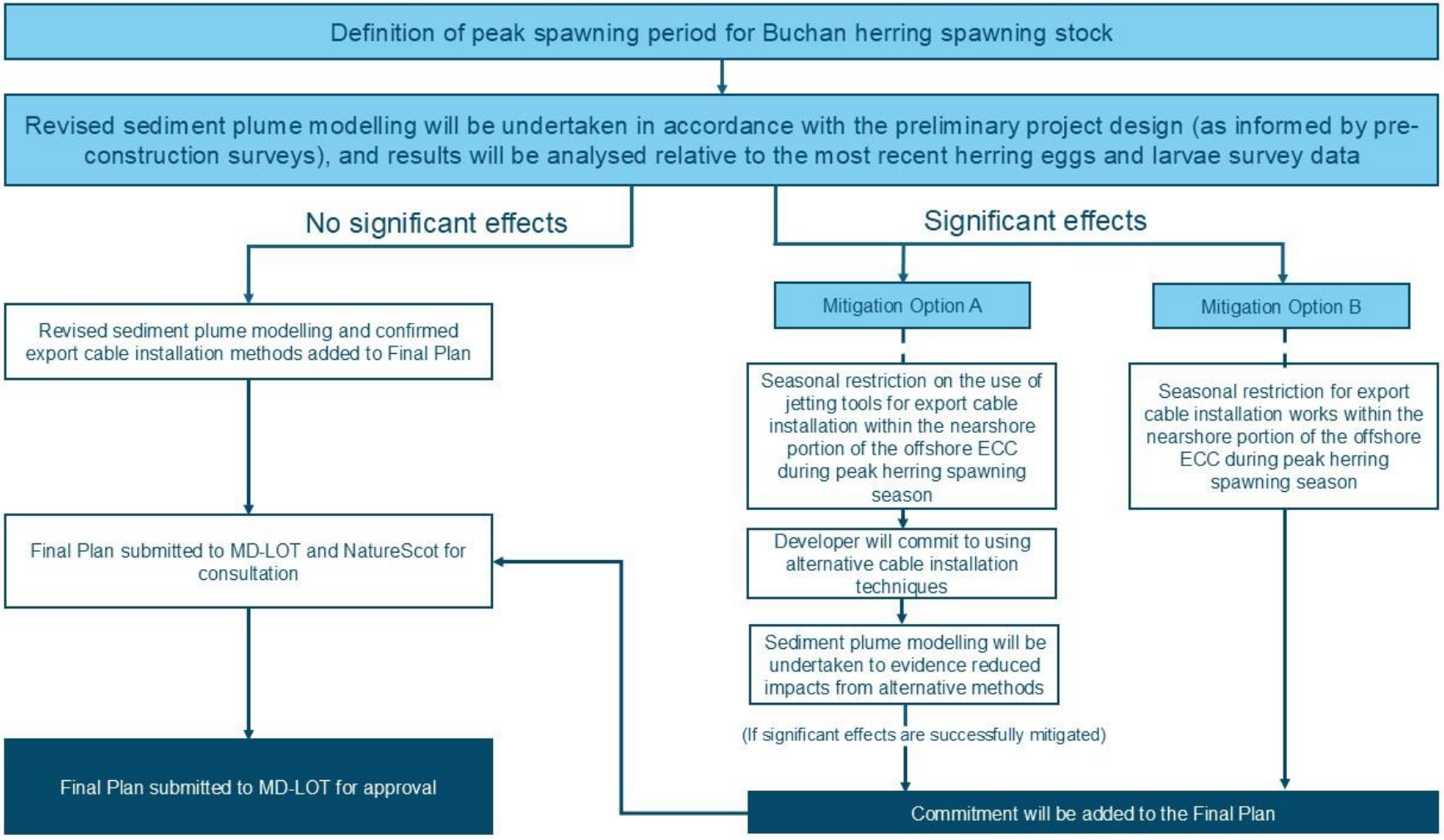


Figure 4-1 Export Cable Installation Mitigation Process

MITIGATION OPTION A: SEASONAL RESTRICTION FOR THE USE OF JET TRENCHING FOR CABLE INSTALLATION IN THE NEARSHORE PORTION OF THE OFFSHORE ECC DURING THE PEAK HERRING SPAWNING PERIOD

4.3.6. As detailed in Table 10-16 of Volume 2, Chapter 10 (Fish and Shellfish Ecology) the installation of export cables using jetting tools represents the realistic worst case for increases in SSC and deposition of disturbed sediments to the seabed, for spawning herring. As evidenced by sediment plume modelling (the outputs of which are detailed in Volume 3, Appendix 7.1 (Marine Processes Modelling Report)), jetting tools have the greatest potential to fluidise and suspend fine sediments, therefore resulting in the largest amount of displaced sediment in the water column, with a realistic trenching rate of 500 m/hr and maximum trenching rate of 700 m/hr representing the highest release rate of sediments and operating in locations with the largest contribution of fine sediments. The maximum SSC modelled for cable installation activities using jetting in the ECC are shown in Figure 4-2 below, and the sedimentation modelled is shown in Figure 4-3. Figure 4-2 shows that the highest increases in SSC occur in the nearshore portion of the offshore ECC, with increases in SSC above 0.5 mg/l being constrained to within 8 km to the north of the offshore ECC and within 20 km south of the offshore ECC, reflecting a southward flow dominance. Directly along the path of the jet trencher, sedimentation thickness is typically around 4 to 6 mm, with some small areas where thickness is more than 10 mm. As shown in Figure 4-3, outside of the offshore ECC the sediment thickness is less than 2 mm, with a more extensive area of deposits to the south of the offshore ECC.

4.3.7. It should be acknowledged that sediment plume modelling, and subsequently the assessment of potential impacts to sensitive receptors has been based on worst case design parameters, which may not be brought forward in the final design.

4.3.8. As stated above, to mitigate against the potential for LSE on spawning Buchan stock herring, the Developer may seek to commit to a seasonal restriction for the use of jetting tools within nearshore portion of the ECC. The precise spatial extent of this restriction will be defined in accordance with the revised sediment plume modelling, that will be undertaken in accordance with the pre-construction survey outputs and proposed preliminary project design. As evident in the sediment plume modelling outputs, the peak increases in SSC and sedimentation are anticipated to occur in the nearshore portion of the offshore ECC, from the use of jetting tools. This mitigation measure will therefore be spatially restricted to the nearshore portion of the offshore ECC (see '*Mitigation Option B Preliminary Restriction Extent*' in Figure 4-2 and Figure 4-3 for an illustrative scenario of the potential spatial extent).

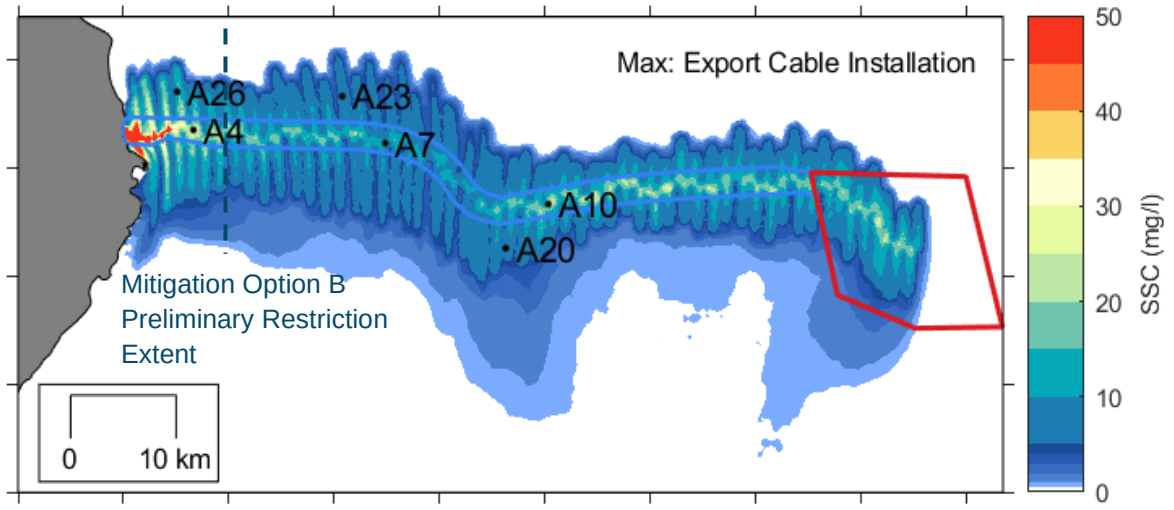


Figure 4-2 Modelled maximum SSC for export cable installation using the jet trencher.

