



Spiorad na Mara Offshore Wind Farm

Offshore Project

Environmental Impact Assessment Report

Chapter 9: Physical and Coastal Processes, Volume 2a

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9 PHYSICAL AND COASTAL PROCESSES

9.1 INTRODUCTION

9.1.1 OVERVIEW

9.1.1.1 This chapter of the Environmental Impact Assessment Report (EIAR) provides an overview of the baseline environment and the assessment of impacts from the Physical and Coastal Processes related to the activities of the proposed Spiorad na Mara Offshore Wind Farm (hereafter referred to as 'the Offshore Project').

9.1.1.2 This chapter should be read in conjunction with the Project Description provided in **Chapter 3: Project Description, Volume 1a** and the relevant parts of the following chapters which will consider whether the identified impact pathways of Physical and Coastal Processes will result in a significant effect to other sensitive receptors considered by other topics:

- **Chapter 10: Marine Sediment and Water Quality, Volume 2a;**
- **Chapter 11: Benthic and Intertidal Ecology, Volume 2a;**
- **Chapter 12: Fish Ecology, Volume 2a;**
- **Chapter 13: Marine Mammals, Volume 2a;**
- **Chapter 14: Marine and Nearshore Ornithology, Volume 2a;**
- **Chapter 15: Offshore Archaeology and Cultural Heritage (incl. array setting impacts), Volume 2a;**
- **Chapter 20: Other sea users, including recreational users, Volume 2a;**
- **Chapter 21: Commercial Fisheries, Volume 2a.**

9.1.1.3 This technical chapter describes the following:

- Legislation, planning policy and other documentation that has informed the assessment (Section 9.2: Summary of policy and legislative context);
- Outcome of the consultation and engagement that has been undertaken to date, including how matters relating to Physical and Coastal Processes have been addressed (Section 9.3: Scoping and consultation);
- Scope of the assessment for Physical and Coastal Processes (Section 9.4: Scope of the assessment);
- The methods of assessment used for baseline data gathering and impact assessment (Section 9.5: Methodology for baseline data gathering and impact assessment);
- Overall baseline (Section 9.6: Baseline conditions);
- Embedded environmental measures relevant to Physical and Coastal Processes and the relevant maximum design scenario (Section 9.7: Basis for Environmental Impact Assessment);

- Assessment of Physical and Coastal Processes likely significant effects and further mitigation (Section 9.8 - 9.10: Assessment of effects and mitigation);
- Assessment of Physical and Coastal Processes combined effects (Section 9.11);
- Assessment of Physical and Coastal Processes consideration of onshore transmission works (Section 9.12);
- Assessment of Physical and Coastal Processes cumulative effects (Section 9.13);
- Assessment of transboundary effects (Section 9.14);
- A summary of residual effects for Physical and Coastal Processes (Section 9.15: Summary of residual effects);
- Information sources and documentation referred to in this chapter (Section 9.17: References).

9.1.1.4 The chapter is supported by the following appendices and figures:

- **Appendix 9.1: Physical and Coastal Processes Modelling Calibration & Validation Report, Volume 2c.** This report details the calibration and validation exercise undertaken to confirm the validity and suitability of the hydrodynamic and spectral waves models in representing conditions at the site. The report confirms the modelling exercise is aligned with industry best practices and appropriate to use for assessment of conditions at the site both in baseline and post-development scenarios;
- **Appendix 9.2: Physical and Coastal Processes Modelling Results Report, Volume 2c.** This report details the baseline hydrodynamic, wave, and sediment transport conditions. It then uses modelling to demonstrate how baseline conditions may change due to impacts from the construction and operational phases of the Offshore Project;
- **Appendix 11.1 Subtidal Environmental Baseline Characterisation Report, Volume 2c.** This report details the results of the sub-tidal environmental baseline surveys. The particle size distribution analysis of grab samples is relevant to this chapter.
- **Figure 9-1 Study Area and Zone of Influence, Volume 2b;**
- **Figure 9-2 Designated Sites of Geological Interest relative to the Zone of Influence, Volume 2b**
- **Figure 9-3 Site bathymetry, Volume 2b;**
- **Figure 9-4 Seabed substrate, Volume 2b;**
- **Figure 9-5 Overview of seabed substrate by Folk classification, Volume 2b;**
- **Figure 9-6 Extraction sites for baseline sediment transport, Volume 2b;**
- **Figure 9-7 Dynamic Coast 2 prediction of coastal erosion susceptibility for the 2100 Future Emission Scenario, Volume 2b;**
- **Figure 9-8 Difference between surface and bed temperature in May, Volume 2b;**
- **Figure 9-9 Difference between surface and bed temperature in June, Volume 2b;**
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- **Figure 9-13 Location of Landfall Exit Pit Area, Volume 2b;**

- **Plate 2-8 Location of timeseries data extraction points, Appendix 9.2, Volume 2c;**
- **Plate 3-20 Borehole locations in geotechnical survey (Bluefield Geoservices, 2024), Appendix 9.2, Volume 2c.**

9.2 SUMMARY OF POLICY AND LEGISLATIVE CONTEXT

9.2.1.1 This section outlines the legislation, policy and guidance that is relevant to the assessment of likely significant effects on Physical and Coastal Processes associated with the construction, operation, maintenance and decommissioning of the Offshore Project. In addition, other national, regional, and local policies are considered within this assessment where they are judged to be relevant. Further information on policies relevant to the Environmental Impact Assessment (EIA) is provided in **Chapter 2: Policy and Legislative Context, Volume 1a**.

9.2.1.2 A summary of the legislative and policy relevant to Physical and Coastal Processes is provided in the **Table 9-1** which examined their relevant to the assessment.

Table 9-1 Legislation and policy in relation to physical and coastal processes

Title	Relevance to physical and coastal processes
Marine Policy	
Sectoral Marine Plan - Offshore Wind Energy (2020)	<ul style="list-style-type: none"> • Confirms Plan Options for ScotWind leasing and provides a spatial strategy for offshore wind development; • Highlights the need for this strategy to minimise the potential adverse effect on other marine users, economic sectors and the environment; • Section 4.1 lists a range of potential adverse impacts identified through plan-level Strategic Environmental Assessment (SEA), Habitat Regulations Appraisal (HRA) and Strategic Environmental Impact Assessment (SEIA) which require further consideration through project level assessments, including the following of relevance to the marine geology, oceanography and physical processes scoping assessment and EIA: <ul style="list-style-type: none"> – <i>“loss of/damage to marine and coastal habitats;</i> – <i>effects on subsea geology, sediments and coastal processes arising from changes in hydrodynamics and existing wave regimes;</i> – <i>effects on landscape and coastal characters and visual receptors”.</i>
The Water Environment (Water Framework Directive) Regulations 2017	<ul style="list-style-type: none"> • The Water Environment (Water Framework Directive) (England and Wales) Regulations 2017, transposed the European Union (EU) Water Framework Directive (WFD) into UK law, focusing on the protection and improvement of water bodies, including coastal and estuarine waters; • For offshore activities, the regulations require assessments to demonstrate that any proposed activity will not cause deterioration of water body status or prevent it from meeting its objectives;

Title	Relevance to physical and coastal processes
	<ul style="list-style-type: none"> The regulations require assessments for activities that could impact these water bodies. Requiring any marine license application, except for low-risk activities, to be accompanied by a WFD assessment.
<p>Scottish National Marine Plan (2015)</p> <ul style="list-style-type: none"> GEN 8 - Coastal process and flooding GEN 9 - Natural Heritage GEN 21 - Cumulative Impacts 	<ul style="list-style-type: none"> GEN 8 provides guidance for how developments and activities in the marine environment should be resilient to coastal change and flooding and not have unacceptable adverse impact on coastal processes or contribute to coastal flooding; GEN 9 requires development to comply with legal requirements for protected areas; not to result in significant impact on the national status of Priority Marine Features (PMFs) (which includes geodiversity features); and to protect, and, where appropriate, enhance the health of the marine area; GEN 21 requires cumulative impacts affecting the ecosystem to be addressed.
<p>UK Marine Policy Statement (2011)</p>	<ul style="list-style-type: none"> Sets out high-level objectives for the marine space, including achieving a sustainable marine economy and identifies a wide range of relevant marine uses; Requires that the use of the marine environment benefits society as a whole, contributing to resilient and cohesive communities that can adapt to coastal erosion and flood risk, as well as contributing to physical and mental wellbeing; Requires use of the marine environment and its resources to maximise sustainable activity, prosperity and opportunities for all; States that offshore wind farm (OWF) fixed bottom foundation designs are likely to influence hydrodynamics and consequent sediment movement.

9.2.2 TECHNICAL GUIDANCE

9.2.2.1 This section outlines the technical guidance that is relevant to the assessment of likely significant effects on Physical and Coastal Processes associated with the construction, operation and maintenance (O&M) and decommissioning of the Offshore Project.

9.2.2.2 This guidance has been used to help assess the adequacy of metocean data used to inform the assessment, inform set-up, calibration and validation of the numerical wave model which was developed (see **Appendix 9.1, Volume 2c**).

9.2.2.3 Technical guidance that has been used to define the assessment is set out in **Table 9-2**.

Table 9-2 Relevant technical guidance

Guidance reference	Relevance to the Assessment
Environmental impact assessment for offshore renewable energy	Provides a summary of marine physical process impact pathways, potential assessment methods and tools. Also provides guidance on the development of impact assessment matrices. The potential impact assessment pathways

Guidance reference	Relevance to the Assessment
projects (British Standards Institute (BSI), 2015)	identified in this guidance are all considered later in this document, within the likely significant effects section.
Guidelines for Data Acquisition to Support Marine Environmental Assessments of Offshore Renewable Energy Projects (CEFAS, 2012)	These guidelines assist in the design, review and implementation of environmental data collection and analytical activities associated with all stages of offshore renewable energy developments. There is a specific section covering 'physical and sedimentary process studies', setting out guidance on data acquisition and adequacy, survey design and impact assessment techniques (including modelling).
Coastal Process Modelling for Offshore Wind farm Environmental Impact Assessment: Best Practice Guide (ABPmer and HR Wallingford 2009)	This report provides an update to existing best practice guidance on the application and use of numerical models to predict the potential impact from OWFs on physical and coastal processes. As such, it provides guidance on the scoping and design stages of the coastal processes part of an EIA, as well as on the requirements for numerical modelling, and how to assess the extent and quality of numerical modelling work proposed and undertaken.
Guidelines in the use of metocean data through the lifecycle of a marine renewables' development (CIRIA, 2008)	This guide has been developed to identify and recommend on the uses of metocean data through the life cycle of a marine renewable energy development. It includes a review of metocean data types, data sources and identifies the importance of good data management.
Offshore Windfarms: Guidance note for Environmental Impact Assessment in Respect of FEPA and CPA requirements (CEFAS, 2004)	This guidance provides scientific guidance to those involved with the gathering, interpretation and presentation of data within an EIA. The marine physical process parameters which require assessment are set out and divided into direct and indirect impacts, with guidance also given regarding the key parameters which need documenting in the marine processes baseline. Recommendations for mitigation and monitoring are also set out.
Review of Environmental data associated with post-consent monitoring of licence conditions of offshore wind farms (MMO, 2014)	<p>This report reviews the results and findings from monitoring programs conducted to fulfil statutory obligations placed on developers of OWFs in UK waters through consent conditions.</p> <p>It details how to conduct an evaluation of post-consent monitoring data and develop a set of recommendations to enhance future monitoring efforts, ensuring data collection focuses on areas with the greatest risks and uncertainties.</p>

Guidance reference	Relevance to the Assessment
Guidance on Best Practice for Marine and Coastal Physical Processes Baseline Survey and Monitoring Requirements to Inform EIA of Major Development Projects (Brooks <i>et al.</i> , 2018)	<p>This report offers guidance on baseline survey and monitoring requirements for EIAs related to marine, coastal, and estuarine physical processes in major development projects.</p> <p>This has been accomplished by reviewing existing published guidance pertinent to physical processes in EIA studies, analysing project examples (encompassing both planned and operational developments), and drawing on the authors' experience gained from involvement in large-scale marine projects. For the major developments outlined, pathways for change and potential impacts have been determined for each stage of development (construction, operation, and decommissioning). Efforts have been made to qualitatively assess the potential magnitude of these changes and identify the development types and stages where they are likely to be most significant.</p>

9.3 SCOPING AND CONSULTATION

9.3.1 OVERVIEW

9.3.1.1 This section describes the stakeholder engagement undertaken for the Offshore Project. This consists of early engagement including the outcome of, and response to, the Scoping Opinion in relation to the Physical and Coastal Processes assessment. Informal consultation and consultation undertaken through the Preliminary Application Consultation (PAC) process (hereafter referred to as the 'formal consultation'). An overview of engagement undertaken for the Offshore Project as a whole can be found in **Chapter 5: Approach to EIA, Volume 1a** and **Appendix 5.4: Stakeholder Consultation and Engagement, Volume 1c**.

9.3.1.2 Consultation is a key feature of the EIA process and continues throughout the lifecycle of the Offshore Project, from the initial stages through to consent and post consent.

9.3.1.3 Consultation includes all consultation and engagement with prescribed and non-prescribed consultation bodies and local authorities in relation to Physical and Coastal Processes. All consultation to date has been undertaken in line with the process described in **Chapter 5, Volume 1a** and **Appendix 5.4, Volume 1c**. Feedback received during this process has been incorporated into the EIAR wherever possible as appropriate.

9.3.2 EARLY ENGAGEMENT

9.3.2.1 Early engagement, pre-scoping, was undertaken with several consultation bodies in relation to Physical and Coastal Processes. In accordance with Marine Directorate Licensing Operations Team (MD-LOT) guidance, the Applicant held formal scoping workshops in May and June 2023 to inform the Scoping Report. Further details of the consultation undertaken and the post-workshop

feedback can be found in Section 5.3 and Table 5.3-1 of the Scoping Report (Sporad na Mara Limited, 2023).

Scoping Opinion

- 9.3.2.2 Sporad na Mara Limited (hereafter referred to as 'the Applicant') submitted a Scoping Report (Sporad na Mara Limited, 2023) and request for a Scoping Opinion to the MD-LOT in September 2023. A Scoping Opinion was received in May 2024. The Scoping Report set out the proposed Physical and Coastal Processes assessment methodologies, outline of the baseline data collected to date and proposed, and the scope of the assessment. The comments received in the Scoping Opinion and how these have been addressed in this EIAR is provided in in **Appendix 5.2: Response to Scoping Opinion, Volume 1c**.
- 9.3.2.3 A summary of the comments received and the respective responses relevant to Physical and Coastal Processes is shown in **Table 9-3**. Consideration has also been given to other stakeholder comments that were received in relation to Physical and Coastal Processes in the Scoping Report, which are further included in **Table 9-3**.

Table 9-3 Scoping Opinion responses – Physical and Coastal Processes

Consultee	Date/Document	Comment	Response/where this is addressed in the EIAR
Urras Sgìre Oighreachd Bharabhais Community Company	Scoping Opinion, May 2024	Additional studies should be undertaken to look at coastal erosion and displacement along coastline near turbine construction.	<p>Site surveys that have been undertaken and used to inform the Physical and Coastal Processes assessment are summarised in Table 9-7.</p> <p>The potential impact(s) on coastal change are assessed in this chapter, with disturbed sediment and any change in hydrodynamic conditions being considered as potential drivers for coastal erosion or accretion. Disturbed sediment from construction activities has been modelled, the results of which are discussed in Appendix 9.1, Volume 2c. The magnitude/extent of changes to the wave and current fields associated with the Offshore Project and potential impact on the coastline are analysed and reported for all stages of the Offshore Project (see Section 9.8. 9.9 and 9.10).</p>
NatureScot	Scoping Opinion, May 2024	<p>For physical and coastal processes, unfortunately we are unable to provide any specific advice in respect of the landfall or wider physical processes due to staff resourcing.</p> <p>We guide the developers to the following resource – Dynamic Coast 2 which may be of assistance when designing the landfall and associated infrastructure.</p>	The Dynamic Coast 2 is considered in Section 9.6.2, 9.6.2.37 and 9.6.2.39 as part of analysis for coastline erosion and areas related to designing the landfall and associated infrastructure as noted by NatureScot.

Consultee	Date/Document	Comment	Response/where this is addressed in the EIAR
Marine Directorate – Science, Evidence, Data and Digital (MD-SEDD)	Scoping Opinion, May 2024 – Dated January 2024	<p>In response to the following Scoping Report question “1. Do you agree that the data sources identified, and surveys proposed are sufficient to inform the Physical and Coastal Processes baseline for the EIA?”</p> <p>MD-SEDD advise the use of existing 3D model output to describe the physical water column in the Study Area. Daily mean (or hourly) output of temperature and salinity should be used to describe stratification (magnitude, extent, timing) and hourly current speed data should be used to describe flow conditions. The northwest European shelf reanalysis model runs available on Copernicus Marine (e.g. https://doi.org/10.48670/moi-00059 and https://doi.org/10.48670/moi-00054), or Scottish Shelf Model (https://marine.gov.scot/themes/scottish-shelf-model) would be sensible model choices. Note there is a climatology available from the Scottish Shelf Model (widely used by the aquaculture industry) which could be used, but there is also a 27 year reanalysis available from the Scottish Shelf Waters Reanalysis Service (https://tinyurl.com/SSW-Reanalysis) that can be used to study inter-annual variability (and</p>	<p>As detailed in Appendix 9.1, Volume 2c Table 9-7, a suite of deployments within the Array Area were carried out to collect metocean and wind data to develop/inform the model. Data specifically collected included wind, currents, meteorological, waves, conductivity, temperature, depth, near-full water column currents and near bed currents providing a full picture of the water column in the Study Area. Stratification within the Study Area is described in Section 9.6.2.</p>

Consultee	Date/Document	Comment	Response/where this is addressed in the EIAR
		how this might compare with potential impacts).	
MD-SEDD	Scoping Opinion, May 2024 – Dated January 2024	<p>In response to the following Scoping Report question “2. <i>Have all receptors and potential likely significant effects that could result from the Project been identified? (Noting that the majority of effects discussed within the chapter will be pathways that will be used to inform other chapters)</i>”</p> <p>The potential impacts identified in Table 6.1 - 3 of the Scoping Report, are all relevant and should be scoped into the EIA. The impacts all appear to focus on impacts to bed sediments, e.g. bed morphology changes and sediment transport. MD-SEDD advise that water column and wave processes should also be considered for the operational phase. MD-SEDD advise that potential change to the wave field should be considered in the EIA, as should potential change to mixing, stratification and frontal positions. The scoping report examines frontal positions and stratification, and this should be built on in the EIA. MD-SEDD advise the site appears be in an intermittently stratified region, and the wind farm is unlikely to significantly change stratification (extent,</p>	<p>As noted, the physical and coastal processes effects predominantly comprise the pathways used to inform other chapters (e.g. benthic ecology). For example, O&M impacts to the wave and current fields associated with the Offshore Project are defined using hydrodynamic and spectral wave models.</p> <p>Impacts relating to the seabed morphology and sediment transport have been initially assessed using semi-quantitative methods (e.g. spreadsheet methods described in Appendix 9.2, Volume 2c). A hydrodynamic model coupled with sediment transport modules is also used to define operational phase impacts associated with sediment transport.</p> <p>Construction and decommissioning impacts are assessed using a hydrodynamic model to drive the sediment transport model. This is used to assess the potential extent of construction phase impacts, e.g. the fate of marine sediments released during cable routing, turbine and horizontal direction drilling (HDD) exit pit installation. The results of the construction phase modelling are presented as extent plots for spring tide excursion ellipses, which have the potential to transport liberated sediments furthest from the source.</p> <p>See Section 9.8 and 9.10 of this EIAR and model results are included in Appendix 9.2, Volume 2c.</p>

Consultee	Date/Document	Comment	Response/where this is addressed in the EIAR
		<p>timing and magnitude) compared to natural variability and projected climate driven changes, but this should be assessed in the EIA non-the-less.</p>	<p>The daily temperature and salinity data throughout the water column has been used to assess seasonal stratification extents in the Study Area as defined in Section 9.4.2.</p>
MD-SEDD	<p>Scoping Opinion, May 2024 – Dated January 2024</p>	<p>In response to the following Scoping Report question “3. Do you agree with the proposed approach to assessment, and the methods specified are acceptable for the Project?”</p> <p>MD-SEDD consider the proposed approaches outlined in Section 6.1.6.4 of the Scoping Report, to be broadly proportionate but request further information in the following to enable a better understanding and determine if the methods specified are acceptable.</p> <ul style="list-style-type: none"> • MD-SEDD request more information be supplied on the “semi-qualitative assessment of wave and sediment transport...”. For example how are the numerical models being used, and is the proposed wind farm being modelled? • Are the spreadsheet based tools for modelling the sediment plumes arising from construction able to model the directional dispersion of sediment, e.g. can this method be 	<p>The semi-qualitative assessment of wave and sediment transport comprises analysis of the bed sediment physical properties (e.g. d_{50}) and the potential for tidal and wave induced currents to mobilise and transport the sediment in suspension. The equations consider the critical bed shear stresses and threshold deposition velocities for suspended sediments.</p> <p>The semi-quantitative method (spreadsheet based) results showed potential sediment transport, therefore, the coupled hydrodynamic/sediment transport models have been used to better understand and define the potential impacts including the directional dispersion of sediment.</p> <p>See Section 9.8 and 9.10 of this EIAR and model results included in Appendix 9.2, Volume 2c.</p>

