Environmental Impact Assessment Report
Volume 1, Chapter 6: Marine Geology, Oceanography and Physical Processes

MarramWind Offshore Wind Farm

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6. Marine Geology, Oceanography and Physical Processes

6.1 Introduction

6.1.1.1 This marine geology, oceanography and physical processes Chapter of the Environmental Impact Assessment (EIA) Report presents the results of the assessment of the likely significant effects on the marine physical environment that may arise from the construction, operation and maintenance (O&M) and decommissioning of the offshore Project seaward of Mean High Water Springs (MHWS). It covers impacts on or changes to:

- metocean regimes:
  - water levels;
  - currents;
  - wind and waves; and
  - stratification and frontal systems.
- sediments, morphology, sediment transport and seabed mobility; and
- coastlines, beaches and nearshore processes.

6.1.1.2 This Chapter should be read in conjunction with the project description provided in **Chapter 4: Project Description** and the relevant parts of the following chapters:

- **Chapter 7: Marine Water and Sediment Quality**: Changes to marine geology, oceanography and physical processes have the potential to affect water quality through (amongst other things) changes to suspended sediment concentration (SSC) in the water column. The information from this Chapter will used to inform the marine water and sediment quality assessment.
- **Chapter 10: Benthic Epibenthic and Intertidal Ecology**: Changes to marine geology, oceanography and physical processes have the potential to affect sensitive benthic, epibenthic and intertidal ecology receptor features and habitats.
- **Chapter 11: Marine Mammals**: Floating substructures could influence water column mixing in stratified waters as well as the position of frontal systems. This could potentially alter primary production, marine ecosystems and biogeochemical cycling.
- **Chapter 12: Offshore and Intertidal Ornithology**: As above, floating substructures could influence water column mixing, altering primary production, marine ecosystems and biogeochemical cycling.
- **Chapter 13: Fish Ecology**: As above, floating substructures could influence water column mixing, altering primary production, marine ecosystems and biogeochemical cycling.
- **Chapter 16: Marine Archaeology and Cultural Heritage**: Changes to marine geology, oceanography and physical processes have the potential to affect sensitive marine archaeology receptors through changes in the depositional environment and scour regimes.
- **Chapter 18: Infrastructure and Other Marine Users**: Changes to marine geology, oceanography and physical processes have the potential to affect existing seabed

infrastructure by (for instance) altering patterns of sediment transport, leading to morphological change.

6.1.1.3 The Chapter also informs the **Nature Conservation Marine Protected Area Assessment** which considers the potential for the Project to impact geodiversity and biodiversity features within Nature Conservation Marine Protected Areas (NCMPAs), notable the Southern Trench NCMPA which the offshore export cable corridor intersects.

6.1.1.4 This Chapter describes:

- the legislation, planning policy, guidance and other documentation that has informed the assessment (**Section 6.2: Relevant legislative and policy context**);
- the outcome of consultation and engagement that has been undertaken to date, including how matters relating to marine geology, oceanography and physical processes have been addressed (**Section 6.3: Consultation and engagement**);
- the scope of the assessment for marine geology, oceanography and physical processes (**Section 6.4: Scope of the assessment**);
- the data sources and methods used for gathering baseline data including surveys where appropriate (**Section 6.5: Methodology for baseline data gathering**);
- the overall environmental baseline (**Section 6.6: Baseline conditions**);
- the basis for the EIA Report (**Section 6.7: Basis for EIA Report**);
- methodology for EIA Report (**Section 6.8: Methodology for EIA Report**);
- the assessment of marine geology, oceanography and physical processes effects (**Section 6.9: Assessment of effects: Construction stage**; **Section 6.10: Assessment of effects: Operation and Maintenance stage**; **Section 6.11: Assessment of effects: Decommissioning stage**);
- summary of effects (**Section 6.12: Summary of effects**);
- consideration of transboundary effects (**Section 6.13: Transboundary effects**);
- consideration of inter-related effects and cumulative effects (**Section 6.14: Inter-related effects** and **Section 6.15: cumulative effects assessment**);
- a summary of residual effects for marine geology, oceanography and physical processes (**Section 6.16: Summary of residual effects**);
- a reference list is provided (**Section 6.17: References)**; and
- a glossary of terms and abbreviations is provided (**Section 6.18: Glossary of Terms and Abbreviations**).

6.1.1.5 This Chapter is also supported by the following Appendices in **Volume 3**:

- **Appendix 6.1: Physical Processes Modelling;**
- **Appendix 6.2: Water Framework Directive Assessment;** and
- **Appendix 6.3: Marine Geology, Oceanography and Physical Processes Baseline**.

6.2 Relevant legislative and policy context and technical guidance

6.2.1 Legislative and policy context

6.2.1.1 This Section identifies the relevant legislation and policy context that has informed the scope of the marine geology, oceanography and physical processes assessment. Further information on policies relevant to the EIA and their status is set out in **Chapter 2: Legislative and Policy Context**, which provides an overview of the relevant legislative and policy context for the Project. **Chapter 2: Legislative and Policy Context** is supported by **Volume 3, Appendix 2.1: Planning Policy Framework**, which provides a detailed summary of international, national, marine and local planning policies of relevance to the EIA. Individual policies of specific relevance to this assessment and associated appendices have been taken into account.