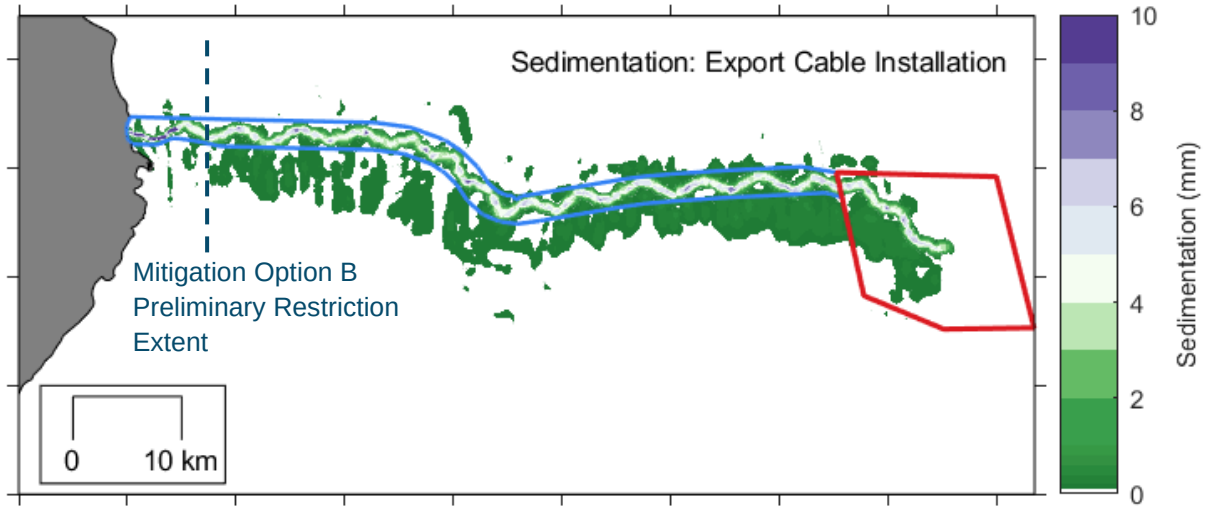


Figure 4-3 Modelled sedimentation for export cable installation using the jet trencher.

4.3.9. As detailed in Volume 1, Chapter 3 (Project Description), the design envelope for export cable installation also includes the use of ploughing and mechanical trenching for export cable installation (as alternative techniques to jet trenching), these are detailed below. The Developer will therefore seek to use these alternative techniques during the peak herring spawning season, in the nearshore portion of the ECC (see the '*Mitigation Option B Preliminary Restriction Extent'* in Figure 4-2 and Figure 4-3 for the potential spatial extent).

4.3.10. The adoption of alternative offshore export cable installation techniques (as alternatives to jetting) in the nearshore portion of the ECC will minimise the direct and indirect (secondary) seabed disturbance footprint to reduce impacts, which will provide mitigation of impacts to spawning herring. The Developer will seek to utilise the most appropriate technology available at the time of construction to reduce the direct and indirect impacts from export cable installation.

4.3.11. Paragraphs 4.3.13 *et seq*. and 4.3.18 *et seq*. provide additional information on the alternative installation techniques that are available to ensure both direct (footprint) and indirect (SSC and deposition) effects are reduced for spawning Buchan stock herring (when compared to the worst-case methodologies (i.e. jetting) assessed within Volume 2, Chapter 10 (Fish and Shellfish Ecology)). The mitigation is aimed at reducing impact risks to no LSE for this receptor.

4.3.12. Further sediment plume modelling will be undertaken to evidence the reduced impacts from SSC and sediment deposition, relative to areas of high densities of herring eggs and larvae, from the use of different cable installation tools. The spatial extent of this restriction will be defined in accordance with the outputs of the sediment plume modelling. If the use of alternative methodologies for cable installation in the nearshore portion of the offshore ECC successfully mitigates the potential for LSE on herring eggs and larvae, the revised sediment plume modelling and confirmed export cable installation methods will be added to the Final Plan, which will be submitted to MD-LOT for approval, in consultation with NatureScot.

PLOUGHING

4.3.13. As detailed in Volume 1, Chapter 3 (Project Description), the installation of the export cables could involve the burial of the cables below the seabed using cable ploughs.

4.3.14. Cable ploughs are suitable across a wide range of soil conditions, including sands and very stiff clays. However, it is not possible to make more than one 'pass' with a cable plough, and consequently any areas of seabed that fail to meet burial specifications cannot be directly remedied using the plough. In such cases, remedial cable protection is often required, as detailed in Volume 1, Chapter 3 (Project Description), cable protection will likely be in the form of rock placement, concrete mattresses, rock/grout bags or frond mattresses.

4.3.15. It should be acknowledged that there are a number of considerations as to which particular ploughs may be suitable, which are not resolvable at the pre-consent stage as noted previously. The key consideration is around the geotechnical properties along the cable route and whether ploughing is considered likely to achieve the required depth of burial for the cables. This will be informed via the pre-construction geotechnical survey and associated update to the CBRA. Additional considerations include the final design and sizing of the cables themselves and compatibility with the specification of the ploughs themselves, as well as installation vessel capabilities and available deck space for equipment.

4.3.16. When considering the potential for increased SSC and sediment deposition from export cable installation within the offshore ECC, the use of a plough will have reduced impacts when compared to jetting tools, with ploughing technologies resulting in less sediment entering the water column. Furthermore, when ploughing operations are used in granular substrates (such as subtidal sands or coarse and mixed sediments, which are present in the nearshore portion of the ECC), the substratum is disturbed but not completely displaced with the majority of the disturbed seabed material being redeposited within or in the immediate vicinity of the trench.

4.3.17. There are a number of potentially suitable ploughing solutions available, which could reduce SSC and sediment deposition impacts to spawning Buchan stock herring (when compared to the worst-case methodologies assessed within Volume 2, Chapter 10 (Fish and Shellfish Ecology)). Details of the specific equipment that could be utilised, if required, will be presented in the Final Plan.

MECHANICAL TRENCHING

4.3.18. As detailed in Volume 1, Chapter 3 (Project Description), the installation of the export cables could involve the burial of the cables below the seabed using mechanical trenching tools.

4.3.19. Mechanical trenchers are self-propelled tracked vehicles and include wheel cutters and chain cutters. Following the lay of cables, a trench is created by the mechanical trencher (using a chain or wheel cutter) that allows the cable to fall into a trough in the seabed. Mechanical trenchers can be used in harder substrates which are less amenable to other trenching techniques (such as ploughing), although it should be acknowledged that the use of these tools have a lower potential for natural backfill, increasing the risk of remedial cable protection or backfill ploughing.

4.3.20. There are a number of considerations as to which particular trenchers may be suitable, which are not resolvable at the pre-consent stage as noted previously. Key considerations include:

- The need or requirement for a support vessel to house pumps and power systems depending on deck space available on the main cable lay vessel;
- The ability to operate in layback from a cable lay vessel, and the distance over which this is possible;
- The degree of disturbance to the seabed, both in terms of the dimensions of the trench excavated, and the disturbance caused by machine tracks;
- The manoeuvrability of the trencher and ability to traverse seabed irregularities; and
- The ability of the nearshore trencher to continue on to successfully complete the offshore scope, thus reducing both repeat impact to the environment and mobilisation costs.

4.3.21. There are a number of potentially suitable trenching solutions available, which could reduce SSC and sediment deposition impacts to spawning Buchan stock herring (when compared to the worst-case methodologies assessed within Volume 2, Chapter 10 (Fish and Shellfish Ecology)). Details of the specific equipment that could be utilised, if required, will be presented in the Final Plan.

MITIGATION OPTION B: SEASONAL RESTRICTION FOR CABLE INSTALLATION WORKS IN THE NEARSHORE PORTION OF THE OFFSHORE ECC DURING THE PEAK HERRING SPAWNING PERIOD

4.3.22. As stated above, to mitigate against the potential for LSE on spawning Buchan stock herring, the Developer may seek to commit to a seasonal restriction for all cable installation works in the nearshore portion of the offshore ECC.

4.3.23. The restriction would be proposed during the peak herring spawning period, which will be defined as per the process set out in Section 4.2.

4.3.24. The precise spatial extent of this restriction will be defined in accordance with the revised sediment plume modelling, that will be undertaken in accordance with the pre-construction survey outputs and proposed preliminary project design. As evident in the sediment plume modelling outputs, as summarised in paragraph 4.3.6 *et seq*., and shown in Figure 4-2 and Figure 4-3, the peak increases in SSC and sedimentation are anticipated to occur in the nearshore portion of the offshore ECC, from the use of jetting tools. This mitigation measure will therefore be spatially restricted to the nearshore portion of the offshore ECC (see *'Mitigation Option B Preliminary Restriction Extent'* in Figure 4-2 and Figure 4-3 for an illustrative scenario of the potential spatial extent).