Consultee	Date/Document	Comment	Response/where this is addressed in the EIAR
		used to predict changes in bed sediment composition in areas of importance to benthic ecology?	
MD-SEDD	Scoping Opinion, May 2024 – Dated January 2024	<p>In response to the following Scoping Report question “4. Do you agree that the embedded mitigation measures described provide a suitable means for managing and mitigating the relevant potential effects of the Project on key receptors? Are there any additional mitigation measures you would include?”</p> <p>MD-SEDD agrees with the embedded mitigation measures proposed.</p>	Embedded mitigation measures are detailed in Section 9.7.2.
Bernera Community Council	Scoping Opinion, May 2024	At our recent community council meeting it was highlighted that the scoping report appears to use desktop survey information/data that does not appear to be accurate or underestimates the severity of the weather conditions on the west side where N4 development is proposed. We advise that waves can reach over 100m in bad storms, which is far greater than the 60m suggested or the 20m recorded previously. We note that the North Atlantic Sea swell will have a significant impact and other windfarm sites elsewhere on the Scottish coasts do not face these conditions. Likewise, the bedrock on the ocean	<p>Since the Scoping Report, a metocean survey campaign has been completed to obtain measured wave data between October 2023 – October 2024. The largest significant wave height recorded during this period was 9.75 m.</p> <p>In addition, measured wave data from the CEFAS WaveNet site located approximately 300 km offshore of the Outer Hebrides/<i>Na h-Eileanan Siar</i> was downloaded. The maximum recorded significant wave height between 2006 and 2024 is 15.9 m.</p> <p>The Scoping Report states that extreme value analysis predicts total sea Hs waves in the region reaching a height of 17.3 m</p>

Consultee	Date/Document	Comment	Response/where this is addressed in the EIAR
		<p>floor is granite – some of the oldest and most ancient rock in the world - and will be impractical to drill through.</p>	<p>with a 100-year return period, 15.1 m with a 10-year return period, and 12.8 m with a 1-year return period.</p> <p>During the EIA, wave data has been analysed to determine extreme wave conditions to be used in the assessment. See Section 9.6.2.14 of this EIAR Chapter and the Extreme Values Analysis in Appendix 9.2, Volume 2c.</p> <p>During the EIA the geology and sediment of the Offshore Project Boundary has been analysed to determine where hard substrate exists to be used in the assessment. See Section 9.6 of this chapter and the Baseline Characterisation in Appendix 9.2, Volume 2c.</p>
MD-LOT	Scoping Opinion, May 2024	<p>The Scottish Ministers direct the Developer to the MD-SEDD advice dated 22 January 2024 on recommended models for physical processes and advise these should be considered and incorporated into the EIA Report. Furthermore, the Scottish Ministers, in line with the NatureScot representation, direct the Developer to the Dynamic Coast 2 resource to assist in finalising the design of the Offshore Proposed Development.</p>	<p>The Dynamic Coast 2 is considered as part of analysis for coastline erosion and areas related to designing the landfall and associated infrastructure as noted by NatureScot.</p>
MD-LOT	Scoping Opinion, May 2024	<p>With regard to baseline characterisation, the Scottish Ministers acknowledge the use of the datasets and site-specific data to inform the EIA Report. The Scottish Ministers advise, in</p>	<p>Surveys that have been undertaken and used to inform the Physical and Coastal Processes assessment are summarised in Table 9-7. Disturbed sediment from construction activities has</p>

Consultee	Date/Document	Comment	Response/where this is addressed in the EIAR
		line with the Barvas Estate Trust representation, the inclusion of additional studies into coastal erosion and displacement along the coastline closest to the area of the Proposed Development.	been modelled, the results of which are discussed in Appendix 9.1, Volume 2c . The potential impact(s) on coastal change are assessed in this chapter. The magnitude/extent of changes to the wave and current fields associated with the Offshore Project and potential impact on the coastline are analysed and reported for all stages of the Offshore Project (see Sections 9.8, 9.9 and 9.10).
MD-LOT	Scoping Opinion, May 2024	The Scottish Ministers are broadly content with the potential likely significant effects scoped in as summarised in Table 6.1-3 of the Scoping Report, however, note this focus on impacts to bed sediments. The Scottish Ministers advise considering water column and wave processes for the operational phase of the Offshore Proposed Development, specifically the potential of a change to mixing, stratification and frontal positions. Section 6.1.3.10 of the Scoping Report references stratification. As the Offshore Proposed Development lies within an intermittently stratified region, the Scottish Ministers advise this should be further assessed in the EIA Report. This is in line with the MD-SEDD advice dated 22 January 2024.	As detailed in Table 9-7 , a suite of deployments within the Array Area were carried out to collect metocean and wind data. Data specifically collected included wind, currents, meteorological, waves, conductivity, temperature, depth, near-full water column currents and near bed currents providing a full picture of the water column in the Study Area. Baseline conditions of stratification and wave processes within the Study Area are described in Section 9.6. Consideration of the water column and wave processes during the O&M Phase of the Offshore Project is covered in Section 9.9.
MD-LOT	Scoping Opinion, May 2024	The Scottish Ministers cannot provide specific advice on the proposed approach to assessment for physical processes as there is a	The advice provided by MD-SEDD, and responses to it, are captured in this table.

Consultee	Date/Document	Comment	Response/where this is addressed in the EIAR
		<p>lack of detail contained within the Scoping Report. The Developer is directed to the MD-SEDD advice dated 22 January 2024 and advised to include the requested information within the EIA Report.</p>	

9.3.3 POST SCOPING OPINION CONSULTATION

9.3.3.1 Following the receipt of the Scoping Opinion, further consultation relating to Physical and Coastal Processes has been held with stakeholders. A summary of this consultation is detailed in **Table 9-4**.

Table 9-4 Summary of post scoping opinion consultation

Consultee	Date/Document	Comment	Response/where this is addressed in the EIAR
NatureScot	Email consultation with NatureScot, October 2024	<p>We have worked through the Coastal Processes Modelling Calibration & Validation Report (Northland Power Aug 2024) for Sporad na Mara OWF. We are content with the details on data, and on validation of the modelling method for both tidal currents and waves.</p> <p>However, in similar consultations for previous OWFs, calibration and validation have been only part of the post-scoping technical report on modelling. In particular:</p> <p>A. It is important to translate the 'generic' validation into what it means for the impact assessment of the actual proposals. Therefore, we would welcome further written discussion, for those aspects of the model that are less well calibrated (e.g. identified in the report as less than "very good" for goodness-of-fit), of whether this has implications for the impact assessment. It is not unusual that the model has less 'fit' for extremes of tidal and wave behaviour, but it is mostly such extremes that have greatest potential to effect physical changes, whether at the seabed or at the coast.</p> <p>If further written discussion is included in an amendment to the current report, we would be happy to comment. However, we are also content if it is part of the EIA.</p> <p>B. The EIA should not interpret the modelling results only in isolation but</p>	<p>The points provided from NatureScot, dating back to October 2024, have been considered in the development of the technical memo from the time of review as it has evolved into Appendix 9.1, Volume 2c, as well as throughout the general considerations and conclusions presented in this chapter and accompanying Appendix 9.2, Volume 2c.</p> <p>Regarding Point A, Appendix 9.1, Volume 2c, includes text addressing the implications of goodness of fit on impact assessment and model validity.</p> <p>Regarding Point B, consideration was given to similar OWF's from which comparisons could be drawn when developing our scope and methodology. These included Caledonia, Rampion 2, and West of Orkney.</p> <p>Regarding point C, the methodology for assessment of potential impacts to sediment transport as a result of the Offshore Project are considered across all phases of the Offshore Project in</p>

Consultee	Date/Document	Comment	Response/where this is addressed in the EIAR
		<p>should also draw on and compare with other available assessments and research, including for other OWFs that are sufficiently similar.</p> <p>C. The report doesn't mention anything on the assessment of potential impacts to sediment transport. The May 2023 Physical Processes Briefing Note (p17) specified semi-quantitative assessment of sediment transport effects, and we are content with this. Should the developer want to submit further details pre-EIA we would be happy to comment.</p> <p>D. In the EIA, we advise that the modelling results should be presented through both written discussion, and 'heat maps' of change using colour scales that maximise ease of interpretation.</p>	<p>Sections 9.8, 9.9 and 9.10 and in Appendix 9.2, Volume 2c.</p> <p>Regarding point D, modelling results are presented Section 4 in Appendix 9.2, Volume 2c which includes heat map figures.</p>

9.4 SCOPE OF THE ASSESSMENT

9.4.1 OVERVIEW

9.4.1.1 This section sets out the scope of the EIA assessment for Physical and Coastal Processes. This scope has been developed as the Offshore Project design has evolved and responds to consultation as set out in Section 9.3.

9.4.1.2 The Physical and Coastal Processes topic specific receptors are discussed within this section; however, it must be noted that the physical processes listed are not, themselves, receptors, but impact pathways that result in a potential receptor effect to be considered by other technical topic assessments (see Section 9.11 for further details).

9.4.2 SPATIAL SCOPE AND STUDY AREA

9.4.2.1 The Physical and Coastal Processes Chapter identifies and assesses receptors and impact pathways identified to occur below Mean High Water Springs (MHWS), with the topic-specific study area varying dependent on the nature and scale of each physical process or pathway that could result in a receptor effect. The Array Area and Offshore Cable Area of Search (OCAS) will be considered as the primary (or near-field) footprint for potential direct physical impacts on Physical and Coastal Processes receptors.

9.4.2.2 However, understanding the dominant influences for the area is key and, as such, this may need to include the footprint of the predominant wave spectra and storm events within a secondary zone of influence (ZOI), also known as far-field footprint. The ZOI of the potential impacts assessment is limited to the spatial extent over which any likely significant effects may occur. This extent is based on the understanding of likely effects, established from baseline investigations and assessment work. The ZOI is defined by a peak spring tidal excursion ellipse, equal to an approximate 6 km offset from the Array Area and OCAS.

9.4.2.3 Together, the near-field and far-field, which comprise the extents of the ZOI, will form the Wider Physical and Coastal Processes Study Area (hereafter the 'Study Area') as shown in **Figure 9-1, Volume 2b**.

9.4.3 TEMPORAL SCOPE

9.4.3.1 The temporal scope of the assessment of Physical and Coastal Processes is the entire lifetime of the Offshore Project, which therefore covers the construction, O&M, and decommissioning phases. The construction phase is anticipated to be between 2028/2029 and 2032/2033, with works being undertaken between April and October each year. The operational lifetime of the Offshore Project will be up to 35 years with maintenance assumed to take place throughout, and decommissioning to take place at the end of life.

9.4.4 POTENTIAL RECEPTORS

9.4.4.1 Whilst Physical and Coastal Processes can largely be considered as impact pathways on other sensitive receptors associated with non-physical and coastal processes receptor groups, Physical and Coastal Processes receptors have been identified and assessed accordingly.

9.4.4.2 The spatial and temporal scope of the assessment enabled the identification of potential Physical and Coastal Processes receptors which may experience a change as a result of the Offshore Project.

9.4.4.3 The main receptor groups identified that may experience likely significant effects for Physical and Coastal Processes are:

- The surrounding coastline (coastline landward of Mean Low Water Springs (MLWS) to MHWS);
- The surrounding sub-tidal seabed (seabed offshore of MLWS to Study Area seaward boundary);
- Designated sites of geological interest (the North-West Coast of Lewis Geological Conservation Review (GCR) Site).

9.4.4.4 These physical and coastal processes receptors represent the corresponding key receptors identified in the Scoping Report. A comparison of the terminology used to describe the key receptors defined in the EIA versus the *Scoping Report* is outlined below:

- The surrounding coastline is equivalent to; "*potential changes in morphology at the coast*";

- The surrounding sub-tidal seabed is equivalent to; *"potential changes in morphology of offshore morphological features (including moraines)"*;
- Designated sites of geological interest is equivalent to; *"changes affecting designated site"*.

9.4.5 ACTIVITIES OR IMPACTS SCOPED INTO ASSESSMENT

- 9.4.5.1 The Physical and Coastal Processes receptors that have been scoped in for the assessment were identified in relation to the project related activities for the construction, O&M, and decommissioning phases of the Offshore Project as detailed in the Project Description provided in **Chapter 3, Volume 1a**.
- 9.4.5.2 During the Construction Phase the activities scoped in included the drilling of pin piles to install Wind Turbine Generator (WTG) and foundations, the burial of Array Cables to Final WTG and Array Cables to Landfall, the drill cutting release from HDD, and the construction of HDD exit pits.
- 9.4.5.3 During the Operational Phase the long-term placement of subsea structures on the seabed (e.g. WTG foundations and scour protection) may result in changes in seabed morphology and tidal currents.
- 9.4.5.4 During the Maintenance Phase the activities scoped in included remedial works to the cables, scour protection or foundations.
- 9.4.5.5 During the Decommissioning Phase the activities scoped in included the removal of Turbine foundation and their pin piles, and the removal of Array Cables to Final WTG and Array Cables to Landfall.
- 9.4.5.6 The activities scoped into the assessment are detailed in **Table 9-5**, along with the corresponding physical processes, which in this case are impact pathways that can result in a potential receptor effect for other topics as listed Section 9.1.1.2.
- 9.4.5.7 When considering the physical processes related to the project activities, there is first the potential to disturb seabed sediment which can be mobilised into the water column ("Sediment Disturbance"), transported, and deposited elsewhere causing changes to the seabed ("Seabed Change"). Secondly, there is the potential for effects related to the presence of offshore wind turbine structures causing potential changes to hydrodynamics (water levels and current speeds), seabed (scour), waves, and stratification.
- 9.4.5.8 Therefore, the physical processes (impact pathways) in the impact assessment are categorised under Sediment Disturbance, Seabed Change or Effects Related to the Presence of Infrastructure.

Table 9-5 Activities and impact pathways scoped into the assessment for Physical and Coastal Processes

Receptor	Activity	Physical Processes Impact Pathway
Construction		
Surrounding Coastline	<p>Cable installation Disturbance of the seabed arising from construction activities (such as, seabed preparation, cable laying via open cut trenching, ploughing, jet trenching, rock cutting) at landfall locations resulting in disturbance of the nearshore seabed.</p>	<p>Sediment Disturbance and Seabed Change Physical disturbance to the nearshore seabed has the potential to mobilise sediment or cause localised changes to sediment transport.</p>
	<p>HDD Drill Cutting Release and HDD Exit Pit Construction Trenchless techniques (such as HDD) may be used to install cables at landfall during the construction phase. In addition, construction of the HDD Exit Pits will require excavation of sediments. Trenchless activities and excavation have the potential to release drilling fluid, muds and very low levels of bentonite into the water column and mobilise sediment into the water column, respectively.</p>	<p>Sediment Disturbance and Seabed Change Temporary release of drilling fluid mud, drilling arisings and/or bentonite into the water column and subsequent sedimentation. Physical disturbance to the seabed has the potential to temporarily increase suspended sediment concentrations and sediment deposition from mobilised sediment.</p>
Surrounding sub-tidal seabed	<p>Installation of WTG foundations Turbine installation resulting in disturbance of the seabed arising from construction activities, such as drilling of jacket pile foundations.</p>	<p>Sediment Disturbance and Seabed Change Physical disturbance to the seabed has the potential to temporarily increase suspended sediment concentration and sediment deposition from mobilised sediment.</p>
	<p>Cable installation Disturbance of the seabed arising from construction activities (such as, seabed preparation, cable laying via open cut trenching, ploughing, jet trenching, rock cutting).</p>	
	<p>HDD Drill Cutting Release and HDD Exit Pit Construction Trenchless techniques (such as HDD) may be used to install cables at landfall during the construction phase. In addition, construction of the HDD Exit Pits will require excavation of</p>	<p>Sediment Disturbance and Seabed Change Temporary release of drilling fluid mud, drilling arisings and/or bentonite into the water column and subsequent sedimentation.</p>

Receptor	Activity	Physical Processes Impact Pathway
	sediments. Trenchless activities and excavation have the potential to release drilling fluid, muds and very low levels of bentonite into the water column and mobilise sediment into the water column, respectively.	Physical disturbance to the seabed has the potential to temporarily increase suspended sediment concentrations and sediment deposition from mobilised sediment.
Designated sites of geological interest	Installation of WTG foundations, Cable Installation and HDD Drill Cutting Release and HDD Exit Pit Construction Disturbance of designated site of geological interest arising from construction activities as listed above.	Sediment Disturbance and Seabed Change Subsequent sediment deposition from temporary increases in suspended sediment concentrations generated by construction activities could cause accretion of sediment to the geology of designated sites of geological interest.
Operation and maintenance		
Surrounding Coastline	Presence of Infrastructure WTG Foundations causing changes to the hydrodynamic regime (i.e. blockage effects impacting water depths, current speeds, scour, waves and stratification).	Effects Related to the Presence of Infrastructure Alteration to the wave conditions, baseline sediment transport regime resulting in changes to erosion/accretion rates at the surrounding coastline.
	Maintenance of infrastructure Disturbance of the seabed arising from maintenance activities (such as cable remedial works).	Sediment Disturbance and Seabed Change Physical disturbance to the nearshore seabed has the potential to mobilise sediment or cause localised changes to sediment transport.
Surrounding sub-tidal seabed	Presence of infrastructure The long-term placement of subsea structures on the seabed may result in changes in seabed morphology and tidal currents, causing localised scouring in these areas.	Seabed Change Scour around turbine bases resulting in geomorphological changes to the seabed.
	Maintenance of infrastructure Disturbance of the seabed arising from maintenance activities (such as cable remedial works).	Sediment Disturbance and Seabed Change Temporary increase in Suspended Sediment

Receptor	Activity	Physical Processes Impact Pathway
		Concentration (SSC) and potential for sedimentation.
Designated site of geological interest	Maintenance of infrastructure Disturbance of designated site of geological interest arising from maintenance activities associated with the project infrastructure listed above.	Sediment Disturbance and Seabed Change Subsequent sediment deposition from temporary increases in suspended sediment concentrations from maintenance activities could cause accretion of sediment to the geology of designated sites of geological interest.
	Presence of infrastructure WTG Foundations causing changes to the hydrodynamic regime (i.e. blockage effects impacting water depths, current speeds, scour, waves and stratification).	Effects Related to the Presence of Infrastructure Alteration of wave conditions or sediment transport patterns could cause increased erosion or other damage to the geology of designated sites of geological interest.
Decommissioning		
Surrounding Coastline	Removal of cables Disturbance of the nearshore seabed in the OCAS arising from cable removal.	Sediment Disturbance and Seabed Change Physical disturbance to the nearshore seabed has the potential to mobilise sediment or cause localised changes to sediment transport.
Surrounding sub-tidal seabed	Removal of WTG foundations Turbine foundation removal resulting in disturbance of the seabed.	Sediment Disturbance and Seabed Change Physical disturbance to the seabed has the potential to temporarily increase suspended sediment concentration and sediment deposition from mobilised sediment.
	Removal of cables Disturbance of the seabed in the Array Area arising from infrastructure removal.	
	Removal of HDD Exit Pits Disturbance of the seabed in the OCAS arising from infrastructure removal.	

Receptor	Activity	Physical Processes Impact Pathway
		sediment deposition from mobilised sediment.
Designated sites of geological interest	Removal of WTG Foundations, cables and HDD Exit Pits Disturbance of designated site of geological interest arising from decommissioning activities as listed above.	Sediment Disturbance and Seabed Change Subsequent sediment deposition from temporary increases in suspended sediment concentrations generated by decommissioning activities could cause accretion of sediment to the geology of designated sites of geological interest.

9.4.6 ACTIVITIES OR IMPACTS SCOPED OUT OF ASSESSMENT

- 9.4.6.1 The potential for transboundary impacts to Physical and Coastal Processes receptors has been scoped out of further assessment. As the Offshore Development Area of Search resides within Scottish territorial waters and there is no potential for transboundary impacts to Physical and Coastal Processes receptors as a result of construction, operation (and maintenance) and decommissioning activities, transboundary effects are not assessed (see Section 9.14).
- 9.4.6.2 Potential impacts from scour have not been assessed as scour protection will be included as part of the project design (see **Chapter 3, Volume 1a**) to prevent localised seabed change around the turbine foundations and cables, and therefore no further assessment is required.
- 9.4.6.3 No other the potential environmental impacts have been scoped out of the Physical and Coastal Processes Report assessment.

9.5 METHODOLOGY FOR BASELINE DATA GATHERING AND IMPACT ASSESSMENT

9.5.1 MODELLED DATA

- 9.5.1.1 The main aim of the Physical and Coastal Processes assessment is to characterise and understand the baseline environment in order to characterise the magnitude of impact on the physical processes (impact pathways) associated with the project activities, and subsequently the significance of effect on the Physical and Coastal Processes receptors, particularly with respect to the metocean regime and any associated sediment transport regimes. This has then been used to inform the assessment of the magnitude of impact and significance of effect on receptors in other chapters.

- 9.5.1.2 Physical processes baseline characterisation of water depth, depth-averaged current speed and bed shear stress conditions have been modelled to provide a basis for baseline hydrodynamic conditions of the Offshore Project.
- 9.5.1.3 The hydrodynamic model was then coupled with a Particle Tracking (PT) module for the assessment of construction activity impact sediment plumes.
- 9.5.1.4 For the O&M phase, the hydrodynamic model was used to assess potential blockage effects due to the presence of offshore wind turbine structures causing potential changes to hydrodynamics (water levels and current speeds), seabed (scour), waves and stratification.

9.5.2 METHODOLOGY FOR BASELINE DATA GATHERING

Overview

- 9.5.2.1 Baseline data collection has been undertaken to obtain information within the Study Area described in Section 9.6. This baseline data collection has included desktop data sources, site-specific surveys, and additional sources identified during stakeholder consultation. Data relating to baseline hydrodynamics, waves, and sediment transport was further processed using modelling as detailed in **Appendix 9.1, Volume 2c** and **Appendix 9.2, Volume 2c**.
- 9.5.2.2 The baseline data was used to develop the 2D hydrodynamic and spectral wave models using the Danish Hydraulic Institute (DHI) MIKE 2023 software suite as described in **Appendix 9.1, Volume 2c**, alongside the calibration and validation exercise undertaken to confirm that the 2D hydrodynamic model to be used in this analysis is suitable and representative of physical processes in the area covered by the model.
- 9.5.2.3 The model duration covers a month-long period to include spring and neap tides which represent a range of typical tidal conditions. Baseline characterisation model outputs are presented in Section 3 of **Appendix 9.2, Volume 2c**.

Desk study

- 9.5.2.4 The desktop data sources that have been collected and used to inform this Physical and Coastal Processes assessment are summarised in **Table 9-6**. Those sources marked with an asterisk have also been used within the modelling exercise as described in **Appendix 9.1, Volume 2c** and **Appendix 9.2, Volume 2c**.