6.2.1.2 This summary provides a foundation for understanding the specific requirements that this Chapter must address in terms of assessing and mitigating impacts on receptors and relevant environmental issues.

6.2.1.3 The legislation relevant to marine geology, oceanography and physical processes include:

- Marine Environment (Amendment) (EU Exit) Regulations 2018;
- Conservation of Offshore and Marine Habitats and Species Regulations 2017;
- Water Environment (Controlled Activities) (Scotland) Regulations 2011;
- The Marine Strategy Regulations 2010;
- Marine and Coastal Access Act 2009;
- EC Directive (2008/56/EC) establishing a framework for Community action in the field of marine environmental policy (Marine Strategy Framework Directive);
- Conservation (Natural Habitats, &c.) Regulations 1994;
- European Commission Directive (92/43/EEC) on the Conservation of Natural Habitats and of Wild Fauna and Flora; and
- Electricity Act 1989.

6.2.1.4 The policies relevant to marine geology, oceanography and physical processes include:

- Draft Updated Sectoral Marine Plan 2025 (Scottish Government, 2025a).
- National Planning Framework 4 2023 (Scottish Government, 2023a);
- Aberdeenshire Council Local Development Plan 2023 (Aberdeenshire Council, 2023a);
- Sectoral Marine Plan for Offshore Wind 2020 (Scottish Government, 2020);
- Scottish National Marine Plan 2015 (Scottish Government, 2015); and
- UK Marine Policy Statement 2011 (HM Government, 2011).

6.2.2 Relevant technical guidance

6.2.2.1 Other information and technical guidance relevant to the assessment undertaken for marine geology, oceanography and physical processes include:

- Metocean Procedures Guide for Offshore Renewables (Institute of Marine Engineering, Science and Technology, 2024);
- Guidance on Best Practice for Marine and Coastal Physical Processes Baseline Survey and Monitoring Requirements to Inform EIA of Major Development Projects. Report No 243 (Natural Resources Wales, 2018);
- Environmental impact assessment for offshore renewable energy projects (British Standards Institution, 2015);
- Guidelines for Data Acquisition to Support Marine Environmental Assessments of Offshore Renewable Energy Projects (Centre for Environment, Fisheries and Aquaculture (Cefas), 2012);
- Coastal Process Modelling for Offshore Wind farm Environmental Impact Assessment: Best Practice Guide (ABPmer & HR Wallingford 2009);
- Guidelines in the use of metocean data through the lifecycle of a marine renewables development (Construction Industry Research and Information Association, 2008);
- Review of Cabling Techniques and Environmental Effects applicable to the Offshore Wind farm Industry Technical Report (Department for Business, Enterprise and Regulatory Reform (BERR), 2008); and
- Offshore Windfarms: Guidance note for Environmental Impact Assessment in Respect of FEPA and Coast Protection Act requirements (Cefas, 2004).

6.3 Consultation and engagement

6.3.1 Overview

6.3.1.1 This Section describes the consultation and stakeholder engagement undertaken on the Project in relation to marine geology, oceanography and physical processes. This includes early engagement, the outcome of and response to the Scoping Opinions (Scottish Government, 2023b; Aberdeenshire Council, 2023b) in relation to the marine geology, oceanography and physical processes assessment, non-statutory consultation, and the findings of the Project's Statutory Consultation. An overview of engagement undertaken for the Project as a whole can be found in Section 5.5 of **Chapter 5: Approach to the EIA**.

6.3.2 Key issues

6.3.2.1 A summary of the key issues raised during statutory and non-statutory consultation, specific to marine geology, oceanography and physical processes, is outlined below in **Table 6.1**, together with how these issues have been considered in the production of this EIA Report.

Table 6.1 Stakeholder issues responses – marine geology, oceanography and physical processes

Stakeholder	Stakeholder issue ID	Date, document, forum	Stakeholder comment	How is this addressed in the EIA Report
Aberdeenshire Council	72	22 March 2023, Aberdeenshire Council's Scoping Opinion (Aberdeenshire Council, 2023b).	*"NatureScot also advise that natural re-exposure of a trenched landfall cable(s) be scoped in to the EIA Report as any demand for protective measures may interrupt coastal processes. Changes to sediment transfer and coastal processes should be considered in relation to the protected features of designated sites."*	The Red Line Boundary (including areas relating to landfall) has been refined since Scoping. Open-cut and fill have been excluded from the design envelope since Scoping. This is reported upon in **Chapter 3: Site Selection and Consideration of Alternatives**, where the landfall locations taken forward for EIA are also described. A full landfall assessment is presented in in **Section 6.9, Section 6.10** and **Section 6.11**, covering potential impacts during construction, operation and maintenance, and decommissioning, respectively.
NatureScot	125	22 March 2023, Aberdeenshire Council's Scoping Opinion Representation (Aberdeenshire Council, 2023b).	*"The potential for climate change and accelerating sea-level rise on landfall and onshore grid connection infrastructure should be considered. We advise that natural re-exposure of a trenched landfall cable(s) should be scoped in as any demand for protective measures could interrupt coastal processes. The impacts of changes to sediment transfer and coastal processes should be considered in relation to the protected features of designated sites, including the Loch of Strathbeg Site of Special Scientific Interest (SSSI) / Special protection Area (SPA) / RAMSAR."*	A full description of coastal processes understanding at the landfall zones is set out in **Volume 3, Appendix 6.3**. A cable landfall assessment is presented in **Section 6.9, Section 6.10** and **Section 6.11**, covering potential impacts during construction, operation and decommissioning, respectively. This assessment considers the nature of ongoing and potential future shoreline change at the landfall zones and the potential for associated impact to landfall zone infrastructure. It also considers the potential for re-exposure of cables during