4.3.25. This commitment will be detailed in the Final Plan, which will be submitted to MD-LOT for approval, in consultation with NatureScot for consultation.

4.4. MITIGATION MEASURES FOR NOISE GENERATED BY FOUNDATION INSTALLATION WITHIN THE ARRAY AREA

4.4.1. This section sets out the approaches and methodologies proposed to be employed to provide mitigation of the following impact identified in Volume 2, Chapter 10 (Fish and Shellfish Ecology), that could lead to LSE on spawning herring:

- Recoverable injury, TTS and behavioural impacts arising from UWN, from piling of OEP foundation piles and WTG anchor piles in the Array Area.

4.4.2. The proposed approaches to delivering mitigation for LSE are supported by information and examples of the types of equipment that may be used, or alterations to the piling parameters and piling scenarios. Details of available mitigation technology have been presented to provide confidence that the required levels of noise attenuation can be delivered (either through one of the examples given, or through other future potential mitigation technology) and can therefore be relied upon to avoid LSE that may arise in the absence of mitigation.

4.4.3. Delivery of the Final Plan and measures outlined therein will be secured within the relevant conditions of the Section 36 Consent and associated Marine Licences, to provide certainty on the provision of the mitigation commitments made by the Developer in progressing the development of the Proposed Development, whilst maintaining the flexibility required at the pre-consent stage. This allows the Developer to select the most appropriate options closer to the time of construction works, once the design of the Proposed Development has been finalised.

4.4.4. As set out within Volume 2, Chapter 10 (Fish and Shellfish Ecology), and stated above, the impact ranges of mortality and potential mortal injury are predicted to be very localised, even with unmitigated piling scenarios, and not found to represent an impact on Buchan stock herring at a population scale. The mitigation measures are therefore focused on the lower noise levels that might still elicit recoverable injury, TTS and behavioural effects during these sensitive periods on spawning herring. The principles underpinning the piling mitigation are set out below and the primary driver for the noise mitigation plan is avoidance of LSE on spawning Buchan stock herring.

4.4.5. The noise mitigation plan has been designed on the following principles:

- Noise mitigation is focused on reducing noise emission levels at the locations of sensitive receptors (i.e., at areas of high densities of herring eggs and larvae, indicative of actively spawning herring) below the level at which a meaningful response might be expected to occur, which could result in a significant population effect on the Buchan stock herring during the peak spawning period;
- Assumptions on attenuation performance of the noise mitigation techniques are based on demonstrable performance of the technology, in relevant environmental conditions to ensure confidence in delivering the required noise level reductions; and
- Actual installation equipment choice and noise mitigation techniques will be selected pre-construction but will conform to the noise reduction levels required to meet the criteria set for noise mitigation plan.

4.4.6. In developing this section of the Plan, the noise mitigation measures under consideration are detailed below, and where relevant, UWN modelling outputs are presented to demonstrate the potential mitigated impact ranges from an illustrative scenario. This illustrative scenario is provided to demonstrate and evidence that the implementation of these measures would be sufficient to reduce the effects on spawning herring to no LSE (in EIA terms) and that the reduction in the magnitude of impact predicted is appropriate and achievable.

4.4.7. The mitigation measures currently being considered include the following:

- The adjustment of piling parameters and piling scenarios to reduce UWN impact ranges during the peak herring spawning season;
- The use of different foundation types (i.e. non-piled) for OEP(s), and different anchor types for WTGs;

- The use of noise abatement systems during the peak herring spawning season; and
- The implementation of a seasonal piling restriction during the peak herring spawning season.

4.4.8. The mitigation measures identified above may be implemented as of suite of measures, or as a single measure in isolation. The specific mitigation measure (or suite of measures) that will be implemented during the construction of the Proposed Development will be determined, in consultation with MD-LOT and NatureScot, following confirmation of the final project design, collection of additional survey data, and/or acquisition of noise monitoring data, and/or information on maturation of emerging technologies.

4.4.9. These principles will be applied in a staged approach as set out below (and presented visually in Figure 4-4):

- **Step 1:** The Developer will define the peak herring spawning period (and therefore the associated potential seasonal restriction dates) using the process set out in Section 4.2;
- **Step 2:** UWN modelling will be undertaken in accordance with the preliminary project design (as informed by pre-construction survey outputs) and analysed relative to the most recent herring eggs and larvae survey data (used as a proxy for actively spawning herring). If the UWN modelling no longer indicates the potential for LSE on spawning herring, then no further mitigation measures will be proposed. The revised UWN modelling will be added to the Final Plan, which will be submitted to MD-LOT for approval, in consultation with NatureScot (and other consultees as required at the discretion of the Scottish Ministers). If it is considered that LSE on spawning herring could still occur, then the Developer will progress to Step 3;
- **Step 3:** The Developer will commit to one or more of the following Mitigation Options summarised below:
  - **Mitigation Option A:** Piling during the peak herring spawning season will be undertaken using alternative, refined piling scenarios;
  - **Mitigation Option B:** WTG anchors and OEP foundations will not be installed using piles that require impact driving;
  - **Mitigation Option C:** WTG anchor piles and OEP foundation piles will be installed using alternative pile installation techniques during the peak herring spawning season;
  - **Mitigation Option D:** Noise abatement systems will be implemented during piling operations in the peak herring spawning season; and
  - **Mitigation Option E:** No piling will be undertaken during the peak herring spawning season.