Table 9-6 Data sources used to inform the Physical and Coastal Processes EIA

Source	Date	Summary	Coverage of Study Area
Scottish Shelf Model	October 2024	Modelled temperature data at the seabed and surface	Full coverage of Study Area
DHI Global Model*	August 2024	Tidal current velocities	Full coverage of Study Area

Source	Date	Summary	Coverage of Study Area
European Marine Observation and Data Network (EMODnet) Bathymetry & Seabed Sediments*	January 2024	Bathymetry and seabed sediment classification data	Full coverage of Study Area
General Bathymetric Chart of the Oceans (GEBCO) Bathymetry*	January 2024	Bathymetry data	Full coverage of Study Area
OpenStreetMap Coastline*	August 2024	Coastline shapefile	Full coverage of Study Area
WaveWatch III *	August 2024	Hindcast wave data including wave height, period and direction	Extracted at Model Boundary, developed through full coverage of Study Area
UKHO Admiralty Total Tide (ATT)	January 2024	Standard astronomical tide levels and tidal diamond	Full coverage of Study Area
ABPmer Renewables Atlas	January 2024	Tidal current speeds and range	Full coverage of Study Area
ABPmer SEASTATES	January 2024	Hindcast wave and wind roses	Full coverage of Study Area
EA Coastal Flood Boundary	January 2024	Extreme sea levels (2017 baseline)	Full coverage of Study Area

*Note: Used within the modelling exercise as described in **Appendix 9.1, Volume 2c** and **Appendix 9.2, Volume 2c** Site-Specific Surveys.

Site Surveys

9.5.2.5 The site-specific surveys that have been undertaken and used to inform this Physical and Coastal Processes assessment are summarised in **Table 9-7**.

Table 9-7 Site surveys undertaken

Survey Type	Scope of Survey	Coverage of Study Area
Geotechnical	Borehole samples were undertaken within the Offshore Project Boundary (including Array Area and the OCAS) to understand the size and distribution of sediment.	Exact location of boreholes used for the assessment are in Plate 3-20 in Section 3.4.1 of Appendix 9.2, Volume 2c .
Marine environmental baseline	Sub-tidal environmental characterisation. Particle size distribution analysis of grab samples is relevant to this chapter.	11 successful grab sample locations primarily located in the southwest of the Offshore Project Boundary. For locations see Figure 44 in Appendix 11.1, Volume 2c .

Survey Type	Scope of Survey	Coverage of Study Area
<p>Wind and Metocean Monitoring including wave buoys</p>	<p>Partrac Ltd were contracted by Northland Power to monitor metocean conditions in the Offshore Project Boundary. A suite of deployments within the Array Area to collect metocean and wind data to be used for model calibration and validation. Survey included 4 moorings; the instruments deployed include:</p> <ul style="list-style-type: none"> • 2 Directional Waverider (DWR) Wavebuoys; • 3 conductivity, temperature and depth (CTD) instruments; • 1 EOLOS Floating Light Detection and Ranging (FLiDAR); • Seabed current and wave instrumentation housed within the subsurface mooring. <p>Monitored parameters include:</p> <ul style="list-style-type: none"> • Wind; • Currents; • Meteorological; • Waves; • Conductivity; • Temperature; • Depth; • Near-full water column currents; • Near Bed currents. 	<p>Instruments were deployed at 4 mooring locations within the Array Area. The exact locations of the metocean data survey can be found in Plate 2-1 of Appendix 9.1, Volume 2c.</p> <p>The data has been used in the model calibration exercise as set out in Appendix 9.1, Volume 2c. The use of data within the calibration exercise allowed the development and validation of a model with wider coverage of the Study Area, indicating the wider scope associated with the data.</p> <p>Some parameters recorded within the metocean survey will also be applicable outside of these locations, with local differences then accounted for through the modelling exercise.</p>
<p>Bathymetric Survey</p>	<p>Bathymetric Survey completed as part of the <i>Archaeological Assessment of Geophysical and Hydrographic Data</i> document produced by MSDS Marine for the Applicant. The survey was conducted by Ondine Limited (Ondine), on behalf of Aratellus Subsea Solutions PTE Limited (Aratellus) between 15 May 2023 and 6 December 2023. The mobilised sensors included a Multibeam Bathymetry (MBES). Results include Grids and Mosaic MBES at 0.5 m resolution.</p>	<p>The MBES data covered the extent of the Array Area, and the majority of the OCAS.</p>

9.5.3 DATA LIMITATIONS AND ASSUMPTIONS

9.5.3.1 The data limitations relating to Physical and Coastal Processes, including how the effect of limitation has been mitigated, are as follows:

- The geotechnical survey points do not cover the entire Offshore Project Boundary. However, this data has been supplemented by available data from the desk study and worst-case values to classify the sediment characteristics are used in the assessment;
- The depth of boreholes does not cover the maximum proposed turbine foundation depth. However, a worst-case assessment of sediment characteristics has been used based on the available surveyed data, i.e. clay/silt is assumed to be present below the depth of the borehole to represent sediment released during turbine installation (drilling) since this has the potential to remain in suspension for the longest length of time.

9.5.3.2 The cable layout has been assumed since the final layout was not available at this stage. However, the assumed layout (including 12 Array Cables to Landfall, see **Table 9-20** for further details) represents a worst-case layout for the maximum design scenario.

9.5.3.3 The site-specific bathymetry data survey was undertaken after the development of the model and therefore only the GEBCO dataset was used to develop the model. A high-level comparison of the site-specific data with the GEBCO dataset is presented in **Appendix 9.1, Volume 2c** to determine the level of confidence with the publicly available data. Overall, in the areas that are relevant to the study (the Array Area and the OCAS), the delta between the 2 surveys is generally under 5 m, which has been calculated to be between 2-5% of the total water depth. The comparison between the 2 bathymetric data sets indicates that the depths for the GEBCO dataset are generally shallower. This level of variation is within the allowable tolerances for accuracy ($\pm 5\text{m} + 5\%$ depth) specified in the Hydrographic Survey Specification (Seabed Mapping) Report for offshore surveys relevant to activities planned in water depths up to 200 m (UK Hydrographic Office, 2022). This correlation provides confidence that the GEBCO data used in model development is suitably representative and sufficiently robust for the purposes of the EIA.

9.5.4 METHODOLOGY FOR ENVIRONMENTAL IMPACT ASSESSMENT

Introduction

9.5.4.1 The project-wide generic approach to assessment is set out in **Chapter 5, Volume 1a**. The following sections provide the assessment methodology used to assess the potential impacts on Physical and Coastal Processes only.

9.5.4.2 A matrix approach as described in **Chapter 5, Volume 1a** has been used to determine the significance of effects, by comparing impact magnitude against receptor value and sensitivity.

9.5.4.3 The Physical and Coastal Processes assessment has considered the magnitude and duration of the impact, the reversibility of the impact and the timing and frequency of the activity, and the sensitivity of the Physical and Coastal Processes receptors.

9.5.4.4 This methodology has been used to assess the construction, O&M and decommissioning phases of the Offshore Project.

9.5.4.5 As outlined in Section 9.4.4, Physical and Coastal Processes can also act as impact pathways that have the potential to affect other non-Physical and Coastal Processes receptor groups.

9.5.4.6 The potential effects of Physical and Coastal Processes impact pathways on non-physical and coastal processes receptor groups are assessed in the following chapters:

- Marine sediment and water quality (**Chapter 10, Volume 2a**);
- Benthic and intertidal ecology (**Chapter 11, Volume 2a**);
- Fish ecology (**Chapter 12, Volume 2a**);
- Marine mammals (**Chapter 13, Volume 2a**);
- Offshore archaeology and cultural heritage (**Chapter 15, Volume 2a**);
- Other sea users, including recreational users. (**Chapter 20, Volume 2a**);
- Commercial fisheries (**Chapter 21, Volume 2a**).

Impact Assessment Criteria

Magnitude

9.5.4.7 To determine magnitude of effects on Physical and Coastal Processes from sediment disturbance and seabed change associated with the Offshore Project sediment plume modelling was undertaken using the baseline hydrodynamic model described in Section 9.5.2 coupled with a sediment particle tracking model.

9.5.4.8 The sediment plume modelling undertaken presents the depth-averaged SSC and deposited sediment impacts of construction activities based on the proposed Offshore Project design envelope (see **Chapter 3, Volume 1a**).

9.5.4.9 Construction activities were modelled in different locations and combinations. Details of the construction scenarios considered are given in Section 2.3.2 of **Appendix 9.2, Volume 2c**, with assumptions and parameters specific to each activity described in Section 2.3.3 of **Appendix 9.2, Volume 2c**.

9.5.4.10 Model outputs for impacts from sediment plumes resulting from construction activities are presented in Section 4 of **Appendix 9.2, Volume 2c**. As was the case for the baseline modelling, the model duration covers a month-long period to include spring and neap tides which represent a range of typical tidal conditions.

9.5.4.11 The magnitude of blockage effects from the presence of infrastructure during the operation phase of the Offshore Project were assessed through modelling of proposed infrastructure on modelled baseline hydrodynamics, wave, and sediment transport parameters.

9.5.4.12 Model outputs for the operation and maintenance phase due to the presence of infrastructure are presented in Section 5 of **Appendix 9.2, Volume 2c**. Again, the model duration covers a month-long period to include spring and neap tides which represent a range of typical tidal conditions.

9.5.4.13 Based on the model outputs described above magnitude was determined using the criteria outlined below in **Table 9-8**.

Table 9-8 Impact magnitude criteria

Magnitude of Impact	Definition	
No change	No loss or alteration of characteristics, features or elements; no observable impact in either direction.	
Negligible	Adverse	Immediate spatial extent, with scale of impact smaller than the natural variability, occurring infrequently over a brief (hours) timescale.
	Beneficial	Very minor benefit to, or positive addition of 1 or more characteristics, features or elements.
Low	Adverse	Near-field spatial extent with scale of impact smaller than the natural variability, frequently occurring over a short/temporary (days) timescale.
	Beneficial	Minor benefit to, or addition of, 1 (maybe more) key characteristics, features or elements; some beneficial impact on attribute or a reduced risk of negative impact occurring.
Medium	Adverse	Near-field spatial extent with scale of impact with the same order as the natural variability, frequently occurring in the long-term; or immediate spatial extent (the Array Area/OCAS) with scale of change greater than the natural variability, occurring frequently over a medium (weeks) timescale.
	Beneficial	Benefit to, or addition of, key characteristics, features or elements; improvement of attribute quality.
High	Adverse	Large far-field spatial extent with scale of change greater than the natural variability with a continuous impact extending long-term (months).
	Beneficial	Large scale or major improvement of resource quality; extensive restoration or enhancement; major improvement of attribute quality.

Sensitivity (and Value)

9.5.4.14 Sensitivity criteria for physical and coastal processes receptors are based on their vulnerability (capacity to tolerate the impact), ability to recover and the time anticipated it will take to do so, as well of the value of the receptors.

9.5.4.15 To incorporate value into the assessment, it has been included as part of the sensitivity criteria outlined in **Table 9-9**. It should be noted, however, that conservation value and high sensitivity are not necessarily linked for a particular impact. For example, a receptor can be of international or national importance (e.g. an interest feature such as outcropping strata for a geological protected site) but have a low or negligible physical/ecological sensitivity to an impact (such as short-term and localised suspended sediment increases) and vice versa. Consequently, when determining the

sensitivity level taken forward to assessment, site-specific considerations and professional judgement have been considered.

Table 9-9 Sensitivity criteria for physical and coastal processes receptors

Sensitivity	Definition
Negligible	<p>Vulnerability: The receptor has a high capacity to tolerate the impact.</p> <p>Recoverability: The receptor is anticipated to recover immediately (seconds to days).</p> <p>Value: The receptor is very low importance and rarity, local scale.</p>
Low	<p>Vulnerability: The receptor has a reasonable capacity to tolerate the impact.</p> <p>Recoverability: Full recovery will occur but will take many months (or more likely years) but should be complete within about five years.</p> <p>Value: The receptor is of regional or local value.</p>
Medium	<p>Vulnerability: The receptor has limited capacity to tolerate the impact.</p> <p>Recoverability: Only partial recovery is likely within 5 years, and full recovery is likely to take up to 10 years.</p> <p>Value: The receptor is of national or regional value.</p>
High	<p>Vulnerability: The receptor cannot or has very low capacity to tolerate the impact.</p> <p>Recoverability: Partial recovery is only likely to occur after about 10 years, and full recovery may take over 25 years.</p> <p>Value: The receptor is of international or national value.</p>

Significance

9.5.4.16 Following the identification of the impact magnitude criteria (**Table 9-8**), and sensitivity criteria for physical and coastal processes receptors (**Table 9-9**), it is possible to determine the significance of effect.

9.5.4.17 The significance of any effects has been evaluated against the likely naturally occurring variability in, or long-term changes to, the marine physical environment within the Offshore Project's lifetime due to natural cycles, for example storm events, and/or climate change.

9.5.4.18 The matrix provided in **Table 5-2** in **Chapter 5, Volume 1a** is used as a framework to aid in determination of the impact assessment and provides further detail of what effect is considered to be significant by comparing impact magnitude against receptor value and sensitivity.

9.6 BASELINE CONDITIONS

9.6.1 OVERVIEW

9.6.1.1 Baseline conditions have been examined for the Study Area as described in Section 9.4.2. This has been undertaken separately for both current baseline and future baseline. The key receptors assessed for both current baseline and future baseline are as previously identified in Section 9.4.4 and include;

- The Surrounding Coastline;
- The Surrounding Sub-tidal Seabed;
- Designated sites of geological interest.

9.6.1.2 Within the Study Area, the Surrounding Coastline is defined as the area landwards of MLWS to MHWS, and the Surrounding Sub-tidal Seabed is defined as the area offshore of MLWS to Study Area seaward boundary.

9.6.1.3 The North-West Coast of Lewis GCR site was identified as a designated site of geological interest that is located within the ZOI and approximately 7km east of the Array Area at its closest point (see **Figure 9-2, Volume 2b**). The Quaternary of Scotland interest of this GCR site is expressed in soft coastal cliffs/slopes determined by wave energy. Although the site is not notified as a Site of Special Scientific Interest (SSSI), it nonetheless represents nationally important geodiversity.

9.6.2 CURRENT BASELINE

9.6.2.1 The subsequent sections provide information on baseline conditions covering the following relevant Physical and Coastal Processes subjects:

- Bathymetry;
- Water levels;
- Waves;
- Tidal currents;
- Stratification;
- Geology;
- Seabed sediments;
- Sediment Transport Pathways.

Bathymetry

9.6.2.2 Water depths off the north coast of Scotland/*Alba*, and to the west of the Hebrides, are typically between 100-150 m, deepening to the northwest, with a gentle averaged gradient $<1^\circ$ (Baxter *et al.*, 2011).

9.6.2.3 The water depths across the Turbine Area range from 37 m – 67 m with the southwest corner of the Array Area reaching 72m (**Figure 9-3, Volume 2b**).

Tidal Levels

9.6.2.4 Tides in the Outer Hebrides are dominated by 2 semidiurnal constituents; the M2 and the S2 constituents. M2 is the principal lunar semidiurnal tidal constituent caused by the Moon's gravitational pull, while S2 is the principal solar semidiurnal constituent caused by the Sun's gravitational pull. Both constituents follow the same distribution, with the S2 constituent having a tidal amplitude of 40% that of the M2 constituent, which falls between 1.1–1.2 m throughout the Array Area (Inall and Sherwin, 2006).

9.6.2.5 Standard astronomical tide levels were obtained from the UK Hydrographic Office (UKHO) ATT software. Levels for the nearest reference point (Carloway/Càrlabhadh) were extracted. Carloway/Càrlabhadh is approximately 15 km from the centre of the Array Area and 20 km southwest from the centre of the OCAS. The tide type is Semidiurnal (occurring twice a day), with typical levels summarised in **Table 9-10**. The maximum astronomical tidal variation observed between HAT and LAT is 4.5 m.

Table 9-10 Carloway standard tidal levels

Tide Level	Acronym	Chart Datum	mOD
Highest Astronomical Tide	HAT	4.7 m	2.5 m
Mean High Water Springs	MHWS	4.1 m	1.9 m
Mean High Water Neaps	MHWN	3.2 m	1.0 m
Mean Sea Level	MSL	2.43 m	0.23 m
Mean Low Water Neaps	MLWN	1.7 m	-0.5 m
Mean Low Water Springs	MLWS	0.7 m	-1.5 m
Lowest Astronomical Tide	LAT	0.2 m	-2.0 m

Extreme Sea Levels

9.6.2.6 **Table 9-11** shows extreme sea levels from Environment Agency Coastal Flood Boundary Condition (2018) dataset. The baseline year for this dataset is 2017. The data shows extreme sea levels (central statistical estimate values) ranging from +2.58 mOD (1 in 1-year Return Period) to +3.45 mOD (1 in 1000-year Return Period).

Table 9-11 Coastal flood boundary extreme sea levels

Return Period	Extreme Sea Level (mOD) 2017
1 yr	2.58
10 yr	2.83
20 yr	2.90
50 yr	2.99
100 yr	3.05
200 yr	3.12
1,000 yr	3.26

Tidal Currents

9.6.2.7 **Table 9-12** summarises the current speeds extracted from the ABPmer Renewables Atlas model (AMPmer, 2018). These are broadly in-line with the current speeds quoted by Lewis Wave Power Ltd (2012) at the Array Area.

Table 9-12 Current data for point in Tidal Array (ABPmer, 2018)

ID	Distance from Nearest Land (m)	Average Depth (m)	Mean Spring Peak Flow (m/s)	Mean Neap Peak Flow (m/s)	Mean Spring Tidal Range (m)	Mean Neap Tidal Range (m)
22079	10733	53.0	0.33	0.15	3.24	1.48

9.6.2.8 The closest UKHO ATT current prediction point to the site is located approximately 25 km southwest from the centre of the Array Area and 35 km from the centre of the OCAS. **Table 9-13** shows the associated tidal diamond (specific location where tidal stream data has been recorded) extracted from the ATT software. The mean current speed predicted is 0.32 m/s during the spring tide and 0.12 m/s during the neap tide.

9.6.2.9 The ATT currents are similar (within 10-15%) to those presented in Lewis Wave Power Array Ltd (2023) and ABPmer (2018) within the Array Area. The agreement between each of the data sources provides confidence in the values and a likely range of spring and neap current speeds at different points in the Study Area.

Table 9-13 ATT tidal diamond

Time (h)	Direction (degrees)	Spring rate		Neap Rate	
		knots	m/s	knots	m/s
-06	221	0.9	0.46	0.3	0.15
-05	215	0.7	0.36	0.3	0.15
-04	212	0.6	0.31	0.2	0.10
-03	198	0.3	0.15	0.1	0.05
-02	068	0.3	0.15	0.1	0.05
-01	044	0.8	0.41	0.3	0.15
HW	030	0.9	0.46	0.4	0.21
+01	031	0.8	0.41	0.3	0.15
+02	045	0.6	0.31	0.2	0.10
+03	055	0.2	0.10	0.1	0.05
+04	232	0.3	0.15	0.1	0.05
+05	230	0.8	0.41	0.3	0.15
+06	228	1	0.51	0.4	0.21

9.6.2.10 As detailed in **Appendix 9.2, Volume 2c**, within the Study Area, baseline current speed model results show predominantly higher current speeds in the north than the south, regardless of current direction.

9.6.2.11 Within the Array Area, modelled peak flood tide current speeds during spring tides range from 0.40-0.55 m/s. Peak spring tide ebb current speeds range from 0.35-0.50 m/s. Within the OCAS,

modelled peak flood current speeds during spring tides range from 0.20-0.52 m/s. Peak spring ebb tide current speeds range from 0.10-0.45 m/s.

9.6.2.12 Within the Array Area, modelled peak neap flood current speeds range from 0.05-0.20 m/s. Peak neap ebb current speeds range from 0.05-0.10 m/s. Within the OCAS, modelled peak flood current speeds during neap tides range from 0.05-0.15 m/s. Peak neap ebb tide current speeds range from 0.05-0.07 m/s.

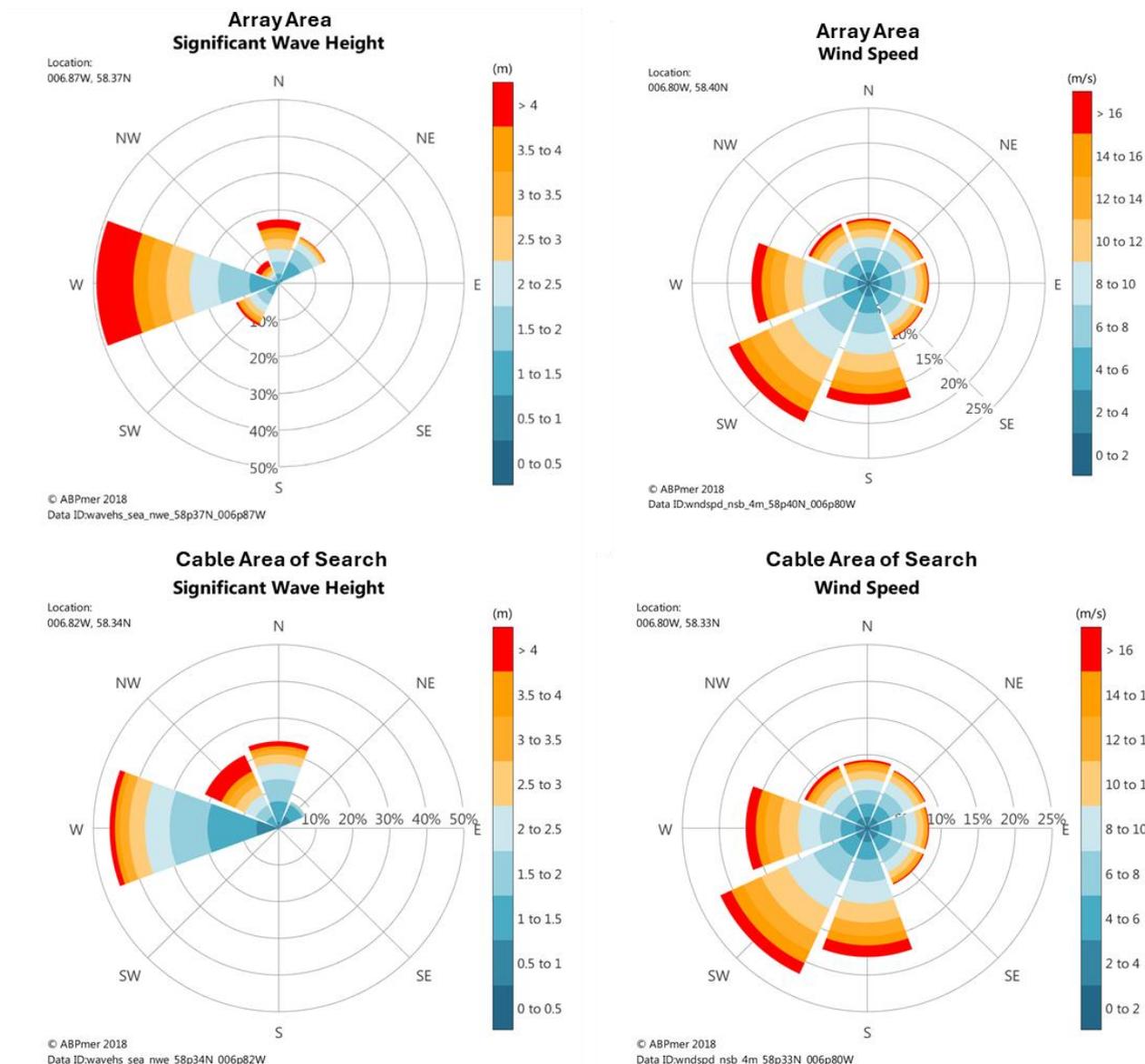
9.6.2.13 The modelled baseline current speeds were calibrated against measured site data, detailed in **Appendix 9.1, Volume 2c**. Overall, the hydrodynamic model accurately modelled current speeds and direction. Current speeds showed a very good agreement between modelled and measured data, being within 20% of measured data for more than 80% of the time. The modelled current direction also shows *good agreement* against the measured data, with the modelled results accurately representing directional variation associated with flood and ebb tides.