Stakeholder	Stakeholder issue ID	Date, document, forum	Stakeholder comment	How is this addressed in the EIA Report
				the operational lifetime of the project. Consideration is also given to the potential for infrastructure at the landfall zones to impact nearby designated sites through the interruption of sediment transport processes.
NatureScot	220	29 September 2022, Scoping meeting.	*"Nature Scot suggestion that any coastal infrastructure should take future climate change into consideration through dynamic coast study."*	A cable landfall assessment is presented in **Section 6.9, Section 6.10** and **Section 6.11**, covering potential impacts during construction, operation and decommissioning, respectively. This assessment considers the nature of ongoing and potential future shoreline change at the landfall zones and the potential for associated impact to landfall zone infrastructure. The assessment is informed by outputs from the Dynamic Coast Phase 2 study (Rennie *et al*., 2021).
Marine Directorate - Licensing Operations Team (MD-LOT)	293	12 May 2023, MD-LOT Scoping Opinion (Scottish Government, 2023b).	*"The Scottish Ministers note that the baseline for physical processes has not yet been fully characterised and that further investigation into sand wave fields is required as per section 5.1.28 of the Scoping Report. The Scottish Ministers advise in line with the NatureScot representation that sand wave fields are mapped and that a desk-based assessment of potential mobility is conducted. The results of such assessment should be explicitly incorporated into the assessment of both the changes to sediment transport and seabed morphology impacts. The Scottish Ministers are otherwise content with the approach to the baseline environment."*	Analysis of multibeam data collected during the Project-specific geophysical survey has enabled sandwaves to be mapped within the Option Agreement Area (OAA) and offshore export cable corridor. The degree to which these features (as well as the wider seabed) may be mobile has been assessed by (i) analysis of historic publicly available bathymetry data (available through the United Kingdom Hydrographic Office (UKHO) and British Geological Survey (BGS) Strategic Environmental Assessment (SEA) data portals) alongside project specific data to determine rates and directions of bedform migration as, well as

Stakeholder	Stakeholder issue ID	Date, document, forum	Stakeholder comment	How is this addressed in the EIA Report
				broad-scale patterns of seabed change; (ii) Analysis of the magnitude and direction of potential sediment transport, based on regional-scale numerical modelling of sediment transport processes developed by ABPmer; and (iii) Empirical relationships between current speed and the potential mobility of various sedimentary bedforms (for example, Belderson *et al.*, 1982). Results from this baseline analysis have been used to inform the assessment.
MD-LOT	294	12 May 2023, MD-LOT Scoping Opinion (Scottish Government, 2023b).	*"The Scottish Ministers broadly agree with the impacts scoped in to and out of the EIA Report; however, note that potential scour around structures on the seabed is not included in the list of impacts to be assessed. The Scottish Ministers advise that scour is fully considered in the seabed morphology impacts assessment, in line with the NatureScot representation."*	The potential for scour around marine structures is considered within **Section 6.10**.
MD-LOT	295	12 May 2023, MD-LOT Scoping Opinion (Scottish Government, 2023b).	*"The Scottish Ministers are broadly content with the approach to assessment described within section 5.1 of the Scoping Report. The Scottish Ministers highlight that definitions of magnitude and sensitivity for the impact assessment have not been set out in comparison to other topic sections where this detail is included."*	Definitions of magnitude and sensitivity are set out in **Section 6.8**.
MD-LOT	296	12 May 2023, MD-LOT Scoping Opinion (Scottish Government, 2023b).	*"The Scottish Ministers advise that the Developer must consult NatureScot on modelling methodology details, including how results will be presented, in the "changes to the wave regime" assessment at an interim stage before the submission of the EIA Report."*	A wave modelling method statement was shared with NatureScot and MD-LOT in September 2025 (see SIT ID 999). Details of the methodological approach to the wave modelling are set out **Volume 3, Appendix 6.1**.