4.4.10. Further detail on each of these mitigation options is set out in the sections below.

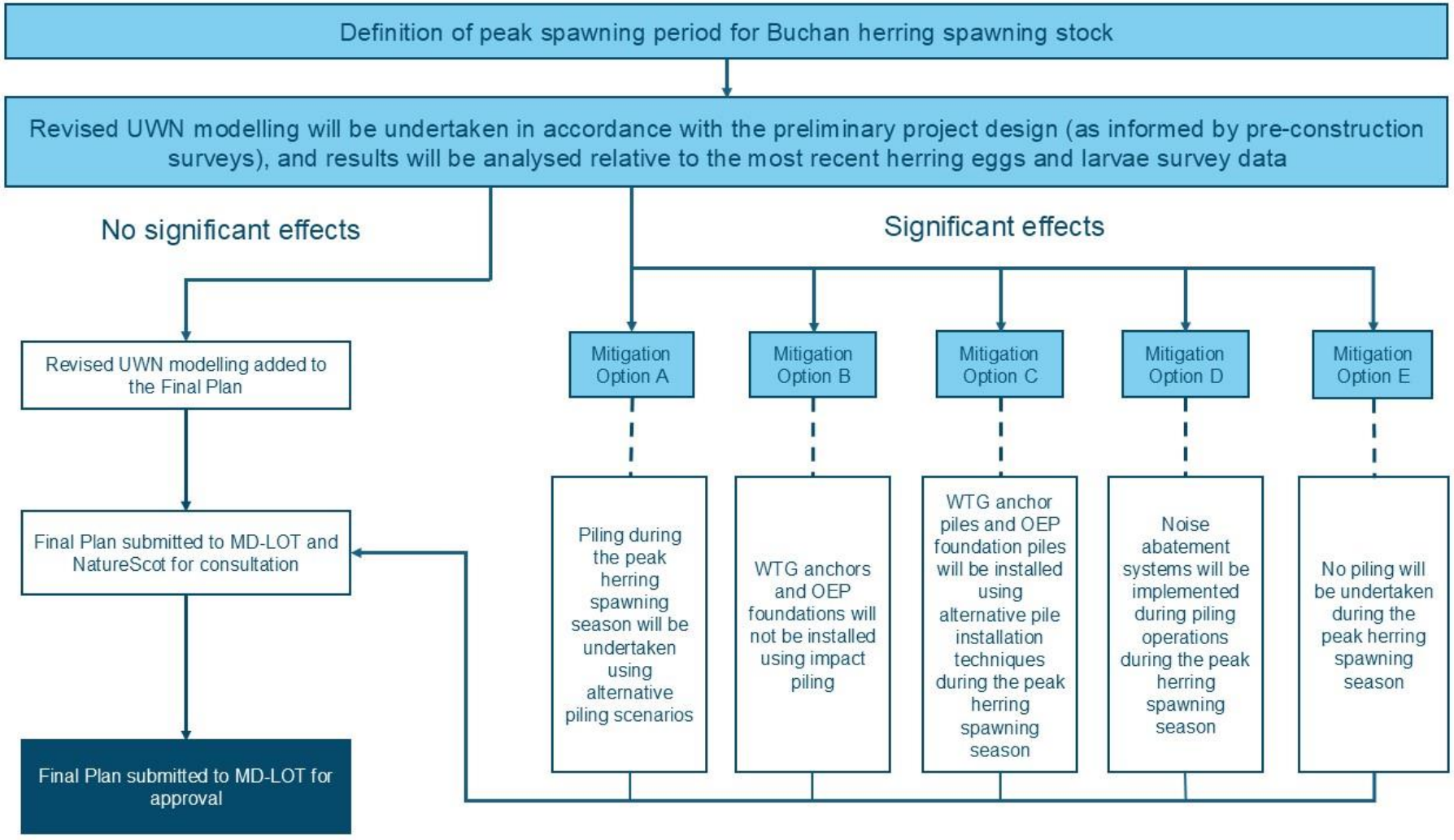


Figure 4-4 UWN Emissions Mitigation Process

MITIGATION OPTION A: PILING PARAMETER AND SCENARIO ADJUSTMENTS

4.4.11. As summarised above, the Developer may consider the use of alternative piling scenarios during the peak herring spawning period. This measure will reduce the impact ranges from UWN, relative to areas of high intensity spawning activity.

4.4.12. Illustrative modelling has been undertaken to demonstrate the potential reduction of noise levels from the use of alternative piling scenarios. The following piling scenarios have been modelled:

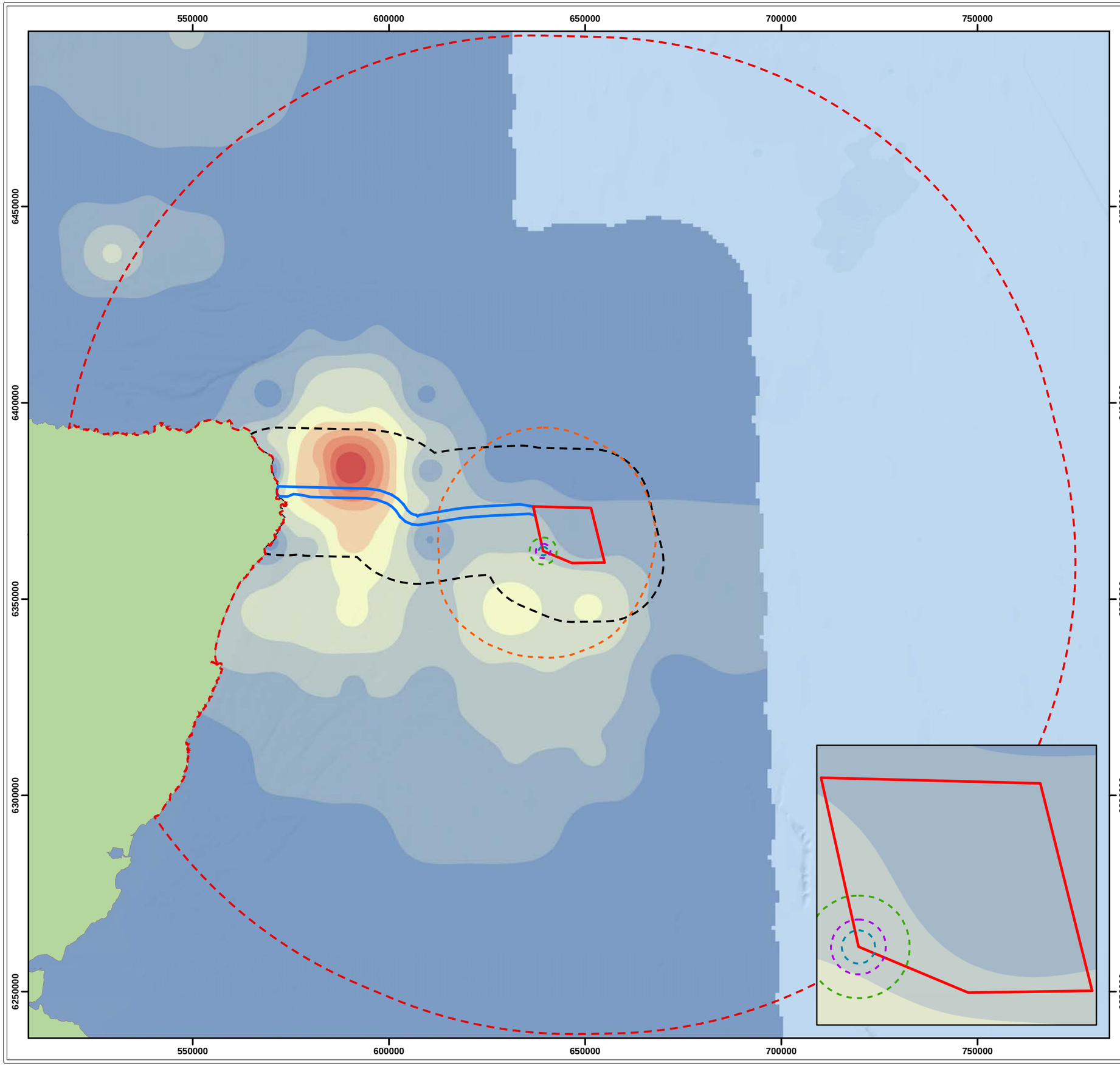
- Sequential installation of up to three anchor piles in a 24-hour period, at a single location (2 m pile diameter, hammer energy 1,000 kJ); and
- Installation of one pin pile in a 24-hour period, for the OEP foundations, at a single location (4 m pile diameter, hammer energy 2,500 kJ).

4.4.13. The outputs of the illustrative modelling have been presented in Table 4-1 below, and Figure 4-7 and Figure 4-8, where the contours are presented relative to herring larval densities (used as a proxy for herring spawning activity). The dashed UWN contours show the maximum impact ranges anticipated for the mortality and potential mortal injury (207 dB cumulative Sound Exposure Level (SEL_{cum})), recoverable injury (203dB SEL_{cum}), and TTS (186 dB SEL_{cum}) of spawning herring (stationary Group 3 receptors (fishes with swim bladders which are involved in hearing (Popper *et al*. 2014))) from the implementation of noise abatement systems. As evident, through the sequential piling of up to three anchor piles in a 24-hour period, at a single location in the Array Area, the impact contours for mortality and potential mortal injury, recoverable injury, and TTS are all mitigated to outside of any areas of high intensity herring spawning. The impact contours are also similarly mitigated to outside any areas of high intensity spawning herring from the installation of one pin pile for the OEP foundations in a 24-hour period in the centre of the Array Area. The illustrative UWN modelling therefore demonstrates the feasibility of using alternative piling scenarios to reduce impacts to spawning herring to no LSE.

Table 4-1 Impact ranges for spawning herring for the alternative piling scenarios for WTG anchor piles and OEP foundations.

Criteria	Noise Level (dB re 1µPa SEL/dB re 1µPa2 SEL)	Impact ranges for the alternative piling scenario for WTG anchor piles	Impact ranges for the alternative piling scenario for OEP foundations
Mortality and Potentially Mortal Injury			
SPL_{peak}	207 dB	150 m	340 m
SEL_{cum} (Static)	207 dB	1.9 km	2.8 km
Recoverable Injury			
SPL_{peak}	207 dB	150 m	340 m
SEL_{cum} (Static)	203 dB	3.5 km	5.3 km
TTS			
SEL_{cum} (Static)	186 dB	31 km	42 km

4.4.14. As stated above, further UWN modelling will be undertaken post-consent, in accordance with the preliminary project design, and piling parameters and scenarios. If the use of alternative piling scenarios successfully mitigates the potential for LSE on spawning herring, the revised UWN modelling will be added to the Final Plan, which will be submitted to MD-LOT for approval, in consultation with NatureScot for consultation.