Waves

9.6.2.14 ABPmer (2018), developed the SEASTATES hindcast database covering a period from 1979 onwards, to provide water level and flow parameters generated by both astronomic (tidal) and meteorological forces across the North West European Continental Shelf and North Sea. The database also contains significant wave height/period/direction and wind speed/direction for each mesh element.

9.6.2.15 **Plate 9-1** shows the associated wave and wind roses that were used to inform the assessment. The wave rose shows that the hindcast model wave climate indicates a predominant westerly direction with up to approximately 10% of the westerly waves being greater than 4 m in height (H_s). A smaller proportion of waves originate from southwest, northwest, north and northeasterly directions with significant wave heights from these directions also exceeding 4 m.

Plate 9-1 ABPmer Wave and Wind Roses for the Study Area (SEASTATES data)



9.6.2.16 The annual mean significant wave height (H_s) is 2.29 m within the Study Area, with seasonal mean H_s values of 3.02 m in winter to 1.57 m in summer (2.18 m in spring and 2.42 m in autumn) (ABPmer, 2008).

9.6.2.17 The wind rose plots in **Plate 9-1** show the prevailing wind direction as south westerly, with speeds greater than 16 m/s for both the Array Area and OCAS. Westerly and southerly winds also frequently occur across the Study Area.

9.6.2.18 **Plate 9-2** shows wave rose plot based on measured data within the Study Area between October 2023 and May 2024. **Table 9-14** shows the statistics derived from the measured dataset. The measured data broadly align with the values obtained from the ABPmer SEASTATES data.

Plate 9-2 Wave rose plot from measured Directional Wave Rider buoy (October 2023 – May 2024)

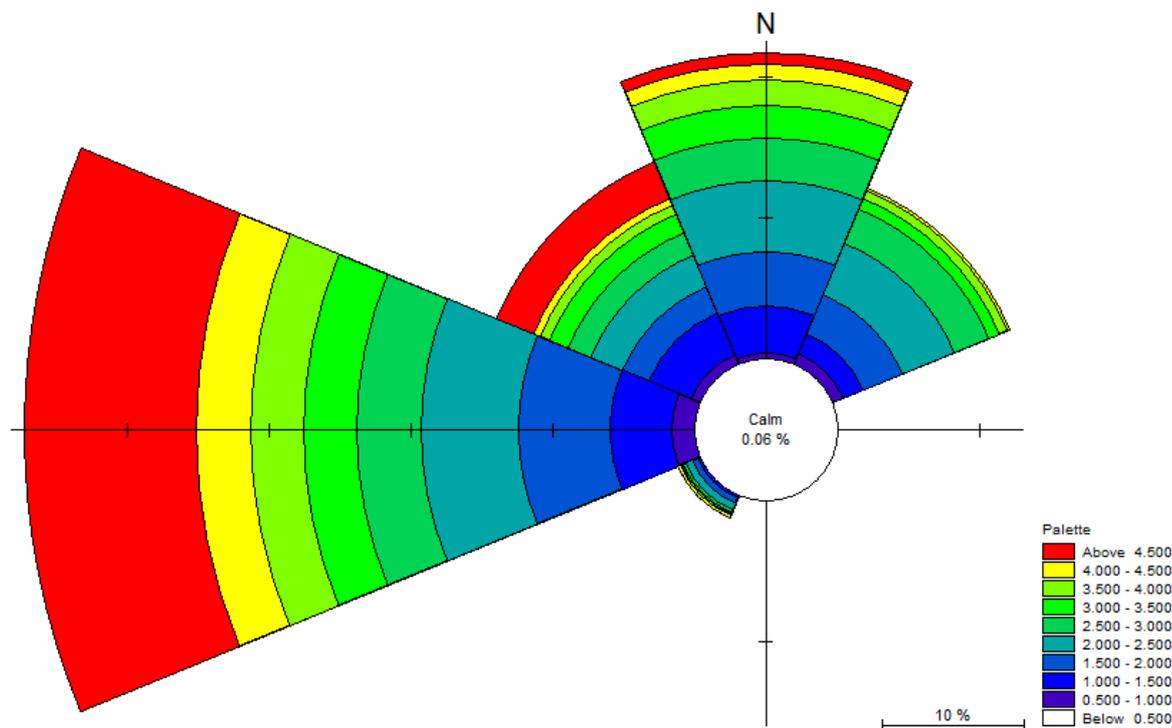


Table 9-14 Wave statistics derived from measured Directional Wave Rider buoy (October 2023 – May 2024)

Parameter	Min	Max	Mean
Wave Period, T_p	4.2 s	22.2 s	11.4 s
Significant Wave Height, H_s	0.62 m	9.79 m	2.90 m

9.6.2.19 The modelled baseline wave parameters were calibrated against measured site data, detailed in **Appendix 9.1, Volume 2c**. Overall, the spectral waves model accurately modelled significant wave heights, wave periods, and wave directions:

- **Significant wave heights** showed a very good agreement between modelled and measured data, being within 10% of measured data for more than 76% of the calibration periods;
- **Modelled wave periods** showed either very good or excellent agreement to measured data, approaching 100% of the calibration period within the required metric of 20% of measured data;
- **Wave directions** showed excellent agreement against the measured data, reaching 100% compliance with their required metrics on more than one occasion.

Stratification

- 9.6.2.20 Ocean stratification is the formation of different layers within the water column as a result of changes in both salinity and temperature. These parameters vary depending on the metocean conditions as well as seasonally.
- 9.6.2.21 Baseline stratification has been quantified using data from the Scottish Shelf Model (Barton *et al.*, 2022) which includes three-dimensional temperature data. Average differences in temperature between the surface and bed layers have been calculated over the model domain for each month between May and September. This data is shown in **Figure 9-8** to **Figure 9-12, Volume 2b**. The region around the Study Area experiences little temporal variation in surface and bed temperature difference and the difference is of a small magnitude (0-2°C).
- 9.6.2.22 The Offshore Project is located within the shallower depths along the sea shelf of the Hebrides. This region is situated within the surface ocean layer which is above the main thermocline. The majority of the main thermoclines are known to form in the deeper regions of the ocean where greater stratification occurs.
- 9.6.2.23 As part of the Metocean Monitoring survey specified and presented in **Table 9-7**, temperature readings were obtained from both a surface mooring and a seabed mooring from 22 July-4 November 2024. **Plate 9-3** shows a comparison of near bed and surface sea temperatures between December 2023 and October 2024. **Table 9-15** shows the temporal differences between near bed and surface sea temperatures.

Plate 9-3 Difference between surface and bed temperature from measured site data

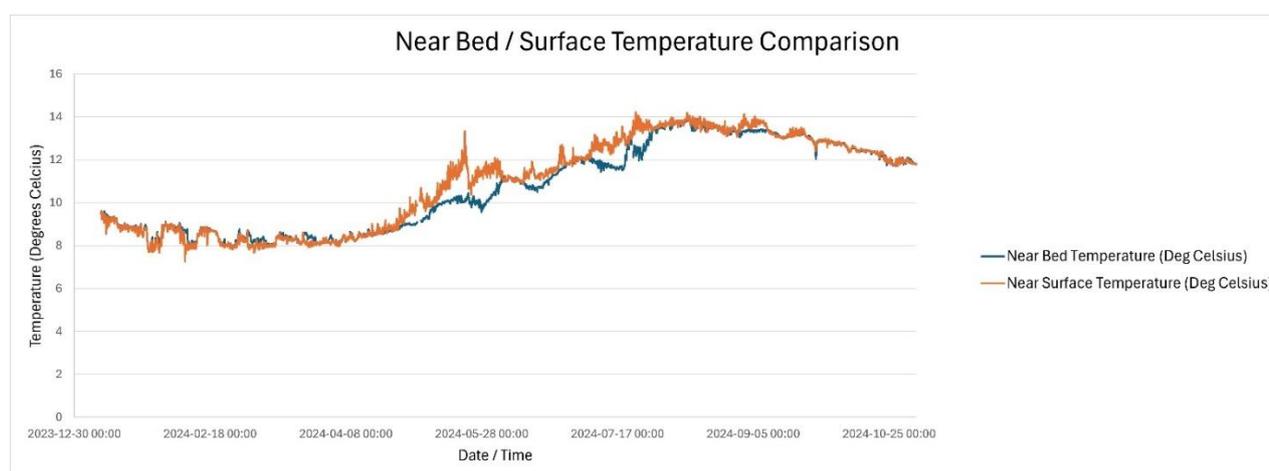


Table 9-15 Temporal difference between surface and bed temperature from measured site data

Temperature Difference (Surface - Bed)	Percentage of Time
<0.5 degrees	80.6%
0.5-1 degrees	10.0%
1-2 degrees	8.9%
2-3 degrees	0.4%

9.6.2.24 Overall, the measured data within the Study Area shows very minor thermal stratification between the surface and bed layers, occurring between May and August. The magnitude of the temperature differential is less than 1°C for over 90% of the time. Therefore, the baseline strength of stratification within the Study Area is deemed to be weak.

Geology

9.6.2.25 The regional bedrock geology of the Offshore Project Boundary is characterised by complex lithologies of Lewisian Gneiss, Torridonian Sandstone, and Mesozoic sedimentary rocks. The Lewisian Gneiss Complex, some of the oldest rocks in Europe, underlies much of the Outer Hebrides/*Na h-Eileanan Siar* and extends offshore beneath a veneer of Quaternary deposits. These ancient metamorphic rocks form a structurally complex basement, often overlain by younger sequences of sandstones, siltstones, and mudstones deposited during the Mesozoic and Palaeozoic eras (Spiorad na Mara Limited, 2023).

9.6.2.26 Superficial geological deposits are largely the result of glacial and post-glacial processes. Quaternary sediments include till, glaciofluvial sands and gravels, and post-glacial marine deposits. The glacial history of the region has led to variable sediment thickness across the Offshore Project Boundary, with some areas displaying thin sediment cover over bedrock, while others contain infilled depressions or paleochannels with significantly thicker accumulations (Spiorad na Mara Limited, 2023).

9.6.2.27 The locations of boreholes undertaken as part of the geotechnical investigation are shown in **Plate 3-20** of **Appendix 9.2, Volume 2c**. Full details of the findings, such as sediment descriptions, are included in Section 3.4 of **Appendix 9.2, Volume 2c**. In summary, the borehole data showed that:

- In the OCAS there are fine to coarse gravels in the upper 2.5 m of the seabed with sandy silt present alongside gravels deeper than 2.5 m;
- In the northeast of the Array Area there are fine to coarse sands and gravels mixed throughout the seabed; and
- In the southwest of the Array Area there are gravelly sands and clays in the upper 3 m of the seabed with some gravel present alongside the sands and clays deeper than 3 m.

Surface Seabed Sediments

- 9.6.2.28 Desktop review of regional seabed sediment data sets which are based on regional sampling data sets and modelling indicate seabed sediments range from coarse sediment within the Array Area and rock and other hard substrates within the OCAS (see **Figure 9-4** and **Figure 9-5**) (EMODnet, 2019; BGS, 2015; BGS, 2020).
- 9.6.2.29 To assist with classifying surface seabed sediments further within Offshore Project Boundary, site specific geophysical surveys were undertaken through the collection of Side Scan Sonar (SSS) and Multi Echo Beam Sounder (MBES) data. This data was then ground truthed through collection of underwater video and physical grab samples as part of the marine environmental baseline survey (see **Appendix 11.1, Volume 2c**).
- 9.6.2.30 Based on this analysis it was identified that the majority of the Array Area and OCAS was considered circalittoral rock consisting of boulders, stones and pebbles. Areas of the Offshore Project Boundary that differed to this included coarse sediments identified in the eastern/central section of the Array Area. Muddy sand was identified in the southwest of the Array Area. Within the OCAS, outcropping bedrock was identified within northeastern areas and rocky geogenic reef in shallower subtidal and intertidal areas extending parallel to the coast (see **Figure 51** and **Figure 53, Appendix 11.1, Volume 2c**).

Sediment Transport Pathways

- 9.6.2.31 Sediment transport is the movement of sediment driven by hydrodynamic forces or project related activities, with suspended particles being fully suspended in the water column requiring flow or activity driven forcing to keep the particles in suspension. Once the forcing mechanism slows or stops the lack of energy will result in the suspended load settling out and causing deposition on the seabed. Ultimately the potential for deposition is directly related to the concentration of total suspended solids (TSS).
- 9.6.2.32 A CEFAS report is available for suspended sediment climatology's around the UK (2016). Ocean colour satellite images allow mapping of the surface suspended sediments load for large areas. This provides a summary of average Suspended Particulate Matter (SPM) and shows 0 mg/l for the Offshore Project Boundary. **Plate 9-4** and **Table 9-16** shows the average SPM between 1998 - 2015, showing low levels of suspended sediment identified within the Minches and Western Scotland/*Alba* throughout the seasons (<5 mg/l) (CEFAS, 2016).

Plate 9-4 CEFAS average suspended particulate matter 1998 - 2015

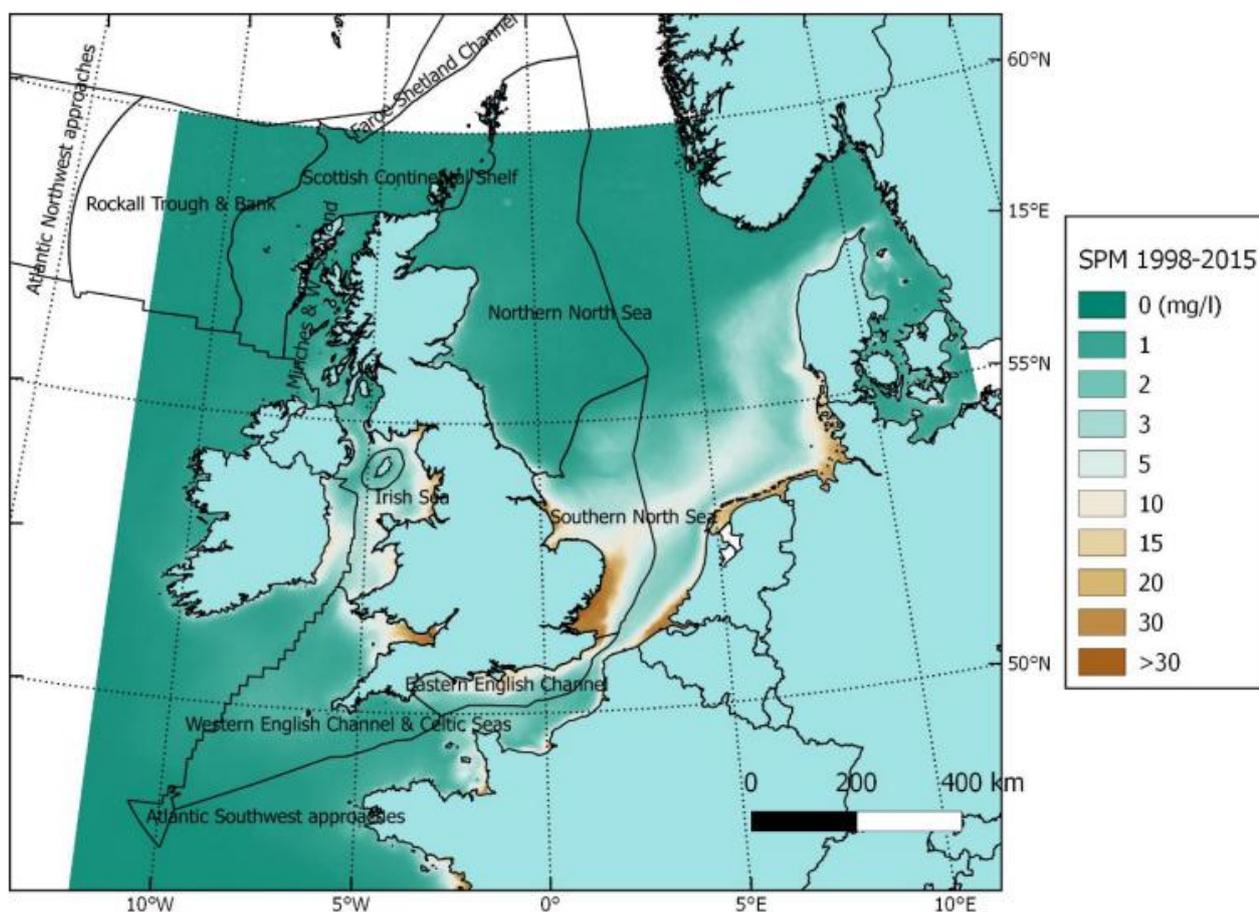


Table 9-16 Average surface suspended particulate matter (mg/l) for the period 1998-2015

On Shelf	Spring	Summer	Autumn	Winter	Annual
Scottish Continental Shelf	0.7	0.6	0.6	0.8	0.7

9.6.2.33 To characterise a baseline for site-specific sediment transport potential, a 31-day timeseries of water levels and flow characteristics (including speed and direction) was extracted from the hydrodynamic model (see **Appendix 9.2, Volume 2c**) for the period between 25 March and 25 April 2025, covering 2 spring-neap tidal cycles. Results were considered for 3 extraction sites located within the Array Area and 2 within the OCAS. The selected points were chosen to allow for an assessment of spatial variability in baseline sediment transport potential across the Array Area and OCAS based on:

- Water depth;
- Seabed sediment composition;
- Flow speed and direction.

9.6.2.34 **Figure 9-6, Volume 2b** illustrates the extraction sites used for the timeseries data as well as those analysed for sediment transport potential. **Table 9-17** details the calculated percentage of time sediment would be mobile at these sites during the spring-neap tidal cycle. Smaller silt and sand sediment is mobilised between 66% and 100% of the time compared to larger gravel sediment which is not mobilised. The wave statistics outlined in Section 9.6.2.14 through 9.6.2.19 have been used to assess the wave induced sediment transport in **Appendix 9.2, Volume 2c**, noting that larger waves experienced during extreme storm events would have the potential to further mobilise the seabed sediment.

Table 9-17 Percentage of time sediment would be mobile

Location	Percentage of Time Sediment would be Mobile (%)		
	Silt	Sand	Gravel
Southwest	100	66	0
Northeast	69	66	0
Middle OCAS	Not present	Not present	0
HDD	100	Not present	Not present

9.6.2.35 The modelling presented in **Appendix 9.2, Volume 2c** calculated settling velocity (based on sediment size) for each area as follows:

- Northeast Array Area: 0.006 m/s (clay/silt), 0.012 m/s (sand) and 0.27 m/s (gravel);
- Southwest Array Area: 0.0003 m/s (clay/ silt), 0.004 m/s (fine sand) and 0.31 m/s (gravel);
- OCAS: 0.53 m/s (gravel).

9.6.2.36 When considering the weak tidal currents and water depths of the baseline environment there are limited means for resuspending and transporting offshore sediment. When that is combined with the generally coarse sediments (gravel) in the Offshore Project Boundary, the potential for resuspension and transportation of sediment is limited to periods of inclement weather during which there are increased wave and current forces (Spiorad na Mara Limited, 2023).

Potential for coastal erosion

9.6.2.37 The Dynamic Coast 2 website was consulted to understand the susceptibility of the northern Lewis coast to coastal erosion within the vicinity of the Array and Landfall Areas.

9.6.2.38 The coastline is relatively stable and is not expected to be at risk of significant erosion in the 2100 High Emission Scenario. Areas of the coastline that are predicted to be at risk of coastal erosion in relation to the Offshore Project Boundary are limited and are depicted in red in **Figure 9-7, Volume 2b**.

9.6.2.39 This risk of erosion is due to the exposure of the cliffs along the shoreline being exposed to naturally driven hydrodynamic force.