Stakeholder	Stakeholder issue ID	Date, document, forum	Stakeholder comment	How is this addressed in the EIA Report
MD-LOT	297	12 May 2023, MD-LOT Scoping Opinion (Scottish Government, 2023b).	*"With regards to the cumulative effects on marine geology, oceanography, and physical processes, the Scottish Ministers agree with the proposed approach considered by the Developer in sections 5.1.46 and 5.1.47 of the Scoping Report."*	A full assessment of cumulative effects is set out in is provided in **Chapter 33: Cumulative Effects Assessment.**
NatureScot	534	12 May 2023, MD-LOT Scoping Opinion Appendix 1: Consultation Responses & Advice (Scottish Government, 2023b).	*"Study area* *We are content with the study area as proposed in Section 5.1.8 and Figure 5.1.1, and which comprises:* *- the Option Agreement Area and entire marine area within the Scoping Boundary;* *- the wider marine area around the project, as based on region-scale marine geology, oceanography, and physical processes; including* *- prevailing wave direction, tidal excursion distances and sediment transport pathways."*	The study area considered within the EIA Report is unchanged from Scoping and is shown in **Volume 2, Figure 6.1: Marine geology, oceanography and physical processes study area**.
NatureScot	535	12 May 2023, MD-LOT Scoping Opinion Appendix 1: Consultation Responses & Advice (Scottish Government, 2023b).	*"We agree that the relevant legislation and policy (Table 5.1.1), technical guidance (Table 5.1.2) and data sources (Table 5.1.4) have been identified."*	Relevant legislative and policy context and technical guidance is set out in **Section 6.2**.
NatureScot	536	12 May 2023, MD-LOT Scoping Opinion Appendix 1: Consultation Responses & Advice (Scottish Government, 2023b).	*"We note that the baseline for physical processes has not yet been fully characterised. Section 5.1.28 describes how further investigation into sand wave fields is needed. One potential implication of mobile sandwaves would be that cable(s) buried through them might over time become naturally re-exposed, necessitating additional armouring that would increase the overall effect of the operational phase on seabed sediment transport and morphology. We*	Analysis of multibeam data collected during the Project-specific geophysical survey has enabled sandwaves to be mapped within the OAA and offshore export cable corridor. The degree to which these features (as well as the wider seabed) may be mobile has been assessed by: (i) Analysis of historic publicly available bathymetry data

Stakeholder	Stakeholder issue ID	Date, document, forum	Stakeholder comment	How is this addressed in the EIA Report
			recommend that sand wave fields should be mapped; there should be a desk-based assessment of potential mobility; and the results should be explicitly incorporated into assessment of the two impacts: "changes to sediment transport" and "impacts to seabed morphology"."	(available through the UKHO and BGS SEA data portals) alongside project specific data to determine rates and directions of bedform migration as, well as broad-scale patterns of seabed change; (ii) Analysis of the magnitude and direction of potential sediment transport, based on regional-scale numerical modelling of sediment transport processes developed by ABPmer; and (iii) Empirical relationships between current speed and the potential mobility of various sedimentary bedforms (for example, Belderson *et al*. 1982). Results from this baseline analysis have been used to inform the assessment.
NatureScot	537	12 May 2023, MD-LOT Scoping Opinion Appendix 1: Consultation Responses & Advice (Scottish Government, 2023b).	*"We are broadly content with the impacts that are to be scoped in/ out of assessment. However, we note that potential scour around structures on the seabed is not included in the list of impacts to be assessed. We recommend that scour should, at the least, be taken fully into account in assessment of "impacts to seabed morphology"."*	The potential for scour around marine structures is considered within **Section 6.10.**
NatureScot	538	12 May 2023, MD-LOT Scoping Opinion Appendix	*"We are generally content with the approach to assessment as described, however we note that definitions of magnitude and sensitivity for the impact*	Definitions of magnitude and sensitivity are set out in **Section 6.8**.

Stakeholder	Stakeholder issue ID	Date, document, forum	Stakeholder comment	How is this addressed in the EIA Report
		1: Consultation Responses & Advice (Scottish Government, 2023b).	*assessment have not been set out in Section 5.1. It is unclear why these have not been included as they are described in detail in other topic sections."*	
NatureScot	539	12 May 2023, MD-LOT Scoping Opinion Appendix 1: Consultation Responses & Advice (Scottish Government, 2023b).	*"We also note the proposed approach to assessing "changes to the wave regime" includes numerical modelling. We recommend that NatureScot are be consulted on details of the modelling methodology (including how results will be presented) at an interim stage before the EIA Report is produced."*	A wave modelling method statement was shared with NatureScot and MD-LOT in September 2025 (see SIT ID 999 and 1000). Details of the methodological approach to the wave modelling are set out **Volume 3, Appendix 6.1**.
NatureScot	540	12 May 2023, MD-LOT Scoping Opinion Appendix 1: Consultation Responses & Advice (Scottish Government, 2023b).	*"We are content with the proposed approach to cumulative assessment described in Sections 5.1.46-47."*	A full assessment of cumulative effects is set out in is provided in **Chapter 33: Cumulative Effects Assessment**.
NatureScot	541	12 May 2023, MD-LOT Scoping Opinion Appendix 1: Consultation Responses & Advice (Scottish Government, 2023b).	*"We advise that there are unlikely to be any transboundary impacts."*	A screening of transboundary effects has been carried out and has identified that there were no likely significant transboundary effects with regard to marine geology, oceanography and physical processes upon the interests of European Economic Area (EEA) states.