Legend:

- Array Area
- Offshore Export Cable Corridor
- Secondary Zone of Influence
- Underwater Noise Zone of Influence

Unmitigated (0dB) Contours - Sequential Piling of Anchor Piles

- 186dB SELcum
- 207dB SELcum
- 203dB SELcum
- 210dB SELcum

IHLS Season 2011-12 to Season 2023-24
Larval abundance per m^2

- 0
- 0.1 - 1,500
- 1,500.1 - 3,500
- 3,500.1 - 5,500
- 5,500.1 - 9,500
- 9,500.1 - 14,500
- 14,500.1 - 20,000
- 20,000.1 - 26,000
- 26,000.1 - 35,000
- 35,000.1 - 45,000
- 45,000.1 - 59,000

Project:	Report:
Muir Mhòr	In Principal Mitigation Plan

Alternative piling scenario (Mitigation Option A) impact ranges for spawning herring from the sequential piling of anchor piles in the SW location of the array area (static receptor, 1,000 kJ hammer energy, 2 m pile diameter, up to 3 anchor piles in a 24-hour period)

Figure:	Drawing No:
4-5	GoBe-0202

Revision:	Date:	Drawn:	Checked:
01	14/11/24	EV	BPHB

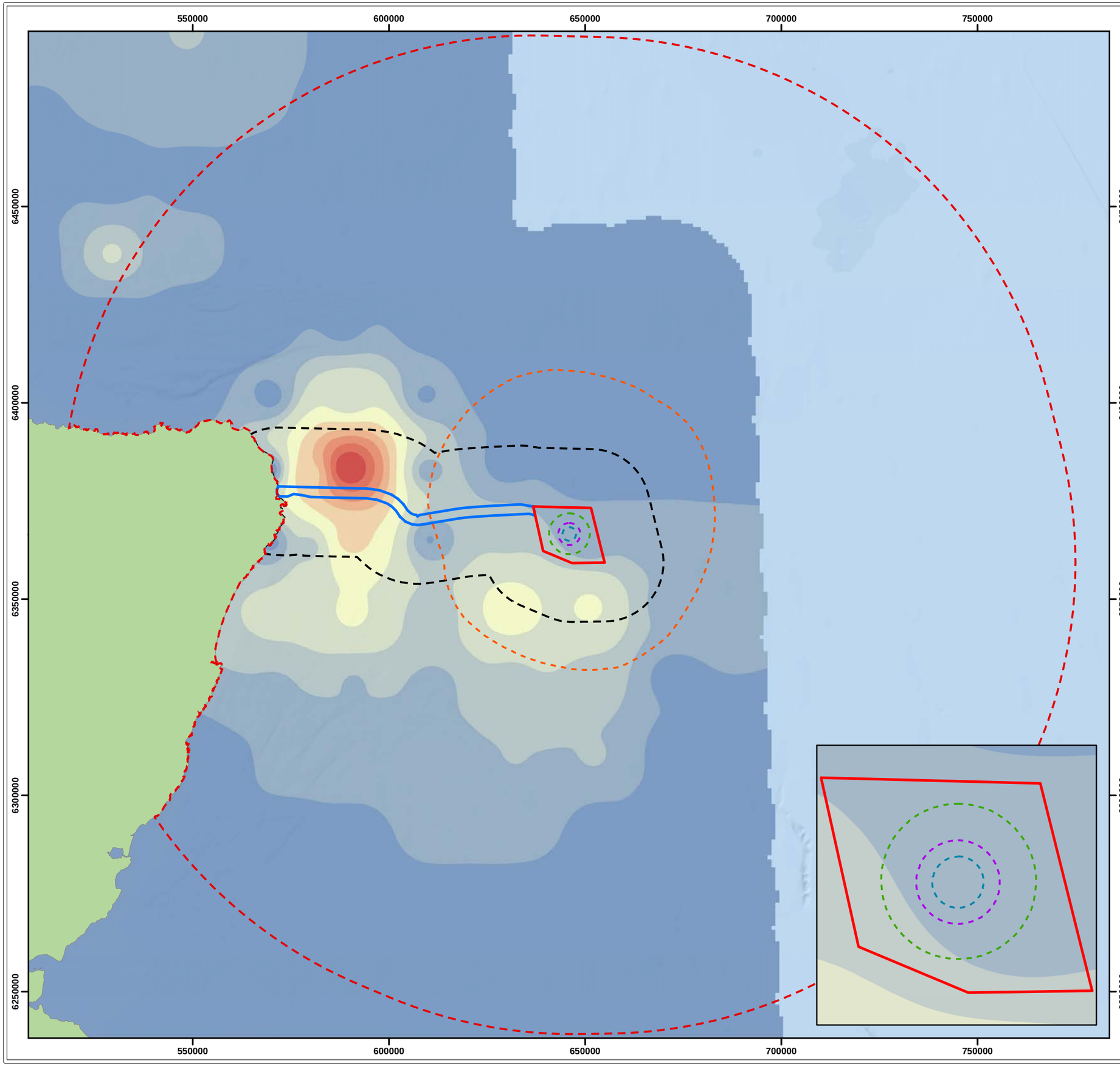
Map scale 1:950,000 @ A3

0 10 20 km

Co-ordinate system: ETRS 1989 UTM Zone 30N **EPSG:** 25830

MUIR MHÒR OFFSHORE WIND FARM
A joint venture between Fred. Olsen Seawind & Vattenfall

Service Layer Credits: Esri, Garmin, GEBCO, NOAA NGDC, and other contributors



Legend:

- Array Area
- Offshore Export Cable Corridor
- Secondary Zone of Influence
- Underwater Noise Zone of Influence

Unmitigated (0dB) Contours - Piling of OEP Pin Piles

- 186dB SELcum
- 207dB SELcum
- 203dB SELcum
- 210dB SELcum

IHLS Season 2011-12 to Season 2023-24
Larval abundance per m^2

- 0
- 0.1 - 1,500
- 1,500.1 - 3,500
- 3,500.1 - 5,500
- 5,500.1 - 9,500
- 9,500.1 - 14,500
- 14,500.1 - 20,000
- 20,000.1 - 26,000
- 26,000.1 - 35,000
- 35,000.1 - 45,000
- 45,000.1 - 59,000

Project:	Report:
Muir Mhòr	In Principal Mitigation Plan

Alternative piling scenario (Mitigation Option A) impact ranges for spawning herring from the piling of OEP pin piles foundations in the centre of the array area (static receptor, 2,500 kJ hammer energy, 4 m pile diameter, 1 pin pile in a 24-hour period)

Figure:	Drawing No:
4-6	GoBe-0203

Revision:	Date:	Drawn:	Checked:
01	14/11/24	EV	BPHB

Map scale 1:950,000 @ A3

0 10 20 km

Co-ordinate system: ETRS 1989 UTM Zone 30N **EPSG:** 25830

MUIR MHÒR OFFSHORE WIND FARM
A joint venture between Fred. Olsen Seawind & Vattenfall

Service Layer Credits: Esri, Garmin, GEBCO, NOAA NGDC, and other contributors

MITIGATION OPTION B: THE USE OF ALTERNATIVE FOUNDATIONS

4.4.15. The Developer could consider whether it is possible (commercially and technically) to use alternative (i.e. non-impact piled) OEP foundation and WTG mooring anchor types (within the consented maximum parameters set out in in Volume 1, Chapter 3 (Project Description)) during the final design process. This decision and design evaluation would be informed by post-consent site investigation and technology developments. One of the key considerations is on the properties and variability of seabed and subsurface geotechnical conditions across the Array Area at the planned foundation locations.

4.4.16. The use of non-piled foundation and anchor types could result in a significant reduction in subsea noise emissions during construction when compared to percussive piling and effectively result in no (or minimal) contribution to the potential for recoverable injury, TTS and behavioural impacts on spawning herring.

4.4.17. As detailed in Volume 1, Chapter 3 (Project Description) the following non-piled WTG mooring anchor types are in the design envelope:

- Suction anchors;
- Gravity anchors;
- Drag embedded anchors (including vertical loaded anchors); and
- Plate anchors.

4.4.18. As detailed in Volume 1, Chapter 3 (Project Description) the following non-piled foundation types are in the design envelope for OEP foundations:

- Jacket with suction caissons.

4.4.19. The installation of non-piled OEP foundations and WTG mooring anchors will avoid high noise emissions *a priori.* (Verfuss *et al*., (2019*),* with noise emissions consisting of low continuous noise (as opposed to impulsive noise from piling operations). The use of alternative (non-piled) foundations will therefore mitigate against potential impacts from UWN on spawning herring – a near 100% efficacy option for providing certainty of no LSE on spawning herring. The confirmed OEP foundations and WTG mooring anchor types would be added to the Final Plan, which will be submitted to MD-LOT for approval, in consultation with NatureScot for consultation.

MITIGATION OPTION C: USE OF ALTERNATIVE INSTALLATION TECHNIQUES

4.4.20. Advancements are being made in relation to techniques for the installation of conventional pile foundations that replace conventional percussive piling techniques and thereby have the potential to reduce the level of subsea noise emissions and correspondingly the risk of recoverable injury, TTS and behavioural impacts. The Developer might consider whether it is possible (commercially and technically) to use such alternative piling systems during the final design process. This decision and design evaluation would be informed by post-consent site investigation and technology developments.