9.6.3 FUTURE BASELINE

- 9.6.3.1 Future baseline conditions for the Physical and Coastal Processes assessment will be primarily driven by climate change, including predicted sea level rise and extremes of weather. Bathymetric/coastal changes could also affect the Offshore Project but are not expected to change in relation to the proposed works and are very difficult to predict reliably over the project’s lifetime to determine any directly related effect.
- 9.6.3.2 In accordance with Scottish Environment Protection Agency (SEPA) guidance document “Climate change allowances for flood risk assessment in land use planning” (2025), sea level rise projections have been obtained for the UKCP18 Representative Concentration Pathway 8.5 (RCP8.5) higher central (70th percentile) and upper end (95th percentile) projections to uplift tidal water levels to the desired epochs. The percentile describes the proportion of possible scenarios that fall below that scenario i.e. an allowance based on the 70th percentile is exceeded by 30% of the projections in the range (Environment Agency, 2022).
- 9.6.3.3 For the purposes of this analysis a baseline year of 2033 has been assumed and future epoch of approximately +35 years (2068) in line with the operational design life.
- 9.6.3.4 The predicted rise in mean sea-level over this period is shown in **Table 9-18**. It is noted that the sea level rise in 2033 is calculated from a baseline year of 2018 (based on the data extracted from the Environment Agency Coastal Flood Boundary Extreme Sea Levels dataset).

Table 9-18 Sea Level Rise Allowances (Environment Agency, 2022)

Year	Higher Central	Upper End
2033	0.08 m	0.10 m
2068	0.36 m	0.47 m

- 9.6.3.5 When considering sea level rise in the context of this assessment, and the marginal predicted changes over the lifespan of the structure, these are considered to be negligible and are highly unlikely to affect or alter the physical and coastal processes at the location of the of the Offshore Project.
- 9.6.3.6 Offshore wind speeds and extreme wave heights are also predicted to increase due to climate change. The appropriate allowances (Environment Agency, 2022) for predicted increases that were accounted for in the sensitivity analysis are shown in **Table 9-19**.

Table 9-19 Wind Speed and Wave Height Climate Change Allowances (Environment Agency, 2022)

Year	Offshore Wind Speeds		Extreme Wave Height	
	Allowance	Sensitivity Test	Allowance	Sensitivity Test
2033	5%	10%	5%	10%
2068	10%	10%	10%	10%

9.6.3.7 The sensitivity test values should be used when assessing credible maximum scenarios for infrastructure projects of national significance (such as the Offshore Project). The purpose of the sensitivity test is to ensure that the development can adapt to 'large-scale climate change' over its lifetime (Environment Agency, 2022).

9.6.3.8 When considering the climate change driven changes over the lifetime of the project relative to offshore wind speeds, the prescribed allowances in the sensitivity test would for example increase higher end offshore winds speeds from 16m/s to 17.6 m/s.

9.6.3.9 When considering the climate change driven changes over the lifetime of the project relative to the extreme significant wave heights, the prescribed allowances in the sensitivity test would increase the extreme significant wave height from 9.79 m to 10.77 m.

9.6.3.10 Again, considering these marginal predicted changes over the lifespan of the structure, they are highly unlikely to affect or alter the physical and coastal processes at the location of the Offshore Project.

9.7 BASIS FOR ENVIRONMENT IMPACT ASSESSMENT

9.7.1 MAXIMUM DESIGN SCENARIO

9.7.1.1 Assessing using a parameter-based design envelope approach means that the assessment considers a maximum design scenario whilst allowing the flexibility to make improvements in the future in ways that cannot be predicted at the time of submission of the consent applications. The assessment of the maximum adverse scenario for each receptor establishes the maximum potential adverse impact and as a result impacts of greater adverse significance would not arise should any other development scenario (as described in **Chapter 3, Volume 1a**) to that assessed within this chapter be taken forward in the final scheme design.

9.7.1.2 The following information from external sources has been considered as part of identifying the Offshore Project maximum design parameters for this assessment:

- As stated within the UK Marine Special Area of Conservation (SAC) project (Parr *et al.*, 1998), "dredging activities often generate no more increased suspended sediments than commercial shipping operations, bottom fishing or generated during severe storms". It is likely that natural events, such as storms, floods and large tides, can increase SSC over much larger areas, and for

longer time periods. Furthermore, the impacts on SSC, as a result of cable burial activities, are generally short term (<1 week) and near field (<1 km from the activity) (Berr, 2008);

- The assessment of sediment disturbance from cable laying, undertaken by Berr (2008), indicates a relatively low level of disturbance (where a score of 1 is low, and 10 is high). For the construction activities associated with the OCAS, ploughing has a score of 1 for disturbance (in all sediment types relevant to the Offshore Project), jetting has a score of 2 (for fluidisation), and mechanical cutting has a score of 3;
- Jet trenching, associated with cable burial, is likely to cause the largest increase in SSC. The Environment Agency's SeDiChem Tool indicates a maximum SSC increase of 400 mg/l for dredging and 400 mg/l for jetting (but could be nearer 10 mg/l). Therefore, there would be a maximum, short-term, nearfield increase in SSC of 0–390 mg/l. However, based on the real-time monitoring completed during construction, as part of Nysted OWF (DONG Energy, 2005), increases are more likely to be between 18 and 75 mg/l, which would remain trapped within the bottom 1–2 m of the water column. This would be an increase of between 40% and 450% on maximum background surface SSCs.

9.7.1.3 The maximum design scenario parameters and maximum assessment assumptions that have been identified to be relevant to Physical and Coastal Processes are outlined in **Table 9-20**. The maximum design scenario parameters are in line with **Chapter 3, Volume 1a**.

9.7.1.1 Although pre-construction surveys may involve some limited and temporary interactions with the marine environment, the potential impacts of any such activities fall well within the MDS parameters assessed for this chapter. The MDS includes activities such as WTG foundation drilling and grouting, and Offshore Cable installation which represent a conservative upper bound on seabed disturbance, and vessel presence. These MDS activities therefore encompass the environmental footprint of pre-construction survey methods, which are significantly lower in magnitude, duration, and spatial extent.

9.7.1.2 For this reason, the potential environmental interactions of pre-construction surveys are not separately assessed, as they are already inherently accommodated within the worst case assumptions underpinning the MDS for this topic.

9.7.1.3 The difference in timing between pre-construction surveys and construction activities does not affect the assessment because the MDS represents the maximum magnitude of change, independent of phasing or scheduling. The pre-construction surveys occur over a much shorter duration and at materially lower intensities than the MDS bounding activities, and therefore do not introduce any temporal additive effects beyond those already assessed.

9.7.1.4 The maximum assessment assumptions outline whether the parameters used in the Physical and Coastal Processes assessment differ from the maximum design scenario. These differences (as justified in **Table 9-20**) are due to modelling constraints and simplifying assumptions but ensure a worst-case assessment scenario has been considered.

- 9.7.1.5 The maximum design scenario assumptions and assessment for construction activity impacts have considered the modelling of multiple activities as presented in Section 4.6 of **Appendix 9.2, Volume 2c**. This includes assessment of maximum suspended sediment concentration and sediment deposition thickness concentration during the model simulation following drilling piles to install 4 WTG foundations (each with 4 piles, equating to 16 in total) and associated burial of cables (assuming drilling and cable burial activities happen sequentially) per month. As well as impacts associated with interactions between different activities, this also captures impacts that may arise from multiple Array Cables to Landfall being in close proximity (150 m) to each other within the OCAS. Multiple HDD activities (HDD exit pit construction and HDD drill cutting release) were also quantitatively assessed within the Landfall Exit Pit Area to determine maximum suspended sediment concentration and sediment deposition thickness concentration arising during sequential HDD exit pit construction and HDD drill cutting release, in a single location and multiple locations.
- 9.7.1.6 Construction activity impacts on sediment disturbance and seabed change are assumed to be representative of a worst-case scenario for O&M and decommissioning activity impacts as presented in **Table 9-20**. This is because activities carried out during O&M and decommissioning are expected to use methodologies with the same or lesser sediment disturbance than during construction and take place over the same or lesser temporal and spatial scales.
- 9.7.1.7 The maximum design scenario for hydrodynamics and waves is the same, however the assumptions required for the hydrodynamic and spectral wave models vary (described in Sections 2.4.2 and 2.4.3 of **Appendix 9.2, Volume 2c**).

Table 9-20 Maximum Design Scenario' considered for Physical and Coastal Processes impact pathways

Offshore Project Activity and Associated Physical Processes (Impact Pathway)	Maximum Design Scenario	Maximum assessment assumptions	Justification
Construction			
<p>Installation of WTG Foundations: resulting in sediment disturbance and seabed change (e.g. temporary increase in suspended sediment concentrations and deposition from mobilised sediment) and effects related to the presence of construction infrastructure (alteration of tidal currents or sediment transport patterns)</p>	<p>Scenario 2 (60 WTGs and 12 Array Cables to Landfall): the installation of up to 60 multi-leg jacket foundations with pin piles via drilling and grouting within the Turbine Area to support up to 60 WTGs.</p> <p>Number of piles per WTG and spacing: Each multi-leg jacket pile foundation will have up to 4 legs (1 pin pile per leg), each spaced 30-55 m apart at seabed level and 15-35 m apart at MSL.</p> <p>Pin pile diameter: Each pin pile will have a maximum diameter of up to 5 m.</p> <p>Drilling depth: Pin piles will be drilled below the seabed to a depth of 15-120 m, depending on location within the Turbine Area (i.e. whether it is inside or outside of the buried channel).</p> <p>Volume of drill arisings: Per pin pile is assumed to be 588 m³, and 141,120 m³ for all 60 turbine multi-leg jacket foundations (assuming a 30 m average depth per drill event).</p>	<p>Volume of drill arisings: 4 piles per foundation are modelled in one location; with a volume of 1,374 or 2,356 m³/pile/day (for foundation depths of 70 m and 120 m, respectively).</p> <p>Concurrent pile drilling events: The model assumes that 3 pile drilling events will occur concurrently.</p> <p>Maximum pile depth assumption: Maximum depth of piles within the buried channel (deeper sections of seabed substrate within the Turbine Area) is 120 m and elsewhere within the Turbine Area it is 70 m.</p> <p>Tidal modelling assumption: A neap-spring tidal cycle is modelled with pile installation at the northeastern/southwestern extents of the Turbine Area.</p> <p>Sediment release: Sediment plumes associated with foundation installation construction activities are assumed to be limited to 2 m from the seabed (see justification in Section 2.3.3.2, Appendix 9.2, Volume 2c).</p>	<p>Scenario 2 (60 WTGs and 12 Array Cables to Landfall): represents the largest spatial extent of infrastructure and greatest volume of potential sediment disturbance during the construction phase.</p> <p>Number of piles per WTG and spacing: The resolution of the model mesh is not small enough for a spacing of sediment sources 30-55 m apart to influence the results. Therefore, spacing parameters were not included in the model, this ensures a reasonable computational run time.</p> <p>Concurrent pile drilling events: 3 piles are modelled simultaneously, with the single remaining pile for this location modelled on its own, which represents the maximum design scenario.</p> <p>Maximum pile depth and diameter assumption: Maximum pile depths and diameter have been modelled to ensure a worst-case volume of sediment disturbance.</p> <p>Volume of drill arisings: Maximum design scenario volume of drill arisings per pin pile value is based on a 30 m average embedment depth. Modelling has used depths of 70 m and 120 m to reflect the maximum depths pin piles will be buried e.g. in the buried channel representing worst case.</p> <p>Tidal modelling assumption: A neap-spring tidal cycle has been modelled to allow for an adequate range of tidal levels and current representation in the modelling exercise. Modelled locations at the edge of the Turbine Area shows the maximum extent of sediment disturbance outside the Offshore Project Boundary.</p> <p>Sediment release: Sediment disturbed by project construction activities is assumed to be released from within 2 m of the seabed. This assumption enables a conservative assessment of the concentration of the total suspended sediments and subsequent sediment deposition thickness (see Section 2.3.3, Appendix 9.2, Volume 2c).</p>
<p>Cable installation: resulting in sediment disturbance and seabed change (e.g. temporary increase in suspended sediment concentrations and deposition from mobilised sediment, localised changes to sediment transport) and effects related to presence of</p>	<p>Scenario 2 (60 WTG and 12 Array Cables to Landfall): the installation of 12 66 kV Array Cable to Final WTG (within Array Area) and 12 66 kV Array Cables to Landfall (within OCAS) via jet trenching.</p> <p>Array Cables:</p> <ul style="list-style-type: none"> • Array Cables to Final WTG have a maximum length of 160 km; 	<p>Sediment release: Assumes Array Cables will be installed at 300 m/hr with 20% of sediment released into the water column.</p>	<p>Scenario 2 (60 WTGs and 12 Array Cables to Landfall): equates to the greatest length (350 km) of Array Cables to be installed and greatest area of potential sediment disturbance during the construction phase.</p> <p>Installation method: is the worst-case cable installation method as the sediment release is likely to be at a greater height above the seabed (than the other Array Cable burial methods) where current speeds are higher (see paragraph 9.7.1.2 for further details).</p>

Offshore Project Activity and Associated Physical Processes (Impact Pathway)	Maximum Design Scenario	Maximum assessment assumptions	Justification
<p>infrastructure (alteration of tidal currents or sediment transport patterns).</p>	<ul style="list-style-type: none"> • Array Cables to Landfall have a maximum length of 190 km; • Maximum length of Array Cables is therefore 350 km and maximum diameter of 300 mm. <p>Installation method:</p> <ul style="list-style-type: none"> • Assumes 60% of cable length (210 km) requires installation via jet trenching; • Jetting trench has a maximum width of 7 m and depth of 2 m. Seabed disturbance footprint from jet trenching is anticipated to be approximately 1.47 km². <p>Site Preparation:</p> <ul style="list-style-type: none"> • Assumes 60% of cable length (210 km) requires boulder clearance to facilitate jet trenching; • Boulder clearance width of 15 m. • Seabed disturbance footprint from boulder clearance is anticipated to be approximately 3.15 km². 		<p>Jet trenching extent: Jet trenching 60% of the Offshore Cable length represents a worst case-scenario as it is the maximum amount of jet trenching that could be undertaken to install the Array Cables.</p> <p>Sediment release: Speed and percent of sediment released are reasonable worst-case values based on similar assessments. See Table 2-3 in Appendix 9.2, Volume 2c for details on sediment mass flux in different locations within the Study Area.</p> <p>Seabed Preparation:</p> <p>The potential impacts of seabed preparation activities, including boulder clearance using a boulder plough or boulder grab, were considered as part of the identification of the maximum design scenario for the Physical and Coastal Processes assessment. These activities were reviewed alongside the full range of potential cable installation methods.</p> <p>As outlined in Section 9.7.1.2, a comparison of ploughing, jetting and mechanical cutting indicated that jet trenching would result in the greatest sediment disturbance and seabed change, due to the volume of sediment mobilised.</p> <p>On this basis, jet trenching was selected as the basis for the modelling assessment as it represents a conservative worst-case scenario for sediment mobilisation associated with either cable installation or seabed preparation activities.</p> <p>The potential impacts of seabed preparation are therefore inherently encompassed within the modelling of jet trenching, which captures the upper bound of sediment disturbance and seabed change that could reasonably arise from these activities. Separate modelling of seabed preparation is not required, as it would not result in impacts greater than those already assessed under the maximum design scenario.</p>
<p>HDD Drill Cutting Release: resulting in sediment disturbance and seabed change (e.g. temporary release of drilling fluid mud, drilling arisings, and/or bentonite into the water column).</p>	<p>Number of bores and volume: Up to 13 bores drilled with a maximum volume of 1,285 m³ per bore.</p> <p>Number of rigs: 2 drill rigs.</p> <p>Drill release duration: 24 hours working, 7 days a week.</p> <p>Drill fluid density: Volume of suspended cuttings varies dependent on drilling fluid density.</p>	<p>Single bore modelled: Single representative bore release modelled at a central point within the Landfall Exit Pit Area.</p> <p>Tidal modelling assumption and drill release duration: Drill releases of entire bore over 1 hour at a peak spring tide and during slack water on a neap tide.</p> <p>Drill fluid density: Assumed 27% cuttings in a very dirty drilling fluid.</p>	<p>Number of bores and volume: Represents maximum number of bores and volume per bore reflecting worst case scenario.</p> <p>Number of rigs and single bore modelled: Whilst the Project Design Envelope allows for concurrent HDD activities, works will be managed so that break out activities will occur sequentially (i.e. 1 break out activity is undertaken at once). Although there will be up to 13 HDD bores, only 1 activity has been modelled in a central location to provide a representative drill release scenario.</p> <p>Tidal modelling assumption: The modelled release point at mid-tide on a peak spring has the potential to transport the sediment plume furthest. This is a worst-case impact in terms of extent. The HDD release at slack water on a neap tide is also modelled which will likely result in a higher SSCs. However, this will likely be over a smaller area.</p> <p>Drill release duration: Release over 1 hour is a reasonable worst-case for SSCs.</p>

Offshore Project Activity and Associated Physical Processes (Impact Pathway)	Maximum Design Scenario	Maximum assessment assumptions	Justification
<p>HDD Exit Pit Construction: resulting in physical disturbance to the seabed and temporarily increase suspended sediment concentrations and sediment deposition from mobilised sediment.</p>	<p>Number of Exit Pits: Excavation of up to 13 HDD exit pits by rock cutting or grinding.</p> <p>Sediment volume:</p> <ul style="list-style-type: none"> Maximum volume of sediment excavated per HDD Exit Pit: 75 m length x 5 m width x 3.5 m depth = 1,312.5 m³; Maximum volume of sediment excavated from all 13 exit pits is 17,062.5 m³. 	<p>Sediment types: Assessment considers range of sediment sizes which could be released by rock cutting or grinding.</p>	<p>Drill fluid density: 27% represents worst case drill cutting percent.</p> <p>Number of Exit Pits: 13 exit pits equate to 1 per each of the 12 Array Cables and an additional contingency exit pit to account for exit pit collapse, reflecting the maximum number of exit pits the Offshore Project may construct.</p> <p>Sediment types: The methods (cutting or grinding) for constructing the HDD exit pit construction may release fine or coarse sediment into the water column. There is also uncertainty around sediment properties in the Exit Pit Area and therefore it is appropriate to assess a range of sediment sizes. Coarse and fine sediments behave in different ways and so represent a worst-case for different situations (for example finer sediments can be advected over a greater distance by currents, however coarser sediments will settle in smaller areas with larger deposition thicknesses).</p> <p>Sediment volume: Represents greatest volume of sediment that could be released into the water column during the excavation of a single exit pit. The HDD drill cutting release models a similar volume of sediment release for fine sediment in the same location and likewise with Array Cable trenching for coarse sediment.</p>
Operation and Maintenance			
<p>Presence of Infrastructure: Effects related to presence of infrastructure; causing alterations to the baseline sediment transport regime resulting in changes to erosion/accretion rates at the surrounding coastline.</p>	<p>Scenario 1: (60 WTGs connected to 1 OSP and then to Landfall):</p> <p>Number of WTG and OSP:</p> <ul style="list-style-type: none"> Presence of 60 multi-leg jacket foundations with pin piles. Each multi-leg jacket pile foundation will have up to 4 legs, each spaced 30-55 m apart at seabed level and 15-35 m apart at MSL. Each leg will have a maximum diameter of 5 m; Presence of 1 OSP multi-leg jacket foundation with pin piles. Maximum number of legs 8 with up to 2 pin piles per leg. Each leg will be spaced 30-60 m apart at seabed level and 10-40 m apart at MSL. Each leg will have a maximum diameter of 6 m. Layout of 60 WTGs and 1 OSP shown in Figure 9-1, Volume 2b. <p>Duration: Duration is up to 35 years.</p>	<p>Multi-leg jacket foundation modelling assumption: The WTGs and OSP have been modelled as solid circular structures with constant 50 m diameter throughout water column.</p>	<p>Number of WTGs and OSP: Represents largest number of WTGs and OSP which has greatest spatial extent and therefore greatest potential for blockage effects/scour.</p> <p>Duration: up to 35 year duration is considered the maximum temporal extent related to presence of infrastructure.</p> <p>Multi-leg jacket foundation modelling assumption: Solid structures in the water column are a worst-case for blockage effects and better resolved in the resolution of the model mesh (see Section 2.4.2 in Appendix 9.2, Volume 2c for further details).</p>

Offshore Project Activity and Associated Physical Processes (Impact Pathway)	Maximum Design Scenario	Maximum assessment assumptions	Justification
<p>Maintenance of Infrastructure: Array Cable to Final WTG and Array Cable to Landfall maintenance works resulting in sediment disturbance and seabed change (e.g. temporary increase in suspended sediment concentrations and deposition from mobilised sediment, localised changes to sediment transport).</p>	<p>Total short-term seabed disturbance from all components of the Offshore Project = 27,610,800 m² (27.610 km²): Maintenance activities includes major/minor component replacement and repairs, scheduled inspections and unscheduled maintenance of offshore infrastructure, with repairs and replacement required on an ad hoc basis. It is estimated that the maintenance activities will require:</p> <p>WTG short term disturbance:</p> <ul style="list-style-type: none"> • Major component replacements: up to x 3 per WTG over lifetime (180 total); • Minor component replacements: up to x 10 per WTG per year (21,000 total); • Seabed disturbance per replacement using Jack Up Vessel: Area of spun cans (280 m²) x number of positions (2) = 560 m²; • Total short term seabed disturbance of WTGs: 21,180 x 560 m² = 11,860,800 m² (11.86 km²). <p>Array Cables short term disturbance:</p> <ul style="list-style-type: none"> • Reburial/protection replacement of exposed Array Cable section up to 6 times across Offshore Project lifetime; • Repair and replacement of Array Cables required: up to 9 times during lifetime; • Seabed disturbance for Array Cables (as per construction): 1,750,000 m² (1.75 km²); • Total short term seabed disturbance of Array Cables: 9 x 1,750,000 m² = 15,750,000 m² (15.750 km²). 	<p>N/A</p>	<p>Construction phase maximum design scenario: Maintenance activities are expected to occur with a lower intensity than those during construction. It is assumed that Array Cables will require reburial/protection up to 6 times across the Offshore Project lifetime, and will be repaired or replaced up to 9 times across the Offshore Project lifetime. As such, construction activities are assumed to represent a maximum design scenario.</p> <p>No modelling has been done for SSC during the O&M phase, but levels are expected to be equal to or lower than during construction. This is because the 'multiple activities' modelling scenario, during the construction phase, simulated a maximum suspended sediment concentration during drilling of 4 WTG foundations (each with 4 piles), and burial of cables (assuming drilling and cable burial activities happen sequentially) per month. It is not expected that such large-scale works will be undertaken during the O&M phase. Therefore, temporary increase in suspended sediment concentrations and sediment deposition during operation and maintenance will be of lower magnitude and frequency than that of construction.</p>

Offshore Project Activity and Associated Physical Processes (Impact Pathway)	Maximum Design Scenario	Maximum assessment assumptions	Justification
Decommissioning			
<p>Removal of WTG foundations and cables: Physical disturbance to the nearshore seabed has the potential to mobilise sediment or cause localised changes to sediment transport.</p> <p>Removal of HDD Exit Pits: in the OCAS resulting in physical disturbance to the seabed and temporarily increase suspended sediment concentrations and sediment deposition from mobilised sediment.</p>	<p>The decommissioning sequence will generally be the reverse of the construction sequence and involve similar types and numbers of vessels and equipment. Activities equivalent to or less than the Construction phase. This is because, unlike construction, seabed clearance is not expected to be required for foundation installation or along cable routes. Any seabed clearance during decommissioning is likely to be limited to the placement of jack-up vessel legs. The assumptions for the construction phase therefore apply.</p> <p>Following the operation and maintenance phase, components of the Offshore Project may be left in-situ to avoid unnecessarily disturbing the seabed (i.e. where marine habitat has formed). This could include scour protection associated with the WTG foundations and sections of the Offshore Cable. The potential for infrastructure to remain in-situ will be confirmed through consultation on the Decommissioning Programme to ensure the most suitable approach is taken. At this stage it is unconfirmed which components (if any) would remain in-situ. As such, under the maximum design scenario for increases in suspended sediment concentrations and associated sediment deposition during decommissioning it has been assumed that all infrastructure would be removed.</p> <p>Decommissioning programme: Maximum duration is up to 5 years.</p>	<p>N/A</p>	<p>Construction phase maximum design scenario: Decommissioning activities are expected to occur with a lower intensity than those during construction, as such, construction activities represent a maximum design scenario.</p>

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9.7.2 EMBEDDED MITIGATION MEASURES

- 9.7.2.1 As part of the Offshore Project design process, a number of embedded mitigation measures have been adopted to reduce the potential for impacts on Physical and Coastal Processes. These have evolved over the development process as the EIA has progressed and in response to consultation.
- 9.7.2.2 The embedded mitigation measures include those that have been identified as good or standard practice and include actions that would be undertaken to meet existing legislation requirements. As there is a commitment to implementing the embedded mitigation, and also to various standard sectoral practices and procedures, they are considered inherently part of the design of the Offshore Project and are set out in this EIAR.
- 9.7.2.3 **Table 9-21** sets out the relevant embedded mitigation measures within the design and how these affect the Physical and Coastal Processes assessment.