Stakeholder	Stakeholder issue ID	Date, document, forum	Stakeholder comment	How is this addressed in the EIA Report
Marine Scotland	916	29 September 2022, Scoping meeting.	*"Consideration should be given to the potential for the Project to influence water column stratification and any associated frontal systems."*	The potential for change in water column stratification and the position of frontal systems has been reported in **Section 6.10** and in **Volume 3, Appendix 6.1.** A full baseline description of stratification within the study area is provided in **Volume 3, Appendix 6.3**.
Marine Directorate – Science, Evidence, Data and Digital	999	24 September 2025; Email response on wave modelling statement technical note.	*"MD-SEDD have no concerns about this methodology. The proposed methodology is to compare the modelled wave fields with and without the wind farms (and surrounding wind farms for cumulative assessment). MD-SEDD advise that thresholds of potential impact are clearly detailed within the EIA."*	Details of the methodological approach to the wave modelling are set out **Volume 3, Appendix 6.1.** This approach follows that presented in the wave modelling method statement which was shared with NatureScot and MD-LOT in September 2025 (see SIT ID 999). Thresholds for potential impacts to identified receptors are set out in **Section 6.8**.
NatureScot	1000	10 October 2025; Email response on wave modelling statement technical note.	*"We note the response from MD-SEDD, and are in alignment with it. We are content with the proposed methods and specifically welcome the intention to produce 'maps of difference'."*	

6.4 Scope of the assessment

6.4.1 Overview

6.4.1.1 This Section sets out the scope of the EIA for marine geology, oceanography and physical processes. This scope has been developed as the Project's design has evolved and responds to stakeholder feedback received to-date, as set out in **Section 6.3**.

6.4.2 Spatial scope and study area

6.4.2.1 The spatial scope of the marine geology, oceanography and physical processes assessment has taken into consideration the following, and has formed the basis of the study area described in this Section (**Volume 2, Figure 6.1**).

- The distance away from the Project which suspended sediment plumes may be advected (and meaningfully interact with potentially sensitive receptors). This has been defined by a spring tidal excursion ellipse buffer around the OAA and offshore export cable corridor.
- The distance up / down drift from the landfall zones, that littoral processes could theoretically be impacted by Project infrastructure, has been defined through consideration of coastal processes data and understanding including sub-cell information set out in set out in Ramsay and Brampton (2000a; 2000b).
- The distance from the OAA that wave blockage impacts could theoretically be detected has been informed by expert judgment, drawing upon (amongst other things), the evidence base from analogous projects and consideration of the prevailing wave directions.

6.4.2.2 Finally, the assessment of impacts on marine geology, oceanography and physical processes has been considered over two spatial scales. These are:

- far-field – defined as the area surrounding the Project across which indirect changes may occur (for instance, the study area); and
- near-field – defined as the footprint of the OAA and offshore export cable corridor.

6.4.3 Temporal scope

6.4.3.1 The temporal scope of the assessment of marine geology, oceanography and physical processes is the entire lifetime of the Project, which therefore covers the construction, O&M, and decommissioning stages. It is anticipated that the construction of the Project will commence in 2030, with the first phase becoming fully operational by 2037. It is anticipated that the second phase of the Project would become fully operational by 2040 and the third phase by 2043. The operational lifetime of the Project for each phase is expected to be 35 years.

6.4.4 Identified receptors

6.4.4.1 The spatial and temporal scope of the assessment enables the identification of receptors that may experience a change as a result of the Project. The receptors identified that may experience likely significantly effects for marine geology, oceanography and physical processes are outlined in **Table 6.2** and shown in **Volume 2, Figure 6.1**. These receptors have been identified on the basis of:

- professional judgement and local and regional specialist experience;
- the Scoping Opinions (Scottish Government, 2023; MD-LOT, 2023; and Aberdeenshire Council, 2023);
- outcomes from the consultation process (**Table 6.1**); and
- reference to best practice guidance (see **Section 6.2**).

6.4.4.2 The main marine geology, oceanography and physical processes receptor which requires assessment is the coast itself. This could, potentially, be directly impacted during the construction stage, because of cable installation at the landfall zones, and also in the operational stage if any proposed cable protection (in the form of rock berms) causes disruption to sediment transport.

6.4.4.3 The study area also overlaps with several nationally and internationally designated nature conservation sites, which contain qualifying geological and geomorphological (geodiversity) features. Of particular note is the Southern Trench NCMPA which contains geodiversity features including moraines, tunnel valleys and slide scars. The Southern Trench NCMPA is also designated for its fronts and shelf deeps. These qualifying features are identified and assessed as receptors in this Chapter.

6.4.4.4 Although the potential significance of effect on the Southern Trench NCMPA is assessed in the **Nature Conservation Marine Protected Area Assessment**, the assessment in this Chapter does consider the site conservation objectives (as outlined in (NatureScot, 2025) which are:

- *"so far as already in favourable condition, remain in such condition*; or
- *so far as not already in favourable condition, be brought into such condition, and remain in such condition"*.

6.4.4.5 Favourable condition, with respect to a feature of geomorphological interest, means that a) its extent, component elements and integrity are maintained; b) its structure and functioning are unimpaired; and c) its surface remains sufficiently unobscured for the purposes of determining whether the criteria in paragraphs (a) and (b) are satisfied.

6.4.4.6 Favourable condition, with respect to fronts and shelf deeps (which are large-scale features), means that a) the extent, distribution and structure of that feature is maintained; b) the function of the feature is maintained so as to ensure that it continues to support its characteristic biological communities and their use of the site including, but not restricted to, feeding, spawning, courtship or use as nursery grounds; and c) the processes supporting the feature are maintained.