4.4.21. As detailed in Volume 1, Chapter 3 (Project Description), WTG mooring anchor piles, and OEP piles can be installed into the seabed by drilling techniques, or a combination of both (drive-drill-drive), depending on seabed conditions. Typically, piles may be piled into the seabed using a vibration or hydraulic hammer until any hard ground is encountered, with drilling techniques deployed to install the remaining length of pile, if required.

4.4.22. The installation of piles for WTG mooring anchors and OEP foundations using alternative pile driving systems emits significantly lower noise levels into the marine environment, with noise emissions consisting of continuous noise (as opposed to impulsive noise from piling operations).

4.4.23. The following alternative pile driving systems could be considered by the Developer (these are detailed further in the following sections):

- General hammer noise mitigation (High frequency, Low impact (HiLo);
- PULSE hammer;
- MNRU hammer;
- Blue piling technology; and
- Vibro-hammer.

GENERAL HAMMER NOISE MITIGATION

4.4.24. Procedural measures such as “HiLo” can be implemented to reduce noise emissions. This procedure uses a high frequency, low energy blow method and has been proven to have good noise control capabilities but may not be suitable for all ground conditions due to the lower energies utilised.

PULSE HAMMER (BY IHC IQIP)

4.4.25. As a result of the need to reduce noise emission from percussive hammering construction activities, IHC IQIP has developed an add-on noise mitigation which can be jointed with all existing hammers and will sit between the ram-weight and the anvil, called PULSE (Pile Under Limited Stress), it consists of two pistons with a water cushion of 150 – 300 mm.

4.4.26. For the S-4000 model, currently the largest hammer available from this company, IHC IQIP have calculated a noise reduction capability of 6 to 10 dB.

MNRU HAMMER BY MENCK

4.4.27. The biggest hammer MENCK has currently build is the MHU-4400. The MHU-4400 was built during 2020 and is currently available for use. A 5500 – 6000 kJ hammer is currently being planned but further information is not currently available.

4.4.28. MENCK has enveloped a noise mitigation unit, the MNRU, for its hammer. The unit is inserted between the ram weight and the anvil. The unit consists of six individual round silencer blocks (800x800) acting like a spring. The blocks are guided inside and connected to the housing using plastic/nylon strakes. The unit is currently designed to be used on the 3500 kJ and 4400 kJ hammer.

4.4.29. MENCK has modelled the estimated reduction of the MNRU which resulted in a SEL reduction of 9 dB and peak reduction of 12 dB.

BLUE PILING TECHNOLOGY

4.4.30. BLUE Piling Technology is a noise mitigation system consisting of an impact hammer with lower noise emissions than a conventional impact hammer. The technology consists of a steel housing that is filled with water. The water is then accelerated upwards by the release of a small amount of gas, which applies force to the pile and lifts some of the water in the housing. The lifted water then falls down, providing a secondary force to the pile. The cycle is repeated until the pile is installed to the required depth (Rumes *et al.*, 2016). This technology significantly reduces UWN when compared to an impact hammer, by reducing vibrations on the pile wall and prolonging the pulse duration (Bellmann *et al.*, 2020). A prototype was successfully tested on a full-scale monopile in offshore conditions, with the manufacturer predicting a reduction in noise levels of at least 20 dB SEL (IQIP, 2021).

VIBRO-HAMMER

4.4.31. Vibratory hammer technology is a noise mitigation system and one of the optimum methods available for installing monopiles over 6 m diameter within 80 m water depths (Gerwick, 2007; Wybren, 2011 as cited in University of Strathclyde, 2015; Weilgart, 2023). The noise generated by this activity is non-impulsive and peaks at low frequencies (< 40 Hz; Koschinski and Lüdemann, 2020). The Nordsee Ost OWF (located in the German sector of the North Sea) used a combination of vibropiling and impact pile driving to install 196 pin piles of the 48 jacket foundations for wind turbines and one substation in water depths up to 25 m (Offshore Energy, 2014). Pin piles were vibropiled to one third of the final penetration depth before using an impact pile driving method to final depth (Koschinski *et al*., 2020). Noise emissions from vibropiling are in the order of 10–20 dB lower than mitigated impacts of pile driving at identical situations (Gerke and Bellmann, 2012; Kringelum, 2013; as cited in Koschinski *et al*., 2020); however, vibropiling emits a continuous noise compared to the impulsive characteristic of impact pile driving which makes direct comparisons difficult (Koschinski *et al*., 2020).

JETTING TECHNOLOGIES

4.4.32. A new lower-noise pile installation method, developed by Ørsted and tested at an OWF in Germany (Gode Wind 3), has demonstrated reduced noise levels during foundation installation. This method involves the use of jetting technology attached to the monopile, which lowers the resistance of surrounding sandy soils, allowing the foundation to sink into the seabed. A reduction in of 34 dB relative to the most commonly used installation method was observed, and (without additional mitigation), noise levels were reduced by over 99% to a level marginally above ambient noise levels in German Bight in the North Sea (Ørsted, 2024).

MITIGATION OPTION D: USE OF NOISE ABATEMENT SYSTEMS

4.4.33. Noise abatement systems are currently being developed that can, depending on the environment within which they are deployed, enable a reduction of pile-driving noise at source when conventional piling techniques are employed. A reduction in the noise at source would reduce the risk of recoverable injury, TTS and behavioural impacts to spawning Buchan stock herring. However, it should also be noted that these measures may also increase the total duration of disturbance from UWN during foundation installation (because their use slows the rate of installation extending the overall foundation installation programme) – a factor that requires consideration in the decision on the use of these systems. It should be noted that the suitability of any noise mitigation system is dependent on a number of factors for any given offshore wind farm project; these include (but may not be limited to) pile diameter and length, ground conditions, current speeds and water depth. These factors will need to be considered in any assessment of the efficacy of the measure.

4.4.34. The following sections of this report provide information on noise abatement systems that are currently available on the market and could be used to mitigate against impacts from piling UWN on spawning herring. It should be acknowledged however, that actual installation equipment choice and noise abatement techniques will be selected pre-construction but will conform to the noise reduction levels required to reduce the level of effect on spawning herring to no LSE.

BUBBLE CURTAINS

4.4.35. Bubble curtains are the only far-from-pile noise abatement system available on the market at present and comprise either the single or double Big Bubble Curtain (BBC or DBBC respectively). These abatement systems have been widely utilised in the offshore renewables industry and is the most common method for reducing UWN emissions for offshore wind piling activities.

4.4.36. Bubble curtain systems solution pump compressed air through a perforate hose / pipe laid in a circular configuration on the seabed. The compressed air is then released from the seabed and creates a 'curtain' of rising bubble rings, also known as a pneumatic barrier, which is used to attenuate the propagation of sound waves through the water column, thus reducing noise emissions.

4.4.37. Bubble curtain systems are deployed from a secondary vessel supporting the main installation vessel. The vessel is normally a platform supply vessel (PSV) with a number of air compressors on the back deck and a launch and recovery system for the perforated hose/pipe. The PSV is required to be on site for the full period that the main installation vessel is chartered to a project.

4.4.38. Bubble curtain systems have been proven to provide efficient noise reduction and are suitable for use in Germany where the emissions level limit is 160 dB SEL at 750 m from the source (Bellmann *et al*, 2020). Noise reductions of up to 16 dB have been achieved by means of use of DBBC, at 40 m water depth (Bellmann *et al*, 2020).

ISOLATION CASING

4.4.39. An isolation casing is a form of noise abatement system with a shell-in-shell system around the pile in which a shielding effect of the casing reduces the radiated noise. The most used approach is the IHC Integrated Monopile Installer which includes a noise mitigation screen and provides several additional built-in features which aid in decoupling radiated noise from the water column close to pile. The IHC system is a double-walled steel pipe with an air gap in between, with an additional bubble curtain used in the centre around the pile (Weilgart, 2023). The noise mitigation screen is also insensitive to currents (Bellmann *et al*., 2020). By combining several principles of noise reduction in various layers around the pile, isolation casings, such as the IHC Integrated Monopile Installer, are capable of a high noise reduction comparable to or exceeding that of a bubble curtain (Koschinski and Lüdemann, 2020). Whilst there is less evidence for isolation casings, data collected indicates that a noise reduction of at least 10 dB is achievable (Koschinski and Lüdemann, 2020). Current isolation casings are designed and used during installation of monopiles only, not for other foundation types (IQIP, 2023b; Le Monde International, 2023).

HYDROSOUND DAMPER

4.4.40. The Hydrosound Damper (HSD) is a near-field resonator system which is deployed in close proximity to the pile. The system essentially comprises a tubular mesh with sound dampening elements attached to the mesh which is deployed from a lowering/lifting system and a ballast box.