Table 9-21 Relevant Physical Processes embedded mitigation measures

ID	Environmental measure proposed	Project Phase Measure Introduced	How the environmental measures will be secured	Relevance to Physical and Coastal Processes Assessment
M001	The outputs of the project-specific site investigation surveys, will be reviewed to ensure that the final design and location of key project infrastructure takes full account of the physical environment and considers the potential for long-term changes. The mitigation hierarchy will be applied to avoid any sensitive areas identified, as far as is possible, by micrositing wind turbine generators (WTG) and cables.	Pre-Construction	To be secured through a condition of the Section 36 consent and Marine Licence.	Pre-construction surveys will Inform the placement plan for the WTG and Offshore Cables to limit disturbance to the existing environment and associated physical processes, and any identified designated sites of geological interest.
M002	A Cable Installation Plan will be produced to confirm routing, method of installation and aspects such as target Depth of Burial and need for/location of/type of external cable protection. This Plan will also contain the outputs of a formal Cable Burial Risk Assessment (CBRA). Data from the project-specific geophysical surveys will be used to identify the preferred route, with the use of natural crevasses or channels within the bedrock proposed, where feasible, and areas of thicker Quaternary sediments identified (to maximise opportunities for cable burial).	Pre-Construction, Construction	Secured in the Section 36 Consent and/or Marine Licence conditions. Details will be provided within the Cable Installation Plan.	The Cable Installation Plan will inform the routing locations, installation method, cable protection, and any required burial trench dimensions (depth) to ensure Offshore Cables are appropriately installed, to limit the degree of sediment disturbance.
M019	A final Offshore Environmental Management Plan (OEMP) will be developed prior to commencement	Construction	Secured in the Marine Licence via the condition	The EMP will be used for the implementation of appropriate environmental management

ID	Environmental measure proposed	Project Phase Measure Introduced	How the environmental measures will be secured	Relevance to Physical and Coastal Processes Assessment
	of construction (building on Outline Offshore EMP, Volume 3) in compliance with legislative requirements and/or best practice standards and guidance and adhered to.		for an EMP to be submitted to MD-LOT for approval.	and control measures during the construction phase of the Offshore Project. The EMP will follow industry best practices to limit disturbance (i.e. minimise sediment disturbance and seabed change) to the natural environment and offset potential impacts to physical and coastal processes, through compliance with s.36 and marine licence conditions.
M020	A Decommissioning Plan will be developed prior to the construction of the Project in compliance with legislative requirements and/or best practice standards and guidance and adhered to.	Decommissioning	Secured in the Marine Licence via the condition for a Decommissioning Plan to be submitted to MD-LOT for approval and the Energy Act 2004	The Decommissioning Plan will Inform the approach and programme for decommissioning the Offshore Project, with due consideration and definition of measures to limit disturbance to the residual natural environment and physical processes during and after removal of Offshore Project infrastructure
M025	A final Operational & Maintenance (O&M) Plan (building on Outline Operational & Maintenance Plan, Volume 3) will be developed in compliance with legislative requirements and/or best practice standards and guidance prior to the operation of the Project and adhered to.	Operation and Maintenance.	To be secured through a condition of the Section 36 consent and Marine Licence.	Offshore maintenance and repair activities will align with legislative and best practice guidance detailed in the O&M Plan which will minimise and reduce disturbance to existing physical and coastal processes. Routine inspections of Array Cables will be detailed in the O&M Plan to ensure Array Cables are functioning as intended and disturbance to the seabed is minimised,

ID	Environmental measure proposed	Project Phase Measure Introduced	How the environmental measures will be secured	Relevance to Physical and Coastal Processes Assessment
				routine inspections are vital to inform when repair and maintenance of Array Cables is required.



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9.8 ASSESSMENT OF EFFECTS: CONSTRUCTION PHASE

9.8.1 SEDIMENT DISTURBANCE AND SEABED CHANGE

9.8.1.1 As detailed in Section 9.7.1 a numerical modelling assessment of potential sediment transport has been undertaken to assess sediment disturbance and seabed change related to the Offshore Project activities, using tidal current velocities and the results from the sub-tidal sediment geotechnical surveys as key parameters. Please refer to **Appendix 9.2, Volume 2c** for more details on the methodology and findings of this assessment.

9.8.1.2 The maximum design scenarios relating to sediment disturbance and seabed change during the construction phase are presented in **Table 9-20**. This includes the following activities as identified in **Table 9-5**:

- Drilling of Pin Piles to Install WTG Foundations – Turbine Area;
- Burial of Array Cables to Final WTG – Array Area;
- Burial of Array Cables to Landfall - OCAS;
- HDD Activities - Drill Cutting Release and Exit Pit Construction.

9.8.1.3 The section below sets out the magnitude of impact to sediment disturbance and seabed change arising as a result of these activities.

Magnitude

Drilling of Pin Piles to Install WTG Foundations – Turbine Area

Sediment Disturbance

9.8.1.4 Based on the maximum design scenario detailed in **Table 9-20** and the sediment transport assessment (**Appendix 9.2, Volume 2c**), sediment in the Turbine Area could travel approximately:

- 12-15 km in the southwest of the Turbine Area due to presence of fine silt/clay sediments;
- 3 km in the central and northeast sections of the Turbine Area since sediments predominantly comprise sandy substrates.

9.8.1.5 Sediment plumes in the southwest of the Turbine Area are expected to be up to 500 m wide with a concentration generally less than 40 mg/l. Once the sediment is released during drilling, it remains in suspension within the water column for approximately 12 hours after completion of drilling.

9.8.1.6 Sediment plumes in the central and northeast sections of the Turbine Area are expected to extend to a distance of 300 m wide with a concentration of up to 5 mg/l away from the modelled turbine location. Once the sediment is released during drilling, it remains in suspension for less than an hour since greater current speeds greater than approximately 0.35 m/s are required for the sediment to remain in suspension.

9.8.1.7 Considering the embedded Offshore Project mitigation measures detailed within **Table 9-21**, specifically M001, M019, the magnitude of impact to sediment disturbance is predicted to be **Low adverse** because of the near-field spatial extent with scale of impact smaller than the natural variability, frequently occurring over a short/temporary timescale.

Seabed Change

9.8.1.8 From the sediment transport assessment (**Appendix 9.2, Volume 2c**), sediment deposition resulting from activities associated with the turbine foundation installation (as a worst case) range from 0-30 cm depending on location and tidal conditions during construction.

9.8.1.9 The largest deposition thickness of 30 cm occurs in the immediate vicinity (<1 km in the direction of the tidal current, up to 200 m wide) of the construction of individual activities. Generally, deposition thicknesses resulting from turbine installation are less than 1 cm at a maximum distance of 7.5 km in the direction of the tidal current (over an area up to 1 km wide) from the modelled turbine location. It is noted in Section 3.4.2 of **Appendix 9.2, Volume 2c** that the sediment in the Turbine Area is frequently mobilised by tidal currents and waves. Therefore, any deposited sediments on the seabed are likely to be mobilised within a short period of time by hydrodynamic forces.

9.8.1.10 Furthermore, the sediment releases are predicted to involve low volumes of sediment over a limited portion of the overall tidal cycle, constrained to a localised spatial extent, and deposition thickness generally less than 1 cm. Therefore, the magnitude of impact to seabed change is expected to be **Low adverse**, because of the near-field spatial extent with the scale of impact smaller than the natural variability, frequently occurring over a short/temporary timescale.

Burial of Array Cables to Final WTG - Array Area

Sediment Disturbance

9.8.1.11 The information in this section is based on the maximum design scenario detailed in **Table 9-20** and the sediment transport assessment (**Appendix 9.2, Volume 2c**).

9.8.1.12 When accounting for the presence of predominantly fine silt/clay sediments in the southwest of the Array Area sediment could travel approximately 10 km, with sediment plumes expected to be up to 450 m wide with a concentration ranging from 5-100 mg/l. Once the sediment is released during cable burial it remains in suspension within the water column for most of the tidal cycle (up to approximately 12 hours after cable burial is completed).

9.8.1.13 When accounting for the presence of predominantly sandy substrates in the central and northeast sections of the Array Area sediment could travel approximately 500 m, with sediment plumes expected to be up to 500 m wide with a concentration ranging from 200-300 mg/l for individual activities. Once sediment is released during cable burial it remains in suspension within the water

column for less than an hour since greater current speeds, greater than approximately 0.35 m/s, are required for the sediment to remain in suspension.

9.8.1.14 Maximum transport distances occur when construction activities take place during a peak spring tide current velocity window (with the sediment plume expected to be constrained within 2 m above the seabed).

9.8.1.15 Therefore, considering the embedded Offshore Project mitigation measures detailed within **Table 9-21**, specifically M001, M002, and M019, the magnitude of impact to sediment disturbance **Low adverse**, because of the near-field spatial extent with scale of impact smaller than the natural variability, frequently occurring over a short/temporary timescale.

Seabed change

9.8.1.16 The largest deposition thickness of 10 cm occurs in the immediate vicinity (<400 m) of the construction activity for individual activities. Generally, deposition thicknesses resulting from the activities associated with Array Cable installation is less than 1 cm at a maximum distance of approximately 5 km. It is noted in Section 3.4.2 of **Appendix 9.2, Volume 2c** that the sediment in the Array Area is frequently mobilised by tidal currents and waves based on empirical calculations derived from Soulsby and Clarke (2005).

9.8.1.17 Therefore, any sediments deposited on the seabed are likely to be mobilised within a short period of time by hydrodynamic forces. Therefore, the magnitude of impact to seabed change is expected to be **Low adverse**, because of the near-field spatial extent with the scale of impact smaller than the natural variability, frequently occurring over a short/temporary timescale.

Multiple Activities (drilling of pin piles to install WTG Foundations – Turbine Area and burial of Array Cables to Final WTG – Array Area)

9.8.1.18 In addition to the activities considered individually above, multiple activities have also been assessed and modelled to determine maximum suspended sediment concentration and sediment deposition thickness concentration arising during the drilling of pin piles and cable burial activities. These activities, which have been assumed to occur sequentially within the Array Area, have been modelled as a maximum design scenario (see paragraph 9.7.1.5 and Section 4.6 of **Appendix 9.2, Volume 2c** for further details).

Sediment Disturbance

9.8.1.19 When considering the drilling of pin piles to install WTG Foundations and burial of Array Cables to Final WTG, the worst-case scenario in terms of increase in suspended sediment concentration results from the southwest drilling of piles to install WTG foundations and sequential Array Cables to Final WTG burial, reaching up to 450 mg/l for a brief period (less than hour) within 500 m of the activity. At a specific location in the southwest of the Turbine Area, suspended sediment concentrations exceed the 25 mg/l threshold for around 3 days and exceeds background

concentration of 0.5 mg/l for around 13 days (see specific location (location 3) depicted in Plate 4-32, **Appendix 9.2, Volume 2a**).

9.8.1.20 When considering the embedded Offshore Project mitigation measures detailed within **Table 9-21**, specifically M001, M002, and M019, the magnitude of impact to sediment disturbance is **Low adverse**, because of the near-field spatial extent with scale of impact smaller than the natural variability, frequently occurring over a short/temporary timescale.

Seabed change

9.8.1.21 When considering the maximum sediment deposition from the modelling of multiple activities (drilling of pin piles to install WTG Foundations and burial of Array Cables to Final WTG), deposition does not exceed the deposition from individual activities given the temporal and spatial variation between activities in relation to the tidal cycle, and potential for resuspension of sediment between subsequent activities.

9.8.1.22 It is noted in Section 3.4.2 of **Appendix 9.2, Volume 2c** that the sediment in the Array Area is frequently mobilised by tidal currents and waves based on empirical calculations derived from Soulsby and Clarke (2005). Therefore, any sediments deposited on the seabed are likely to be mobilised within a short period of time by hydrodynamic forces. Therefore, the magnitude of impact to seabed change is expected to be **Low adverse**, because of the near-field spatial extent with the scale of impact smaller than the natural variability, frequently occurring over a short/temporary timescale.

Burial of Array Cables to Landfall - Offshore Cable Area of Search

Sediment Disturbance

9.8.1.23 Based on the maximum design scenario detailed in **Table 9-20** and the modelling of sediment transport being mobilised by the activities associated with the cable burial (**Appendix 9.2, Volume 2c**), sediment in the OCAS could travel approximately 200 m with maximum concentrations above 350 mg/l (up to 840 mg/l at an isolated location but across an area of 10 m^2). Once sediment is released during cable burial it remains in suspension for less than 15 minutes due to the coarse size of the sediment.

9.8.1.24 The sediment transport modelling (**Appendix 9.2, Volume 2c**) shows that suspended sediment in the OCAS could travel maximum distances occurring when construction activities take place during a peak spring tide current velocity window (with the sediment plume expected to be constrained within 2 m above the bed).

9.8.1.25 The impacts of cable burial activities from adjacent cables may occur within the OCAS as this is where Array Cables to Landfall will be located in close proximity to each other (in comparison to the Array Cables to Final WTGs). In the case of suspended sediment concentrations, maximum values occur at the location of the cable burial and decrease rapidly with distance in the direction

of the tidal current. Assuming that cables are buried equally spaced at 150 m across the width of the OCAS (2 km), the impacts of adjacent cables are not expected to be greater than the maximum impacts along the individual cables. This is based on the model between Landfall and the Array Area indicating a potential zone of influence of approximately 100 m centred on the cable burial route.

9.8.1.26 Within the OCAS, sediments predominantly comprise coarse gravels which fall out of suspension almost immediately. Therefore, considering the embedded Offshore Project mitigation measures detailed within **Table 9-21**, specifically M001, M002, and M019, the magnitude of impact to sediment disturbance **Low adverse**, because of the near-field spatial extent with scale of impact smaller than the natural variability, frequently occurring over a short/temporary timescale.

Seabed change

9.8.1.27 The largest deposition thickness of 10 cm occurs in the immediate vicinity (<100 m) of the Array Cable to Landfall burial. Generally, deposition thicknesses resulting from Array Cable to Landfall installation is less than 1 cm at a maximum distance of 250 m. As noted in Section 3.4.2 of **Appendix 9.2, Volume 2c**, waves greater than 5 m would generate bed shear stresses high enough to mobilise this sediment. Waves of this height are frequently recorded, and the water depth of the OCAS is large enough for this height to be sustained as the wave travels towards the shoreline.

9.8.1.28 Given the previously discussed assumptions that cables are buried equally spaced at 150 m across the width of the OCAS (2 km), the impacts of cable burial activities from adjacent cables are not expected to be greater than the maximum impacts along the individual cables. This includes sediment deposition and is based on the model between Landfall and the Turbine Area indicating a potential zone of influence of approximately 100 m centred on the cable burial route.

9.8.1.29 Therefore, the magnitude of impact to seabed change is expected to be **Low adverse**, because of the near-field spatial extent with the scale of impact smaller than the natural variability, frequently occurring over a short/temporary timescale.

HDD Drill Cutting Release

9.8.1.30 The release of HDD drill cuttings has the potential to release drilling fluid, muds and very low levels of bentonite into the water column (see **Table 9-20**). The Landfall Exit Pit Area is approximately 500-1,500 m offshore, in water depths of 15-27 m MSL (see **Figure 9-13, Volume 2b**). The release of HDD drill cuttings was modelled at a central location approximately 850 m offshore at a water depth of approximately 23 m MSL (see Plate 2-7, **Appendix 9.2, Volume 2c**).

Sediment Disturbance

9.8.1.31 The sediment transport modelling (**Appendix 9.2, Volume 2c**) shows that sediment in this location could travel approximately 6 km when HDD drill cuttings are released during a peak spring tide

current velocity window (with the sediment plume expected to be constrained within 2 m above the bed). Maximum SSCs of 1,000 mg/l were recorded up to 1 km from the HDD modelling location (plume width up to 250 m) and up to 50 mg/l 6 km away with plume width up to 2 km.

- 9.8.1.32 During a neap tide current velocity window, sediment in this location could travel approximately 3 km. Maximum SSCs from individual releases are 1,000 mg/l up to 1 km from the HDD modelling location (plume width up to 300 m) and up to 50 mg/l up to 3 km away (plume width up to 1 km).
- 9.8.1.33 Once the sediment is released following breakout of the HDD bore, it remains in suspension within the water column for most of the tidal cycle (approximately 12 hours after drill release is completed).
- 9.8.1.34 Since the disturbance is predicted to involve very low volumes of sediment release over a very limited portion of the overall tidal cycle and constrained to a localised spatial extent; and considering the embedded Offshore Project mitigation measures detailed within **Table 9-21**, specifically M001, M002, and M019, the magnitude of impact to sediment disturbance is **Low adverse**, because of the near-field spatial extent with scale of impact smaller than the natural variability, frequently occurring over a short/temporary timescale.

Seabed change

- 9.8.1.35 The sediment transport modelling (**Appendix 9.2, Volume 2c**) shows that sediment deposition thicknesses resulting from HDD drill cutting release are up to 7 mm in the immediate vicinity (<500 m) of the HDD construction activity. Generally, deposition thickness is less than 1 mm at a maximum distance of 4 km depending on the tidal conditions during construction. It is noted in Section 3.4.2 of **Appendix 9.2, Volume 2c** that the sediments are frequently mobilised by tidal currents and waves. Therefore, any deposited sediments on the seabed are likely to be mobilised within a short period of time by hydrodynamic forces.
- 9.8.1.36 Therefore, the magnitude of impact to seabed change is expected to be **Low adverse**, because of the near-field spatial extent with the scale of impact smaller than the natural variability, frequently occurring over a short/temporary timescale.

HDD Exit Pit Construction

- 9.8.1.37 The construction of HDD Exit Pits has the potential to mobilise sediment into the water column (see **Table 9-20**). The Landfall Exit Pit Area is located approximately 500-1,500 m offshore, in water depths of 15-27 m MSL (see **Figure 9-13, Volume 2b**).

Sediment Disturbance

- 9.8.1.38 The sediment transport modelling (**Appendix 9.2, Volume 2c**) shows that the maximum SSCs caused by HDD exit pit construction are expected to range between 350 mg/l (within 200 m of HDD exit pit construction) and 1,000 mg/l (within 1 km of HDD exit pit construction) for coarse and

fine sediment respectively. SSCs are expected to be elevated above baseline condition for up to 2 days for the full range of sediment sizes.

9.8.1.39 Since the disturbance is predicted to involve low volumes of sediment release constrained to a localised spatial extent; and considering the embedded Offshore Project mitigation measures detailed within **Table 9-21**, specifically M001, M002 and M019, the magnitude of impact to sediment disturbance is **Low adverse**, because of the near-field spatial extent with scale of impact smaller than the natural variability, frequently occurring over a short/temporary timescale.

Seabed change

9.8.1.40 The maximum sediment deposition thicknesses caused by HDD exit pit construction are expected to range between 3 cm (within 400 m of HDD exit pit construction) and 7 mm (within 500 m of HDD exit pit construction) for coarse and fine sediment respectively. It is noted in Section 3.4.2 of **Appendix 9.2, Volume 2c** that the smaller sediments are frequently mobilised by tidal currents and waves. The deposition of finer sediments will not remain for a significant period of time (within an hour) due to resuspension from the natural hydrodynamic regime.

9.8.1.41 Therefore, sediments deposited on the seabed are likely to be mobilised within a short period of time by hydrodynamic forces. Therefore, the magnitude of impact to seabed change is expected to be **Low adverse**, because of the near-field spatial extent with the scale of impact smaller than the natural variability, frequently occurring over a short/temporary timescale.