Table 6.2 Identified receptors requiring assessment for marine geology, oceanography and physical processes

Receptor group	Receptors included within group
The coast (including designated nature conservation sites)	• Aberdeenshire coast within the study area; • Bullers of Buchan Coast Site of Scientific Interest (SSSI); • Cairnbulg to St Combs Coast SSSI; • Collieston to Whinnyfold Coast SSSI; • Gamrie and Pennan Coast SSSI; • Loch of Strathbeg SSSI; • Rosehearty to Fraserburgh Coast SSSI; and • Sands of Forvie and Ythan Estuary SSSI.
Designated seabed areas (NCMPAs)	• Southern Trench NCMPA; and • Turbot Bank NCMPA.
Designated frontal systems	Fronts within the Southern Trench NCMPA, including Buchan Front.

6.4.4.7 Where the receptors identified in **Table 6.2** have the potential to be affected by changes to physical processes, a full impact assessment (for instance, assigning sensitivity, magnitude and significance) has been carried out, using the criteria set out in **Section 6.8**.

6.4.4.8 It is noted here that for the most part, marine geology, oceanography and physical processes are not in themselves receptors but are instead 'pathways'. However, changes to physical processes have the potential to indirectly impact other environmental receptors (ABPmer and HR Wallingford, 2009). For instance, the creation of sediment plumes (the potential for which is considered in **Section 6.9.2**) may lead to the settling of material onto benthic habitats. The potential significance of this particular change is assessed in **Chapter 10: Benthic, Epibenthic and Intertidal Ecology**.

6.4.5 Potential effects

6.4.5.1 Potential effects on marine geology, oceanography and physical processes receptors that have been scoped in for assessment are summarised in **Table 6.3**.

Table 6.3 Potential effects for marine geology, oceanography and physical processes

Receptor	Activity or impact	Potential effect
Construction stage		
Potential pathway of effect for marine ecological receptors	Project construction activities (such as cable trenching and anchor installation) causing seabed disturbance, leading to elevated SSC, changes in bed level and sediment type.	Potential changes to SSCs, bed levels and sediment type.
Designated seabed areas (NCMPAs)	Project construction activities (such as cable trenching and anchor installation) leading to seabed disturbance and associated morphological change.	Potential impacts to seabed morphology.

Receptor	Activity or impact	Potential effect
The coast	Project construction activities at the landfall zones and in nearshore areas (such as horizontal directional drilling (HDD) (or similar trenchless techniques) exit pit excavation) leading to seabed disturbance and associated morphological change. In relation to trenchless crossings, HDD has been presented in the EIA. Whilst other trenchless methods are available, HDD is presented herein as it is likely to have the largest construction footprint.	Potential impacts to landfall morphology.
O&M stage		
Potential pathway of effect for marine ecological receptors	Hydrodynamic blockage due to the presence of Project infrastructure (such as floating units) in the water column and at the seabed.	Potential changes to the tidal regime.
Potential pathway of effect for marine ecological receptors	Wave blockage due to the presence of Project infrastructure (such as floating units) in the water column.	Potential changes to the wave regime.
Potential pathway of effect for marine ecological receptors	Sediment transport blockage due to the presence of Project infrastructure (such as floating units) in the water column and at the seabed.	Potential changes to the sediment transport regime.
Designated seabed areas (NCMPAs)	Morphological impact to designated seabed areas caused by blockage of hydrodynamic, wave and sediment transport processes arising from the presence of Project infrastructure in the water column and at the seabed.	Potential changes to seabed morphology.
The coast	Morphological impact to the coast caused by blockage of hydrodynamic, wave and sediment transport processes arising from the presence of Project infrastructure in the water column and at the seabed.	Potential impacts to coastal morphology.
Potential pathway of effect for marine ecological receptors	Presence of Project infrastructure at the seabed, resulting in localised accelerated flow and scouring of sediments.	Scour
Designated frontal systems	Hydrodynamic blockage due to the presence of Project infrastructure as well as possible atmospheric wake effects altering water column mixing processes.	Potential changes to stratification and frontal systems.
Decommissioning stage		
Potential pathway of effect for marine ecological receptors	Project decommissioning activities causing seabed disturbance, leading to	Potential changes to SSCs, bed levels and sediment type.

Receptor	Activity or impact	Potential effect
	elevated SSC, changes in bed level and sediment type.	
Designated seabed areas (NCMPAs)	Project decommissioning activities leading to seabed disturbance and associated morphological change.	Potential impacts to seabed morphology.
The coast	Project decommissioning activities at the landfall zones and in nearshore areas leading to seabed disturbance and associated morphological change.	Potential impacts to landfall morphology.

6.4.6 Effects scoped out of assessment

6.4.6.1 Based on the baseline environment information presented in **Volume 3, Appendix 6.3** and the project description provided in **Chapter 4: Project Description**, no impacts to physical processes receptors or pathways have been scoped out. This is principally due to the potential for pathway changes to impact on other aspect receptors and the requirement for informing those assessments.

6.5 Methodology for baseline data gathering

6.5.1 Overview

6.5.1.1 Baseline data collection has been undertaken to obtain information over the study area described in **Section 6.4: Scope of the assessment**. The current and future baseline conditions are presented in **Section 6.6: Baseline conditions**.