4.4.41. The sound dampening elements consist of various foam elements which can be of a range of sizes and materials. Each of these foam elements acts as a local resonator, which can be tuned in relation to sound frequencies and water depth criteria. The HSD is deployed around the pile from the seabed to the water surface, effectively shrouding the entirety of the pile within the water column.

4.4.42. When suitably designed and deployed, the system can reliably deliver noise reductions of 10 dB as demonstrated on several hundred pile installations across five OWF projects in German waters (Bellmann *et al*., 2020).

IHC NOISE MITIGATION SCREEN

4.4.43. IHC Noise Mitigation Screen is a noise mitigation system that has recently been assessed as the most effective near-pile mitigation system (Weilgart, 2023). This technology features a pipe-in-pipe system that reduces SEL up to 17 dB (Bundesamt für Seeschifffahrt und Hydrographie (BSH), n.d.). This technology is independent of current and can be used in any water depth in principle; however, to date, this system has only been used in water depths of 40 m (Weilgart, 2023). It is recommended to be used with a DBBC which can further reduce SELs up to 22 dB in shallow water depths (ca. 40 m; Weilgart, 2023).

ADBM NOISE MITIGATION SCREEN

4.4.44. The company AdBm developed a customisable noise mitigation screen which was first deployed commercially in 2019 (Verfuss *et al*. 2019). Limited studies have focussed on the system's acoustic performance (Weilgart, 2023), but noise reports for Borsselle 2 OWF which used the AdBm noise mitigation system and DBBC within 32 m water depth measured a max SEL of 157 dB at a distance of 752 m from the pile (Van Oord, 2020). Degraer *et al*. (2019) report on the AdBm system reducing zero to peak Sound Pressure Level (SPL) by 3 – 6 dB re 1 µPa at a distance of 750 m from five pile driving events (7.2-7.8 m diameter piles driven using a 3,500 kJ hydraulic hammer in 26 – 47 m water depth). AdBm suggest that their system should be used with a DBBC to increase the noise mitigation system's performance as hammer energies and pile sizes continue to increase (AdBm technologies, 2020).

MODELLED PILING SCENARIOS WITH NOISE ABATEMENT SYSTEMS

4.4.45. To estimate the potential level of mitigation that could be achieved by the implementation of noise abatement systems (such as those detailed in paragraph 4.4.33 *et seq*.) during piling operations in the peak herring spawning season, illustrative UWN modelling has been undertaken for the use of noise abatement systems during the piling of both the installation of anchors for floating WTGs, and the installation of pin piles for the OEP foundations. A 10dB reduction from noise abatement systems has therefore been modelled for the following illustrative piling scenarios:

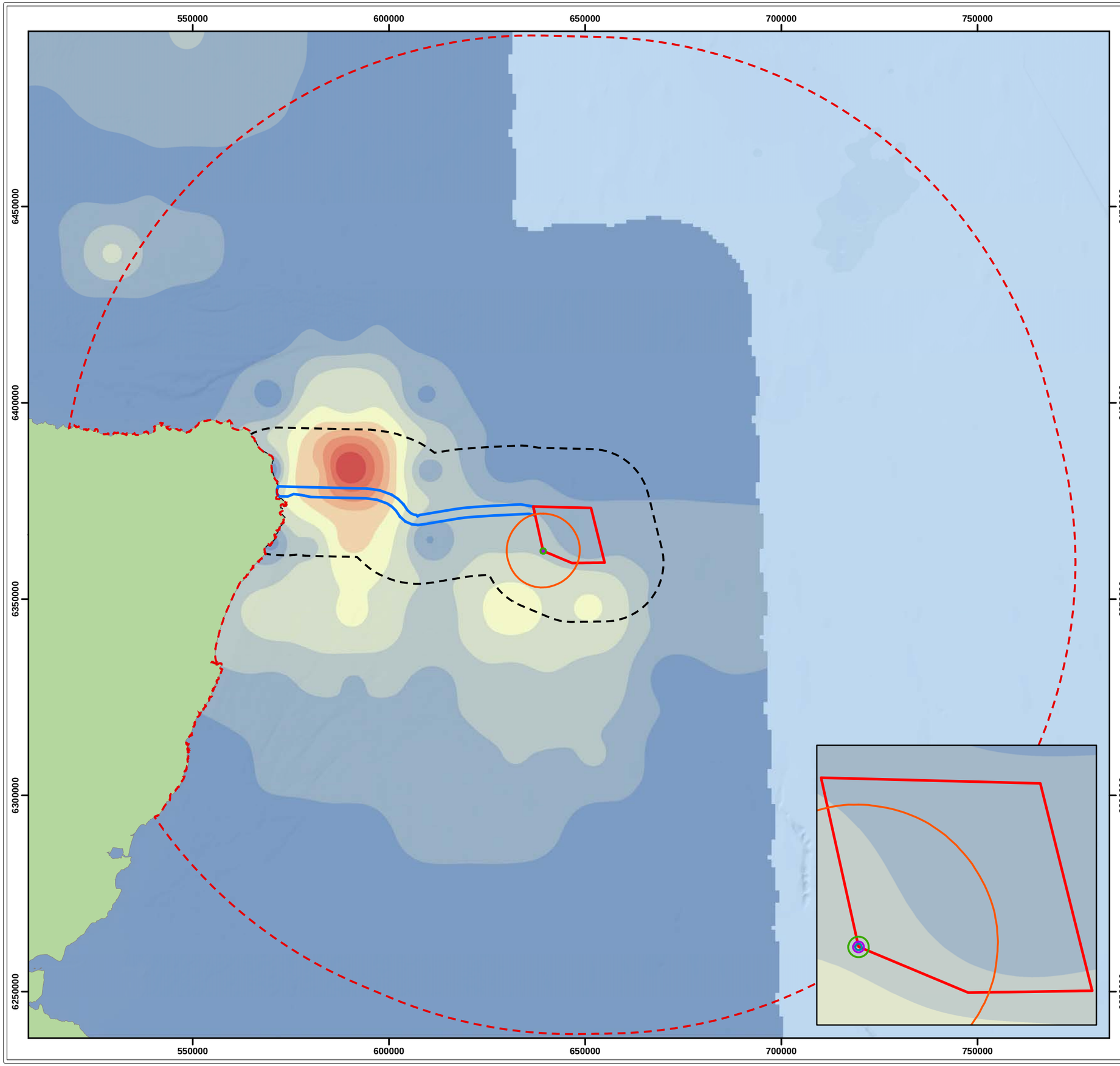
- Sequential installation of up to three anchor piles in a 24-hour period, at a single location (2m pile diameter, hammer energy 1,000 kJ) with 10dB noise reduction; and
- Installation of one pin pile in a 24-hour period, for the OEP foundations, at a single location (4m pile diameter, hammer energy 1,000kJ) with 10dB noise reduction.

4.4.46. The source level reductions predicted from the implementation of noise abatement systems have been presented in Table 4-2 below, and Figure 4-7 and Figure 4-8 where the contours are presented relative to herring larval densities (used as a proxy for herring spawning activity). The 'mitigated' UWN contours show the maximum impact ranges anticipated for the mortality and potential mortal injury (207 dB cumulative Sound Exposure Level (SEL_{cum})), recoverable injury (203 dB SEL_{cum}), and TTS (186 dB SEL_{cum}) of spawning herring (stationary Group 3 receptors (fishes with swim bladders which are involved in hearing (Popper *et al*. 2014))) from the implementation of noise abatement systems. As is evident, with a 10 dB noise abatement from the implementation of a noise abatement system, the impact contours for mortality and potential mortal injury, recoverable injury, and TTS are all mitigated to outside of any areas of moderate to high intensity herring spawning. The impact contours are also similarly mitigated to outside any areas of high intensity spawning herring from the installation of pin piles for the OEP foundations using a noise abatement system. The illustrative UWN therefore demonstrates the feasibility of using noise abatement systems (that would deliver a 10dB reduction in sound levels), to reduce impacts to spawning herring to a non-significant level.

Table 4-2 Impact ranges for spawning herring for the use of noise abatement systems during the installation of WTG anchor piles and OEP foundations.