Multiple Activities (HDD Drill Cutting Release and HDD Exit Pit Construction)

9.8.1.42 In addition to the HDD activities considered individually above, sequential HDD activities (HDD exit pit construction and HDD drill cutting release) have also been quantitatively assessed in **Appendix 9.2, Volume 2c** to determine maximum suspended sediment concentration and sediment deposition thickness concentration arising during HDD Exit Pit construction and HDD drill cutting release.

Sediment disturbance

9.8.1.43 If multiple HDD activities (HDD exit pit construction and HDD drill cutting release) occur within 2 days, then there could be accumulation of suspended sediment within 1 km of the activities. Suspended sediment concentrations are expected to return to baseline conditions within 2 days of a construction activity taking place. This is based on a worst-case assumption that the activities are aligned in the direction of the tidal current (i.e. the direction where sediment advection distances are the largest).

9.8.1.44 The disturbance is predicted to involve low volumes of sediment release constrained to a localised spatial extent; and considering the embedded Offshore Project mitigation measures detailed within **Table 9-21**, specifically M001, M002 and M019, the magnitude of impact to sediment disturbance

is **Low adverse**, because of the near-field spatial extent with scale of impact smaller than the natural variability, frequently occurring over a short/temporary timescale.

Seabed change

9.8.1.45 The potential impacts of sediment deposition from multiple HDD activities (HDD exit pit construction and HDD drill cutting release) occurring in a single location or multiple locations have been considered in **Appendix 9.2, Volume 2c**.

9.8.1.46 In a single location, the worst-case sediment deposition thickness from multiple HDD activities (i.e. HDD exit pit construction and HDD drill cutting release) is limited by the by the natural re-mobilisation of sediments by tidal currents and waves. The maximum deposition thickness resulting from HDD exit pit construction or drill cutting release is 7 mm for fine sediments. The sediment will be re-mobilised by tidal currents and waves under normal conditions so preventing accumulation even where activities overlap. For coarse sediments, combined deposition from overlapping HDD exit pit construction and release of drilling fluids could reach up to 4 cm. This will be limited to the single location where the HDD exit pit and release of drill cuttings overlap.

9.8.1.47 Sediment may accumulate due to multiple activities occurring in multiple locations within the Exit Pit Area. Sediment deposition thickness decreases with distance from the construction activity in the direction of the tidal current. Sediment deposited due to release of drill cuttings is assumed to be re-mobilised by tidal currents and waves in normal conditions so is expected to not accumulate significantly across different locations. This also applies to fine sediments released by HDD exit pit construction. For coarser sediments released by HDD exit pit construction, sediment could accumulate by up to a maximum of 3 cm per HDD exit pit within 400 m of each other if 100% of the sediment is assumed to be coarse, and the HDD exit pit locations are directly aligned in the direction of the tidal current.

9.8.1.48 Sediments deposited on the seabed are likely to be re-mobilised within a short period of time by hydrodynamic forces. Therefore, the magnitude of impact to seabed change is expected to be **Low adverse**, because of the near-field spatial extent with the scale of impact smaller than the natural variability, frequently occurring over a short/temporary timescale.

Sensitivity or value of receptor

9.8.1.49 The sensitivity described for each receptor is based on the criteria provided in **Table 9-9**. Based on the potential maximum distance travelled, marine sediments released from the construction of HDD Exit Pits have the potential to affect the surrounding sub-tidal seabed and surrounding coastline and marine protected areas.

Surrounding sub-tidal seabed

9.8.1.50 The sensitivity of the surrounding sub-tidal seabed receptor is **Low**. This is on the basis that the receptor is of a regional or local value and is considered to have reasonable tolerance to long term

impacts as it will be routinely exposed to periods of elevated suspended sediment during winter storm events

Surrounding coastline

9.8.1.51 Whilst the value of the surrounding coastline receptor is **High**, overall, the sensitivity of this receptor to temporary uplifts in suspended sediment is considered to be **Low**. This is on the basis that in the long term the coastline will be routinely exposed to periods of elevated suspended sediment during winter storm events.

Designated Sites of Geological Interest

9.8.1.52 Whilst the value of the designated site of geological interest receptor is **High**, overall, the sensitivity is **Low**. This is on the basis that in the long term the GCR will be routinely exposed to periods of elevated suspended sediment during winter storm events and subsequent deposition of mobilised sediment following storm events.

Significance of effect

9.8.1.53 The Offshore Project embedded mitigation measures (as shown in **Table 9-21**) include M001, M002 and M019, alongside adherence to the Offshore Environmental Management Plan (EMP), to reduce the impact of sediment disturbance and seabed change. Overall, it is predicted that the magnitude of impact of sediment disturbance and seabed change is **Low**. The sensitivity of the receptors (i.e. sub-tidal seabed, surrounding coastline and designated site of geological interest) is **Low**. Therefore, the effect will be **Negligible**, which is **Not Significant** in EIA terms.

9.8.2 FURTHER ENVIRONMENTAL MITIGATION AND RESIDUAL EFFECT

9.8.2.1 No additional Physical and Coastal Processes mitigation is considered necessary because the likely effect in the absence of further mitigation (beyond the embedded commitments outlined in Section 9.7.2) is not significant in EIA terms.

9.9 ASSESSMENT OF EFFECTS: OPERATION AND MAINTENANCE

9.9.1 SEDIMENT DISTURBANCE AND SEABED CHANGE

9.9.1.1 Potential impacts associated with sediment disturbance and seabed change have been considered to assess long term sediment transport effects over the period of O&M. Activities associated with O&M are expected to occur with a lower intensity than those during construction, see justification provided in **Table 9-20**. As such, construction activities are assumed to represent the maximum design scenario. Given that sediment disturbance and seabed change as a result of construction activities are not anticipated to result in significant effects on receptors (i.e. sub-tidal seabed, surrounding coastline and designated sites of geological interest), it is not anticipated that activities during O&M will lead to significant effects either.

9.9.2 EFFECTS RELATED TO THE PRESENCE OF INFRASTRUCTURE

- 9.9.2.1 Based on the Physical and Coastal Processes Modelling Results Report (**Appendix 9.2, Volume 2c**), during the O&M phase, there is potential for blockage effects due to the presence of offshore wind turbine structures causing potential changes to hydrodynamics (water levels and current speeds), seabed (scour), waves, and stratification.
- 9.9.2.2 The maximum design scenario relating to potential blockage effects during the O&M phase are presented in **Table 9-20**.
- 9.9.2.3 The magnitude of impact is based on the criteria detailed in Section 5.7.5 and **Chapter 5, Volume 1a**. A description of the likely magnitude of impact on receptors caused by each identified impact is given below.

Magnitude

Water Depth

- 9.9.2.4 The change in maximum water depths between the baseline and post-development runs was calculated as less than ± 5 mm throughout the Turbine Area and OCAS. For the majority of areas, the difference was less than ± 2 mm. The largest changes were located in the immediate vicinity of the turbine structures.
- 9.9.2.5 Therefore, considering the embedded Offshore Project mitigation measures detailed within **Table 9-21**, specifically M001, M019, and M025. The magnitude of impact on water depth is predicted to be **Negligible** because of the localised spatial extent, with the scale of impact smaller than the natural variability, occurring infrequently over a short/temporary timescale.

Current Speed

- 9.9.2.6 The change in current speed during peak spring and neap flood and ebb currents within the Turbine Area both increases (between the turbines) and decreases (in the lee of the turbines) in speed occur with differences up to ± 0.05 m/s. The results are shown in Section 3.2.2 of **Appendix 9.2, Volume 2c**.
- 9.9.2.7 During neap tides, the differences are smaller and constrained to the Turbine Area. Larger differences occur during spring tides and differences of up to ± 0.005 m/s reach approximately 5 km away from the Turbine Area.
- 9.9.2.8 In general, reductions in maximum current speed of up to -0.04 m/s are observed in the lee of the turbine structures and do not extend significantly outside of the Turbine Area.
- 9.9.2.9 Therefore, considering the embedded Offshore Project mitigation measures detailed within **Table 9-21**, specifically M001, M019, and M025. The magnitude of impact on current speed is predicted to be **Negligible** because of the immediate spatial extent, with the scale of impact smaller than the natural variability, occurring infrequently over a short/temporary timescale.

Scour

9.9.2.10 Although the presence of seabed structures will ultimately lead to increased scour, the placement of rock and concrete scour protection measures will be incorporated into the Offshore Project's engineering and design to address this issue. These measures are planned to be implemented during construction and therefore no scour is expected to develop at the base of the foundations.

9.9.2.11 Therefore, considering the embedded Offshore Project mitigation measures detailed within **Table 9-21**, specifically M001, M002, M019, and M025. The magnitude of impact on scour is predicted to be **Negligible** because of the immediate spatial extent, with the scale of impact smaller than the natural variability, occurring infrequently over a short/temporary timescale.

Waves

9.9.2.12 Wave impacts relevant to O&M have been assessed for measured storm conditions as well as for extreme return period events, using the outputs of the Extreme Values Analysis (EVA) detailed in Section 3.3.2 of **Appendix 9.2, Volume 2c**.

9.9.2.13 The impacts of the turbines on measured storm conditions at the site have been assessed through an analysis of the differences in Significant Wave Height (Hs) in post-development conditions when compared to the baseline scenario.

9.9.2.14 Extreme events obtained through the EVA were utilised to investigate the response of the post-development scenario to incoming waves from 4 directional sectors: southwest, west, northwest, and north. The impact of structures on the wavefield in the Offshore Project Boundary is shown in **Plate 5-16** to **Plate 5-23** in Section 5.3.2 of **Appendix 9.2, Volume 2c**. These difference plots compare post-development results to those obtained from the baseline study using the same EVA outputs.

9.9.2.15 EVA outputs are included in **Table 9-22**, alongside the percentage change in the post-development scenario compared to the baseline, obtained from the maximum value within the difference plots. Maximum values are taken outside of the immediate wake effects to better show reductions to the wider area around the Turbine Area.

Table 9-22 Maximum percentage and absolute reduction in significant wave height

Direction	Significant Wave Height (m) for Return Period (years)					
	1 in 1-year Hs	Max % Change	Max Absolute Change	1 in 100-year Hs	Max % Change	Max Absolute Change
Southwest	6.40	4.69%	0.30	11.61	3.45%	0.40
West	8.01	4.37%	0.35	12.86	3.11%	0.40
Northwest	6.92	3.61%	0.25	11.16	2.69%	0.30
North	6.69	3.74%	0.25	10.48	2.39%	0.25

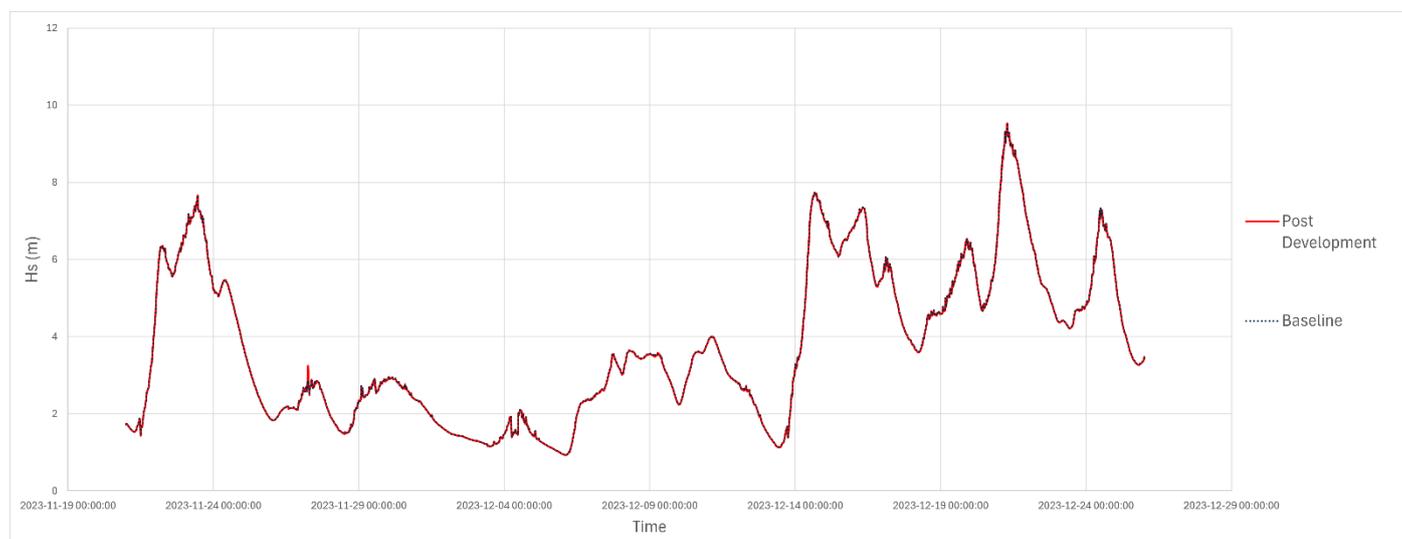
9.9.2.16 During the O&M phase, a decrease in wave height is seen to occur in lee of the Turbine Area, for both lower and higher return period events. The largest decreases are occurring for lower 1 in 1-year return period events, with the largest decrease occurring for a westerly significant wave height of 6.40 m. The reductions are lower for higher return period events, with the smallest decrease associated with a 1 in 100-year return period northerly significant wave height of 10.48 m.

9.9.2.17 In addition to the extreme events a 35-day period was simulated which includes a maximum Hs of 9.54 m, as well as a storm event with a Hs of 7.70 m, in line with 1 in 1-year return period events at the site. The differences between post-development conditions and baseline conditions are shown in **Plate 5-12** through **Plate 5-14** in Section 5.2.2 of **Appendix 9.2, Volume 2c**.

9.9.2.18 **Plate 9-5** shows the Hs timeseries comparison between the post-development and baseline runs for a point showing the highest difference increase in Hs (Easting 116997.56 Northing 960875.78).

9.9.2.19 **Plate 9-5** shows that there is minimal change in the baseline and post-development absolute significant wave height values, such that is barely visible in the timeseries comparison.

Plate 9-5 Hs Timeseries Extracted at Easting 116998 Northing 960876



9.9.2.20 Therefore, considering the embedded Offshore Project mitigation measures detailed within **Table 9-21**, specifically M001, M019, M025, and M020, the magnitude of impact on waves is predicted to be **Negligible** because of the immediate spatial extent, with the scale of impact smaller than the natural variability, occurring infrequently over a short/temporary timescale.

Stratification

9.9.2.21 A literature review has been carried out to qualitatively assess the magnitude of impact on stratification. Several studies have been conducted to look at the potential impacts of OWFs on water stratification both based on site observations and modelling. A summary of these studies is

provided in this section. These studies vary in methodology but provide useful conclusions which provide an understanding of the potential impacts of the Offshore Project.

9.9.2.22 In the study of monopiles located in the North Sea, Schultze *et al.*, 2020 states that foundation structures of offshore windfarms are shown to generate additional turbulence within the water column with monopiles shown to have a significant effect. This is due to the wake created by monopiles generating strong turbulence within the first 50–100 m downstream, dissipating within 300 m. As a result of the increased turbulence experienced within the water column, mixing of the water layers occurs. The study attributes the amount of mixing caused by monopiles to approximately 10% of the turbulence driven by bottom boundary layers which may have the potential to alter the balance between mixing and stratification buildup. However, the study concludes that the OWFs' mixing effect is comparable to natural stratification formation rates, particularly in the North Sea but highlights that larger scale wind farms may amplify these effects causing greater impact on the water column stratification.

9.9.2.23 Carpenter *et al.*, 2016 states that foundations were shown to generate turbulent wakes as tidal currents move past, leading to mixing of the stratified water column. This is particularly impactful in regions with large numbers of OWFs such as the German Bight region of the North Sea. The study identifies 2 critical time scales when looking at the stratification of the water column. These time scales are:

- How long it takes to fully mix the stratification;
- The duration for which a water parcel experiences enhanced wind farm mixing.

9.9.2.24 These time scales affect the amount of stratification that occurs and for how long the impacts last. The study goes on to conclude that the present capacity in the North Sea suggests that OWFs have a limited effect on large-scale stratification.

9.9.2.25 Carpenter *et al.* (2016) also hypothesised that drag forces from scour protection around foundations may further exacerbate turbulent mixing beyond the influence of foundations alone. In relation to the depth at which scour protection will be installed (i.e. the water depths within the OCAS), the influence of rock on the seabed is unlikely to contribute significantly to increased mixing. Therefore, the primary influence on stratification in this context will be the presence of the WTGs and OSP foundations.

9.9.2.26 Cazenave *et al.*, 2016 focuses on the localised effects of individual turbine monopiles and identifies a 5% reduction in peak velocities within a horizontal radius of around 1 km, or approximately 250 times the monopile diameter. Within the vertical water column, the monopiles were shown to induce significant mixing due to water flow around the structures. This is a result of increased vertical transport caused by monopiles which decreases stratification in seasonally stratified regions. This disturbance was shown to extend significantly beyond the monopile footprint. The study also highlights that there could be a significant decrease in stratification in the North Sea should a considerable portion of the shelf sea be filled with OWFs.

- 9.9.2.27 Dorrell *et al.*, 2022 focuses on the potential for increased water column mixing as a result of anthropogenic infrastructure in the marine environment. This study states that wind turbines introduce turbulence in stratified waters, breaking down induced vortices and mixing the water column. These effects are particularly complex in stratifications like the thermocline. However, the length scales of the mixing and consequence on stratification were less clearly defined, with local and natural topographical characteristics further influencing the development of stratification.
- 9.9.2.28 Current research shows that seasonally stratified shelf seas are influenced by surface heating (stratifying) and mechanical energy (mixing) from wind stress and tidal shear. The addition of anthropogenic mixing from large-scale wind farms disrupts this balance, complicating predictions for ecosystem trajectories. However, the research is limited on large-scale OWFs to understand their impact on stratification.
- 9.9.2.29 The study on Jacket Piles by Satari *et al.*, 2024 focuses on the hydrodynamic behaviour around the pile structures. The study highlights how the geometry of the jacket structure impacts flow patterns at various depths, creating flow acceleration and downflow/upflow variations. The variations in vertical flow dynamics could have the potential to affect the mixing of stratified layers in the water column. The results of the study found the emergence of strong downflows and upflows around specific structural components which may result in localised turbulence and disruption of stratified layers near the jacket structure. The study found the upflow to be dominant at higher velocities which could lead to changes in vertical transport processes, affecting stratification stability. In comparison to other pile groups, the jacket pile shows both similarities and differences in flow regimes around the structure which could imply the potential for specific hydrodynamic impacts.
- 9.9.2.30 Previous research highlights OWFs were found to introduce increased turbulence as a result of the wake around the piles. This has been shown to have the potential to cause the mixing of layers within the water column due to changes in velocity resulting from alterations to the hydrodynamics around the piles. Studies also indicated that the foundations of OWFs could cause changes within the Study Area, however the changes were considered relatively insignificant in comparison to naturally occurring variations in the stratification.
- 9.9.2.31 Based on the minimal baseline stratification in the Study Area and the findings of the literature review of the impact of OWFs on thermal stratification, the magnitude of impact that operation will have on stratification is considered to be **Negligible** because of the immediate spatial extent, with the scale of impact smaller than the natural variability, occurring infrequently over a short/temporary timescale.

Sensitivity or value of receptor

- 9.9.2.32 The sensitivity described for each receptor is based on the criteria provided in **Table 9-9**. Based on the potential changes to the hydrodynamic regime, blockage effects during the O&M phase have the potential to affect the surrounding sub-tidal seabed, surrounding coastline and offshore marine waters.

Surrounding sub-tidal seabed

9.9.2.33 The sensitivity of the surrounding sub-tidal seabed receptor is **Low**. This is on the basis that the receptor is of a regional or local value and is considered to have reasonable tolerance to long term impacts as it will be routinely exposed to elevated forcing from waves and currents during winter storm events.

Surrounding coastline

9.9.2.34 Whilst the value of the surrounding coastline receptor is **High** as the coastline is of national value, the sensitivity of this receptor to changes in hydrodynamics and waves is considered to be **Low**. This is on the basis that the coastline comprises bedrock outcrops which minimise coastal erosion. In addition, the coastline is routinely exposed to high wave energy during winter storm events.

Designated Sites of Geological Interest

9.9.2.35 Whilst the value of the designated site of geological interest receptor is **High**, overall, the sensitivity is **Low**. This is on the basis that the receptor is considered to have reasonable tolerance to long term impacts as it will be routinely exposed to elevated forcing from waves and currents during winter storm events.

Significance of effect

9.9.2.36 The Offshore Project embedded mitigation measures (**Table 9-21**) include M001, M002, M019, and M025, alongside adherence to the Operational & Maintenance Plan are proposed to reduce the impact of blockage effect. Overall, it is predicted that the magnitude of impact of the blockage effect to the hydrodynamics (water levels and current speeds), seabed (scour), waves, and stratification is **Negligible**. The sensitivity of the receptors (i.e. sub tidal seabed, surrounding coastline, marine coastal waters) is **Low**. Therefore, the effect will be **Negligible**, which is **Not Significant** in EIA terms.

9.9.3 FURTHER ENVIRONMENTAL MITIGATION AND RESIDUAL EFFECT

9.9.3.1 No additional Physical and Coastal Processes mitigation is considered necessary because the likely effect in the absence of further mitigation (beyond the embedded commitments outlined in Section 9.7.2) is not significant in EIA terms.

9.10 ASSESSMENT OF EFFECTS: DECOMMISSIONING

9.10.1 SEDIMENT DISTURBANCE AND SEABED CHANGE

9.10.1.1 The scope of the decommissioning works follows the guidance found in Marine Directorate (2022) Offshore renewable energy: decommissioning guidance for Scottish waters Guidance Notes (Scottish Government) or the guidance outlined in the Scottish part of the Renewable Energy Zone

under The Energy Act 2004: Guidance notes for industry (in Scotland/*Alba*). Decommissioning activities will comply with all relevant legislation at that time.