6.5.2 Desk study

6.5.2.1 The data sources that have been collected and used to inform this marine geology, oceanography and physical processes assessment are summarised in **Table 6.4**.

Table 6.4 Data sources used to inform the marine geology, oceanography and physical processes chapter

Source	Date	Summary	Coverage of study area
Marine Directorate Data Portal	Data accessed: 2025.	Data layers of bathymetry, ocean climate, waves, sea level, seabed geology, surface and subtidal sediments (MD, 2025).	Partial coverage of the study area.
Scottish Environment Protection Agency	Data accessed: 2025.	A range of datasets related to the environment including flood risk management (SEPA, 2024).	Partial coverage of the study area.
National Tide and Sea Level Facility	Data accessed: 2025.	Tidal water levels from point locations within the study area (NTSLF, 2025).	Partial coverage of the study area.
British Oceanographic Data Centre (BODC)	Data accessed: 2025.	Hydrodynamic data (inc. current speed & direction) from point locations within the study area (BODC, 2025).	Partial coverage of the study area.
Cefas WaveNet data.	Data accessed: 2025.	Wave records from point locations within the study area (Cefas, 2025).	Partial coverage of the study area.
ABP Marine Environmental Research Ltd (ABPmer) SEASTATES	1979 to 2022.	Modelled hindcast wave and hydrodynamic data from across the study area (ABPmer, 2025).	Full coverage of the study area.
ABPmer Marine Renewables Atlas	2008	Modelled hindcast wave and hydrodynamic data from across the study area (ABPmer *et al.*, 2008).	Full coverage of the study area.
United Kingdom Climate Projections 2018 (UKCP18)	2018	Sea level rise predictions for coastal locations within the study area. (Palmer *et al.*, 2018).	Partial coverage of the study area.
Suspended Particulate Matter mapping	2016	Monthly and seasonal Suspended Particulate Matter maps for the study area. (Cefas, 2016).	Full coverage of the study area.
Copernicus	Data accessed: 2025.	Three-dimensional numerical model outputs of temperature, salinity and chlorophyll-a (Copernicus, 2025).	Full coverage of the study area.

Source	Date	Summary	Coverage of study area
BGS offshore geoindex	Data accessed: 2025.	Seabed sediment maps (based on Folk classification) and borehole records from point locations within the study area (BGS, 2025).	Partial coverage of the study area.
UKHO Bathymetric Data	2009	Bathymetric data for the study area in the form of multibeam and single beam data, as well as Admiralty Charts (UKHO, 2009).	Full coverage of the study area.
European Marine Observation and Data Network Data Layers	Data accessed: 2025.	Bathymetric data for the study area and surrounding regions in the form of a continuous surface made of survey data from various European National Hydrographic Offices (EMODnet, 2025).	Full coverage of the study area.
NCMPA Geodiversity Mapping	2025, 2011.	Conservation and Management Advice: Southern Trench NCMPA (NatureScot, 2025). Mapping of geological and geomorphological features within Scottish NCMPAs, based on publicly available seabed surveys and research (Brooks *et al*., 2013).	Partial coverage of the study area.
Dynamic Coast (Phase 1 & 2)	2017, 2021.	The Dynamic Coast project aims to provide the strategic evidence base on the extent of coastal erosion in Scotland. (Dynamic Coast, 2017; 2021).	Partial coverage of the study area.
Coastal Cells in Scotland: sub-cell 2d (Cairnbulg Point to Girdle Ness) and sub-cell 3a (Portknockie to Cairnbulg Point)	2000	Description of coastal characteristics (geology and geomorphology) and processes controlling change (Ramsay and Brampton, 2000a,b)	Partial coverage of the study area.
Scottish Coastal Observatory (SCO)	Data accessed: 2025.	Monitoring data collected as part of the SCO, covering a range of marine environmental variables including temperature and salinity (Scottish Government, 2025b).	Partial coverage of the study area.
Scottish Remote Sensing Portal	Data accessed: 2025.	LiDAR datasets to inform past coastal change. (Scottish Government, 2025c).	Partial coverage of the study area.

Source	Date	Summary	Coverage of study area
(Key publications)	[various]	Public and grey literature considering coastal morphology and behaviour at sensitive coastal locations within the study area for example, Hansom *et al*. (2004) and Baxter *et al*. (2011).	Partial coverage of the study area.

6.5.3 Site surveys

6.5.3.1 The site surveys that have been conducted and used to inform this marine geology, oceanography and physical processes assessment are summarised in **Table 6.5**.

Table 6.5 Site surveys undertaken

Survey type	Scope of survey	Coverage of study area
OAA and offshore export cable corridor geophysical and environmental survey (Fugro, 2023a; 2023b) **Year of survey: 2022-2023**	High resolution side scan sonar (SSS), multibeam bathymetry and sub-bottom profile data.	Full coverage of the OAA and partial coverage of the offshore export cable corridor.
Metocean survey (Fugro, 2023c). **Year of survey: 2022-2023**	Wind speed, wave and current data from 20 September 2022 to 20 September 2023 Floating Light Detection and Ranging (FLiDAR) buoys deployed within the OAA.	Partial coverage of the OAA.
Volume, Appendix 10.2: Environmental Intertidal Survey – Benthic Report **Year of survey: 2023**	Mapping of inter-tidal biotopes. Sediment cores and contaminant sampling also undertaken.	Full coverage of the landfall zones (Scotstown Beach and Lunderton Beach).