Criteria	Noise Level (dB re 1µPa SEL/dB re 1µPa2 SEL)	Impact ranges for the alternative piling scenario for WTG anchor piles	Impact ranges for the alternative piling scenario for OEP foundations
Mortality and Potentially Mortal Injury			
SPL_{peak}	207 dB	< 50 m	80 m
SEL_{cum} (Static)	207 dB	380 m	550 m
Recoverable Injury			
SPL_{peak}	207 dB	< 50 m	80 m
SEL_{cum} (Static)	203 dB	700 m	1.1 km
TTS			
SEL_{cum} (Static)	186 dB	9.6 km	14 km

4.4.47. As stated above, further UWN modelling will be undertaken post-consent, in accordance with the preliminary project design, and piling parameters and scenarios. If the use of a noise abatement system (to achieve 10dB reduction in sound levels) successfully mitigates the potential for LSE on spawning herring, the revised UWN modelling will be added to the Final Plan, which will be submitted to MD-LOT for approval, in consultation with NatureScot for consultation.



Legend:

- Array Area
- Offshore Export Cable Corridor
- Secondary Zone of Influence
- Underwater Noise Zone of Influence

Mitigated (-10dB) Contours - Sequential Piling of Anchor Piles

- 186dB SELcum
- 207dB SELcum
- 203dB SELcum
- 210dB SELcum

IHLS Season 2011-12 to Season 2023-24
Larval abundance per m^2

- 0
- 0.1 - 1,500
- 1,500.1 - 3,500
- 3,500.1 - 5,500
- 5,500.1 - 9,500
- 9,500.1 - 14,500
- 14,500.1 - 20,000
- 20,000.1 - 26,000
- 26,000.1 - 35,000
- 35,000.1 - 45,000
- 45,000.1 - 59,000

Project:	Report:
Muir Mhòr	In Principal Mitigation Plan

Mitigated (-10dB) (Mitigation Option D) impact ranges for spawning herring from the sequential piling of anchor piles in the SW location of the array area (static receptor, 1,000 kJ hammer energy, 2 m pile diameter, up to 3 anchor piles in a 24-hour period)

Figure: 4-7	Drawing No: GoBe-0195		
Revision:	Date:	Drawn:	Checked:
01	14/11/24	EV	BPHB

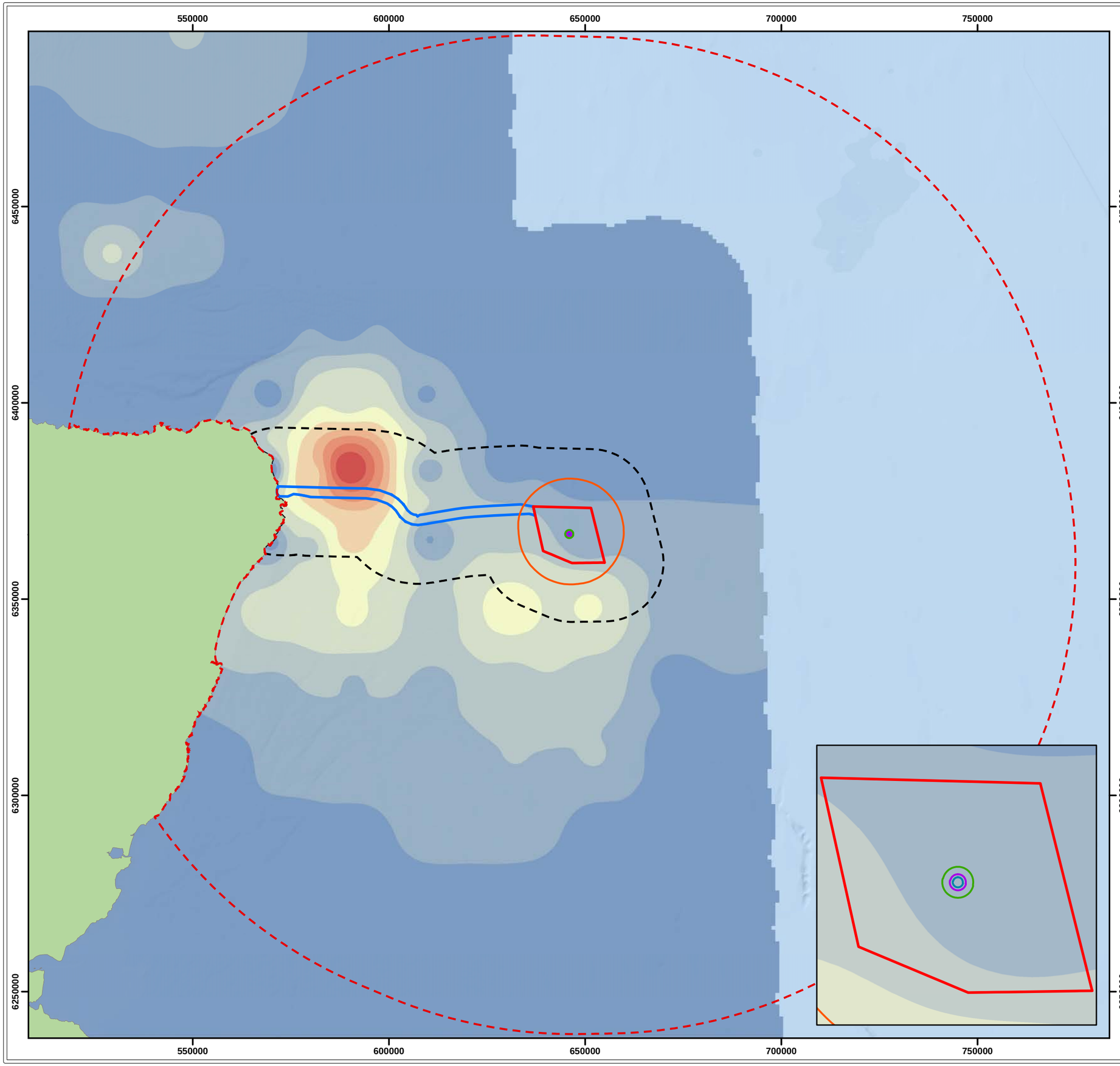
Map scale 1:950,000 @ A3

0 10 20 km

Co-ordinate system: ETRS 1989 UTM Zone 30N **EPSG:** 25830

MUIR MHÒR OFFSHORE WIND FARM
A joint venture between Fred. Olsen Seawind & Vattenfall

Service Layer Credits: Esri, Garmin, GEBCO, NOAA NGDC, and other contributors



Legend:

- Array Area
- Offshore Export Cable Corridor
- Secondary Zone of Influence
- Underwater Noise Zone of Influence

Mitigated (-10dB) Contours - Piling of OEP Pin Piles

- 186dB SELcum
- 207dB SELcum
- 203dB SELcum
- 210dB SELcum

IHLS Season 2011-12 to Season 2023-24
Larval abundance per m^2

- 0
- 0.1 - 1,500
- 1,500.1 - 3,500
- 3,500.1 - 5,500
- 5,500.1 - 9,500
- 9,500.1 - 14,500
- 14,500.1 - 20,000
- 20,000.1 - 26,000
- 26,000.1 - 35,000
- 35,000.1 - 45,000
- 45,000.1 - 59,000

Project:	Report:
Muir Mhòr	In Principal Mitigation Plan

Mitigated (-10dB) (Mitigation Option D) impact ranges for spawning herring from the piling of OEP pin piles foundations in the centre of the array area (static receptor, 2,500 kJ hammer energy, 4 m pile diameter, 1 pin pile in a 24-hour period)

Figure:	4-8	Drawing No:	GoBe-0196

Revision:	Date:	Drawn:	Checked:
01	14/11/24	EV	BPHB

Map scale 1:950,000 @ A3

0 10 20 km

Co-ordinate system: ETRS 1989 UTM Zone 30N **EPSG:** 25830

MUIR MHÒR OFFSHORE WIND FARM
A joint venture between Fred. Olsen Seawind & Vattenfall

Service Layer Credits: Esri, Garmin, GEBCO, NOAA NGDC, and other contributors

MITIGATION OPTION E: SEASONAL PILING RESTRICTION

4.4.48. As stated above, to mitigate against the potential for LSE on spawning Buchan stock herring, the Developer may seek to commit to a seasonal restriction for all piling operations in the Array Area.

4.4.49. The restriction would be proposed during the peak herring spawning period, which will be defined as per the process set out in Section 4.2.

4.4.50. This commitment will be detailed in the Final Plan, which will be submitted to MD-LOT for approval, in consultation with NatureScot for consultation.

5. MONITORING

5.1.1. Following the assessment of LSE and identification of mitigation measures, consideration will be given to the requirement for monitoring to be undertaken. The details of monitoring will be agreed with MD-LOT in consultation with NatureScot and set out in the Final Plan that will be submitted for approval to the Scottish Ministers.

5.1.2. A summary of the likely monitoring for the Proposed Development is presented in Volume 2, Chapter 21 (Summary of Embedded Commitments, Mitigation and Monitoring).

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