9.10.1.2 At the end of the operational lifetime of the Offshore Project, it is expected that WTGs and the OSP (if required) will be completely removed from the seabed. Decommissioning activities within the Offshore Project Boundary are expected to follow the reverse of the construction phase of the Offshore Project, with some infrastructure left in place, with surface infrastructure likely to be fully removed utilising similar types and number of vessels and equipment. The offshore decommissioning options for the Array Cables and subsurface foundation infrastructure will be discussed with stakeholders and regulators at point of decommissioning, however, sections may be left in situ to avoid unnecessarily disturbing the seabed.

9.10.1.3 During decommissioning (removal), as detailed in

9.10.1.4 **Table 9-5**, there is potential for sediment disturbance or seabed change. The maximum design scenarios relating to sediment disturbance or seabed change during the construction phase are presented in **Table 9-20**.

9.10.1.5 For the removal of all Array Cables and WTG Foundations, there is potential to disturb seabed sediment. Methods would be confirmed during specific decommissioning phase EIA closer to the time. However, activities would be similar, albeit potentially of lesser footprint, to those associated with the construction phase.

Magnitude

9.10.1.6 Assessment of sediment transport and deposition has been undertaken, the results of which are discussed in the construction phase (see Section 9.8.1 and in **Appendix 9.2, Volume 2c**). Based on this, the magnitude of impact to sediment disturbance and seabed change, associated with the removal of cables and turbine structures, is **Low**.

Sensitivity or value of receptor

9.10.1.7 The sensitivity described for each receptor is based on the criteria provided in **Table 9-9**. Based on the potential maximum distance travelled, marine sediments released from the decommissioning activities have the potential to affect the surrounding sub-tidal seabed, coastline and designated sites of geological interest.

Surrounding sub-tidal seabed

9.10.1.8 The sensitivity of the surrounding sub-tidal seabed receptor is **Low**. This is on the basis that the receptor is of a regional or local value and is considered to have reasonable tolerance to long term impacts as it will be routinely exposed to elevated suspended sediment during winter storm events.

Surrounding coastline

9.10.1.9 Whilst the value of the surrounding coastline receptor is **High**, the sensitivity of this receptor to temporary uplifts in suspended sediment is considered to be **Low**. This is on the basis that the coastline will be routinely exposed to temporary periods of elevated suspended sediment during winter storm events

Designated Sites of Geological Interest

9.10.1.1 Whilst the value of the designated site of geological interest receptor is **High**, overall, the sensitivity is **Low**. This is on the basis that in the long term the GCR will be routinely exposed to periods of elevated suspended sediment during winter storm events and subsequent deposition of mobilised sediment following storm events.

Significance of effect

9.10.1.2 The Offshore Project mitigation measure (**Table 9-21**) M020 is proposed to reduce the impact of sediment disturbance and seabed change. Overall, it is predicted that the magnitude of impact of sediment disturbance and seabed change is **Low**. The sensitivity of the receptors (i.e. PMFs, sub-tidal seabed and surrounding coastline) is **Low**. Therefore, the effect will be **Negligible**, which is **Not Significant** in EIA terms.

9.10.2 FURTHER ENVIRONMENTAL MITIGATION AND RESIDUAL EFFECT

9.10.2.1 No additional Physical and Coastal Processes mitigation is considered necessary because the likely effect in the absence of further mitigation (beyond the embedded commitments outlined in Section 9.7.2) is not significant in EIA terms.

9.11 ASSESSMENT OF COMBINED EFFECTS

9.11.1.1 The combined effects assessment considers likely significant effects from multiple impacts and activities from the construction, O&M, and decommissioning phases of the Offshore Project on the same receptor, or group of receptors. The overall method following in identifying and assessing potential Combined Effects in relation to the offshore environment is set out in **Chapter 5, Volume 1a**.

9.11.1.2 Combined effects could potentially arise in one of two ways. The first type of combined effect is a Project lifetime effect, where multiple phases of the Project (construction, O&M, and decommissioning) interact to create a potentially more significant effect on a receptor than in one phase alone.

9.11.1.3 The second type of combined effect is receptor-led effects. Receptor-led effects are where effects from different environmental aspects combine spatially and temporally on a receptor. These effects may be short-term, temporary, transient, or longer-term.

- 9.11.1.4 There are no receptor-led effects considered in this chapter for potential interactions between Physical and Coastal Processes.
- 9.11.1.5 Full results of the Project lifetime effects assessment can be found in **Chapter 23, Volume 2a**.

9.12 CONSIDERATION OF ONSHORE TRANSMISSION WORKS PROJECT

- 9.12.1.1 A separate application for the Project's onshore elements (the OTW Project) that includes all infrastructure landwards of Mean Low Water Springs (MLWS) within the Onshore Transmission Works Boundary will be made, under the Town and Country Planning (Scotland) Act 1997 to Comhairle nan Eilean Siar (CnES). The OTW Project EIA will provide a full description of the onshore elements of the Project landward of MLWS, and include an assessment of the associated likely significant effects.
- 9.12.1.2 This EIA has considered the additive interactions between the Offshore Project and OTW Project to understand if there is the potential for any change to the assessment outcomes as a result of both elements of the Project. The approach to identify and consider potential interactions between the Offshore Project and OTW Project is set out in **Chapter 5, Volume 1a** and key design parameters associated with the OTW Project are summarised in **Chapter 3, Volume 1a**.
- 9.12.1.3 The potential for effects identified in **Table 9-5** to interact with effects associated with the OTW Project on a common receptor included within the physical and coastal processes assessment (i.e. receptors which have the potential to experience effects from both projects) has been considered. However, the Zone of Influence associated with Physical and Coastal Processes is limited spatially to the marine environment and only has the potential to cause an effect on receptors which are in the marine environment. The only activity to occur between MHWS and MLWS is associated with HDD and cable installation that will occur under the seabed. The works above the seabed associated with this (i.e. HDD Exit Pit construction and cable pull through vessel activities) are considered within this chapter already. As the works between MHWS and MLWS are below the seabed there is no potential for impact to Physical and Coastal Processes receptors. Further to this, it has been assumed that there will be negligible impact to onshore rivers/water bodies due to the OTW Project following the incorporation of mitigation measures. For example, this could include the use of HDD techniques for installation of the Onshore Cable through a watercourse. As a result of this, there is no pathway for these effects to interact in addition to the OTW Project and this is not considered further. Following consideration of the OTW Project and likely ZOI and influence on common receptors, there are no pathways that have the potential to effect Physical and Coastal Processes' receptors. As a result of this, there is no pathway for these effects to interact in addition to the OTW Project and this is not considered further.

9.13 ASSESSMENT OF CUMULATIVE EFFECTS

9.13.1 APPROACH

9.13.1.1 A cumulative effects assessment (CEA) examines the potential for impacts of the Offshore Project in addition with Other Projects on the same single receptor or resource and the contribution of the Offshore Project to those impacts. The overall method for identifying and assessing potential cumulative effects in relation to the offshore environment is set out in **Chapter 5, Volume 1a**.

9.13.1.2 The offshore screening approach to assessing cumulative effects is based on the Planning Inspectorate's Advice Note Nine (Planning Inspectorate, 2018) and Advice Note Seventeen (Planning Inspectorate, 2024), with relevant components of the RenewableUK (RenewableUK, 2013) accepted guidance, which includes aspects specific to the marine elements of an OWF, addressing the need to consider mobile wide-ranging species (foraging species, migratory routes etc).

9.13.1.3 The screening approach is based on the consideration for other projects present or planned in the region and risks assessment.

9.13.2 CUMULATIVE EFFECTS ASSESSMENT

9.13.2.1 Cumulative effects have been identified; however, this assessment is limited to receptors relevant to the Physical and Coastal Processes chapter of the EIAR. Where impact pathways overlap with sensitive receptors outside the scope of this chapter, they have been considered and addressed within the corresponding topic-specific EIAR chapters.

9.13.2.2 For Physical and Coastal Processes, a ZOI has been applied to ensure direct and indirect cumulative effects can be appropriately identified and assessed. The Physical and Coastal Processes ZOI is shown in **Figure 9-1, Volume 2b** and aligns with the extents of the Study Area.

9.13.2.3 A short list of 'other developments' that may interact with the Project ZOIs during their construction, operation, or decommissioning is presented in **Appendix 5.3: Cumulative effects assessment shortlisted developments, Volume 1c**. This list has been generated applying criteria set out in **Chapter 5, Volume 1a** and has been collated up to the finalisation of the EIA through desk study, consultation, and engagement.

9.13.2.4 Only those 'other developments' in the short list that fall within the Physical and Coastal Processes ZOI have the potential to result in cumulative effects with the Offshore Project on Physical and Coastal Processes. All 'other developments' falling outside the Physical and Coastal Processes ZOI are excluded from this assessment.

9.13.2.5 There are no 'other developments' within the Physical and Coastal Processes ZOI and on this basis there are no 'other developments' that are scoped into the Physical and Coastal Processes CEA.

9.14 TRANSBOUNDARY EFFECTS

9.14.1.1 Transboundary effects occur when a development in one European Economic Area (EEA) State impacts the environment of another EEA State(s). A screening of potential transboundary effects was undertaken within the **Scoping Report**.

9.14.1.2 As the Offshore Development Area of Search resides within Scottish territorial waters and there is no potential for transboundary impacts to Physical and Coastal Processes receptors as a result of construction, operation (and maintenance) and decommissioning activities. Therefore, for this reason transboundary effects are not assessed or discussed any further.

9.15 SUMMARY OF RESIDUAL EFFECTS

9.15.1.1 **Table 9-23** presents a summary of the assessment of significant impacts, any relevant mitigation measures, and residual effects on Physical and Coastal Processes receptors.

Table 9-23 Summary of residual effects

Activity and impact	Receptor	Magnitude of impact	Receptor and sensitivity or value	Embedded mitigation measures	Significance of effect (significance)	Further environmental mitigation	Significance of residual effect (significance)
Construction							
Drilling of Pin Piles to Install WTG Foundations – Turbine Area (sediment disturbance and seabed change)	Surrounding sub-tidal seabed, surrounding coastline and designated site of geological interest	Low	Low	M001, M019	Negligible (not significant)	N/A	N/A
Burial of Array Cables to Final WTG – Array Area and Array Cables to Landfall - OCAS (sediment disturbance and seabed change)		Low	Low	M001, M002, and M019	Negligible (not significant)	N/A	N/A
Multiple Activities (Drilling of Pin Piles to Install WTG Foundations – Turbine Area and Burial of Burial of Array Cables to Final WTG – Array Area)		Low	Low	M001, M002, and M019	Negligible (not significant)	N/A	N/A
Horizontal Directional Drilling activities – Drill Cutting Release and Exit Pit Construction (sediment		Low	Low	M001, M002, and M019	Negligible (not significant)	N/A	N/A

Activity and impact	Receptor	Magnitude of impact	Receptor and sensitivity or value	Embedded mitigation measures	Significance of effect (significance)	Further environmental mitigation	Significance of residual effect (significance)
disturbance and seabed change)							
Multiple Activities (HDD Drill Cutting Release and HDD Exit Pit Construction)		Low	Low	M001, M002, and M019	Negligible (not significant)	N/A	N/A
Operation and maintenance							
Effects Related to the Presence of Infrastructure (changes to water depth)	Surrounding sub-tidal seabed, surrounding coastline and designated site of geological interest	Negligible	Low	M001, M019 and M025	Negligible (not significant)	N/A	N/A
Effects Related to the Presence of Infrastructure (changes to current speed)		Negligible	Low	M001, and M025	Negligible (not significant)	N/A	N/A
Effects Related to the Presence of Infrastructure (seabed structures resulting in scour)		Negligible	Low	M001, M002, M019 and M025	Negligible (not significant)	N/A	N/A
Effects Related to the Presence of Infrastructure (changes to waves)		Negligible	Low	M001, M019 and M025	Negligible (not significant)	N/A	N/A

Activity and impact	Receptor	Magnitude of impact	Receptor and sensitivity or value	Embedded mitigation measures	Significance of effect (significance)	Further environmental mitigation	Significance of residual effect (significance)
Effects Related to the Presence of Infrastructure (changes to stratification)		Negligible	Low	N/A	Negligible (not significant)	N/A	N/A
Decommissioning							
Removal of WTG Foundations and Pin Piles, Array Cables to Final WTG, Array Cables to Landfall, and HDD Exit Pits (sediment disturbance and seabed change)	Surrounding sub-tidal seabed, surrounding coastline and designated site of geological interest	Low	Low	M019	Negligible (not significant)	N/A	N/A



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9.16 GLOSSARY OF TERMS AND ABBREVIATIONS

9.16.1.1 A list of key terms and acronyms used in this chapter are provided in **Table 9-24** and **Table 9-25**.

Table 9-24 Acronyms and abbreviations

Term	Definition
°	Degree
°C	Degrees Celsius
-	Minus
%	Percent
+	Plus
±	Plus-minus
ATT	Admiralty Total Tide
BSI	British Standards Institution
CBRA	Cable Burial Risk Assessment
CEA	Cumulative Effects Assessment
CEMP	Construction Environmental Management Plan
cm	Centimetres
CTD	Conductivity, Temperature & Depth
DHI	Danish Hydraulic Institute
DWR	Directional Waverider
EEA	European Economic Area
EIA	Environmental Impact Assessment
EIAR	Environmental Impact Assessment Report
EMODnet	European Marine Observation and Data Network
EU	European Union
EVA	Extreme Value Analysis
FLiDAR	Floating Light Detection and Ranging
GCR	Geological Conservation Review
GEBCO	General Bathymetric Chart of the Oceans
HAT	Highest Astronomical Tide
HD	Hydrodynamic
HDD	Horizontal Directional Drilling
HRA	Habitat Regulations Appraisal
Hs	Significant Wave Height
km	Kilometres
kV	Kilovolts
LAT	Lowest Astronomical Tide
m	Metres
m ²	Metres squared
m ³	Metres cubed
MBES	Multibeam Bathymetry

Term	Definition
MD-LOT	Marine Directorate – Licensing Operations Team
MD-SEDD	Marine Directorate – Science, Evidence, Data and Digital
mg/l	Milligrams per litre
MHWN	Mean High Water Neap
MLWN	Mean Low Water Neap
m/s	Metres per second
MSL	Mean Sea Level
O&M	Operation and Maintenance
OCAS	Offshore Cable Area of Search
OSP	Offshore Substation Platform
OWF	Offshore Wind Farm
PAC	Preliminary Application Consultation
PMF	Priority Marine Features
PT	Particle Tracking
RCP8.5	Representative Concentration Pathway 8.5
s	Second
SAC	Special Area of Conservation
SEA	Strategic Environmental Assessment
SEIA	Strategic Environmental Impact Assessment
SEPA	Scottish Environment Protection Agency
SPM	Suspended Particulate Matter
SSC	Suspended Sediment Concentration
SSS	Side-Sonar Scan
SSSI	Site of Special Scientific Interest
SW	Spectral Wave
TSS	Total Suspended Solids
UK	United Kingdom
UKHO	United Kingdom Hydrographic Office
WFD	Water Framework Directive
WTG	Wind Turbine Generator
ZOI	Zone of Influence

Table 9-25 Glossary

Term	Meaning
the Applicant	Sporad na Mara Limited (the Project owner).
Array Area	The offshore area within which the offshore wind turbine generators (WTGs), associated foundations, Array Cables, and Offshore Substation Platform (OSP) (if required) will be located. This area encompasses the Turbine Area that will contain all above water surface infrastructure (WTGs/OSP) and an additional area within

Term	Meaning
	which further below water infrastructure (foundations and cables) may also be located.
Array Cables	The offshore electrical and communication cables that connect infrastructure located within the Array Area, for: <ul style="list-style-type: none"> Scenario 1: Array Cables will used to connect Wind Turbine Generators (WTGs) to each other, and to connect WTGs to the OSP Scenario 2: Array Cables will used to connect WTGs to each other.
Array Cables to Landfall	The offshore electrical and communication cables located in the Array Area and Offshore Cables Area of Search that connect the wind turbine generators (WTGs) directly to Landfall for Scenario 2.
Bathymetry/ bathymetric	Topography of sea or estuary bed as measured from a fixed vertical datum.
Bed shear stress	Stress exerted by water on the seabed surface.
Coastal water	Water depths between 5 m and 20 m.
Combined Effects	Combined effect of the individual development on one particular receptor; for example noise, dust and visual. This includes Project-Lifetime Effects and Receptor-Led Effects.
Cumulative Effects	Considers the likely significant effects of multiple impacts and activities from several developments.
d ₅₀	Median sediment particle size.
Deep water	Water depths greater than 20 m.
Depth-averaged tidal current velocity	The average velocity, over a vertical profile, in a given location.
Designated site of geological interest	Areas with protected status designated as earth science features and geological importance.
Effect	Term used to express the consequence of an impact. The significance of an effect is determined by correlating the magnitude of the impact with the importance, or sensitivity, of the receptor or resource in accordance with defined significance criteria.
Embedded or 'Designed-in' Mitigation	Mitigation measures to avoid or reduce environmental effects that are directly incorporated into the preferred design for the Project. This can include standard practice in accordance with or without guidance. Embedded Mitigation is considered as part of the impact assessment, before effect significance is identified.
Environmental Impact Assessment Report (EIAR)	The Environmental Impact Assessment Report (EIAR) prepared to assess the likely significant effects of the Project on the environment.
Geomorphological changes	Changes to topographic or bathymetric features generated by physical, chemical, or biological processes.
Geophysical survey	Imaging or mapping using ground-based physical sensing.
Horizontal Directional Drill (HDD)	A trenchless crossing engineering technique using a drill steered underground without the requirement for open trenches. This method is able to carry out the underground installation of pipes and cables with minimal surface disruption.

Term	Meaning
Horizontal Directional Drill (HDD) Exit Pit	Represents one exit pit that will be located within the Landfall Exit Pit Area.
Hydrodynamic	The movement and forces exerted by water.
Impact	Change that is caused by an action; for example, foundation installation (action) during construction which results in habitat loss (impact).
Landfall	This consists of works from offshore Horizontal Directional Drill (HDD) exit pits (located below MLWS) to onshore at the Transition Joint Bays (TJB) (located above MHWS). The infrastructure and installation methods associated with the Landfall involves both onshore and offshore components.
Landfall Exit Pit Area	The offshore area in which all HDD Exit Pits will be located within.
Landfall Substation	The optional onshore substation located on the west side of the Isle of Lewis/ <i>Eilean Leòdhais</i> . Includes the platform, buildings and associated components which allows the voltage to be increased to meet onward transmission requirements.
Metocean conditions	Changes to the seabed (deepening or raising) leading to changes in tidal current flows and/or wave conditions (height/direction).
Metocean data	Meteorological and oceanographic data including wind, currents, and waves.
Morphological changes	Changes to the form or structure of the seabed.
Neap peak flow	Typical maximum current velocity during neap tides (minimum difference between high and low water levels).
Offshore Cables	Electrical and communication cables located within the Array Area and Offshore Cable Area of Search. The Offshore Cables consist of Array Cables, Array Cables to Landfall, and Export Cables.
Offshore Cable Area of Search (OCAS)	The area within which the offshore electrical and communication cables between the Array Area and Landfall up to Mean High Water Springs (MHWS) will be located.
Offshore Project	The offshore components of the Spiorad na Mara offshore wind farm (the Project) located seaward of Mean High Water Springs (MHWS).
Offshore Project Boundary	The 'red line boundary' encompassing the Offshore Project.
Offshore Substation Platform (OSP)	The optional offshore substation located within the Turbine Area. Includes the platform and associated components which allows the voltage to be increased to meet onward transmission requirements.
Onshore Transmission Works (OTW)/Onshore Project	The components of the Spiorad na Mara offshore wind farm (the Project) located landward of Mean Low Water Springs (MLWS).
Physical and Coastal Processes	Processes such as metocean conditions, seabed geology/morphology, sediment transport, and water quality which could be impacted by the Offshore Project.
Project	The Spiorad na Mara offshore wind farm development. This term describes the whole development, including all offshore and onshore components.

Term	Meaning
Project Design Envelope	A description of the range of possible components that make up the Project design options under consideration when the exact engineering parameters are not yet known.
Project-Lifetime Effects	Assessment of the scope for combined effects that occur throughout more than one phase of the project (i.e. construction, operation and maintenance, decommissioning), to interact to potentially create an effect of greater significance than if assessed just within individual/isolated project phases.
Receptor-Led Effects	Assessment of the scope for all combined effects to interact, spatially and temporally, to create an effect on a receptor of greater significance than when the effects are considered in isolation. Receptor-led effects may be short term, temporary or transient effects, or incorporate longer term effects.
Scoping Opinion	A report presenting the written opinion of the Scottish Ministers, with input from Comhairle nan Eilean Siar (CnES) for the OTW, as to the scope and level of detail of information to be provided in the Environmental Impact Assessment (EIA) for the Project.
Scour protection	The protection of sediment against localised erosion e.g. by placing rock.
Seabed change	Temporary or permanent lowering or raising of seabed levels, e.g. due to scour protection.
Seabed morphology	The form (morphology) of the seabed.
Sediment dispersion	The dilution and settling of sediment as it travels from a source.
Sediment disturbance	Disturbing/displacing sediment (contaminated or uncontaminated).
Sediment plume	A mobile area of increased suspended sediment concentration, usually generated by activities such as construction or dredging.
Sediment transport regime	The size, quantity, sorting, and distribution of sediments.
Shallow water	Water depths less than 5 m.
Significant wave height	Average height of the largest 1/3 of waves.
Spring peak flow	Typical maximum current velocity during spring tides (maximum difference between high and low water levels).
Study Areas	Study Areas are determined for each technical discipline and are described within each technical chapter.
Suspended sediment concentration	The mass concentration (mass/volume) of sediment in suspension.
Thermocline	A distinct ocean layer separating the upper mixed layer from the calm deep water below.
Turbine Area	A reduced area within the Array Area where above water surface infrastructure would be located i.e. Wind Turbine Generators (WTG) or Offshore Substation Platform (OSP) (if required). This area has been developed and refined through stakeholder consultation and environmental assessment.
Water quality	Increase in physical, chemical and biological contaminants through the suspension of contaminated sediment, tidal currents transporting disturbed sediment leading to increased turbidity and/or reduced water-quality until sediment settlement.

Term	Meaning
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.

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