6.5.4 Data limitations

6.5.4.1 Although the geophysical survey achieved 100 per cent coverage of the OAA, this was not achieved within the offshore export cable corridor (the coverage extent is shown in Figure 2 within **Volume 3, Appendix 6.3**). However, this limitation does not impact the assessment and has been overcome through the use of existing UKHO bathymetry data, which is available for much of the area not covered by the Project specific survey.

6.5.4.2 Uncertainty exists regarding the characterisation of the future baseline with respect to global climate change. Key areas of uncertainty include actual future rates of sea level rise and the extent to which future changes in the wave regime may occur. There is also related uncertainty regarding how the coastline may respond to a future wave climate acting in combination with higher than present sea levels. More detail on the future baseline is provided in **Volume 3, Appendix 6.3**.

6.6 Baseline conditions

6.6.1 Current baseline

Option Agreement Area

6.6.1.1 The OAA is located in a meso-tidal setting, with the mean spring tidal range typically between approximately 1.7 metres (m) and 1.9m. Mean spring peak current speeds are weak and are typically less than approximately 0.4 metres per second (m/s). Flow direction is approximately northwards during the ebb tide and south southeast during the flood tide.

6.6.1.2 The OAA is exposed to longer wave fetches (distances of open water over which waves can develop) from the north to north-east. Smaller, but more frequently occurring, wave conditions generated by local winds predominately come from southerly directions. Significant wave heights of approximately 9.2m are predicted for a 1:1 year event, increasing to 13.8m for a 1:50 year event.

6.6.1.3 The OAA is located in an area described by van Leeuwen *et al*. (2015) as being 'seasonally stratified', defined as >120 days in the year where the water column is stratified and <90 in the year where the water column is fully mixed. During the winter months (November to April), reduced solar heating and increased turbulent mixing from wind and waves result in very weakly stratified to mixed waters in the OAA, characterised by homogeneous temperature and density profiles, with potential energy anomaly (PEA) values around 30J/m³. With the onset of spring and summer, calmer weather and longer, warmer days enhance stratification, overcoming the mixing effects of tide and winds. From May to October, this leads to a vertical temperature gradient and an increase in PEA values. Over the 14-year analysis period (2010-2023), PEA typically reaches around 140 joule per cubic metre (J/m³) in mid-summer, indicating a strongly stratified water column. However, there is variability in the strength of summer stratification from year to year.

6.6.1.4 During summer, elevated chlorophyll-a concentrations - likely associated with a tidal mixing front - are commonly observed west of the OAA. However, their exact positioning varies significantly between years.

6.6.1.5 The seabed within the OAA can be generally described as a widely distributed but thin veneer of relatively sandy sediment, laid down and reworked during the Holocene period (the last 11,700 years since the last major glacial period). The seafloor sediments mainly comprise a combination of sand and silt, varying from slightly silty fine to medium sand to fine to medium sandy silt. Silty fine to medium sand is the predominant seafloor sediment. The only patches of gravels present are located within some of the seafloor depressions, where there are accumulations of gravel (shell and lithic fragments) and occasional cobbles / boulders. The thickness of the surficial Holocene veneer within the OAA is typically thin (0.25m to 1m) and may be absent in some locations (exposed bedrock or other erosion resistant substrate). These surficial units are underlain by various sequences of Pleistocene age (the period between approximately 2.6 million years ago and 11,700 years ago).

6.6.1.6 Consideration of the project specific geophysical survey data shows that water depths within the OAA range between approximately -88m and -134m below lowest astronomical tide (LAT). The average gradient within the OAA is very gentle (<1°), with steep and very steep gradients mainly associated with the flanks of large depressions (relict pockmarks).

6.6.1.7 Across the OAA, tidal current speed is normally insufficient, and the water depth is too large for waves to cause sediment mobility on a regular basis. Mainly sandy sediment is still present in a thin veneer but there is an absence of current induced bedforms that are interpreted as mobile. The seabed level in this area is unlikely to be naturally variable except

possibly during very large storm events. Even then, vertical change is expected to be less than approximately 0.25m.

Offshore export cable corridor

6.6.1.8 Tidal range increases with proximity to the coast along the offshore export cable corridor, increasing from around 1.9m at the offshore end to approximately 3.1m at the landfall zones (ABPmer *et al.*, 2008). Tidal current speeds also increase from offshore to nearshore, from around 0.4m/s where the offshore export cable meets the OAA to around 1m/s in the vicinity of the landfall zones. Residual flow fields are found to be relatively weak and variable along the offshore export cable corridor although the general trend is for residual flow in a southward and eastward direction.

6.6.1.9 Waves are generally from northerly or southerly directions although further inshore, towards the landfall zones, waves have a greater easterly component since they are progressively refracted as they approach the adjacent coastline.

6.6.1.10 Within the offshore export cable corridor, the seafloor sediments mainly comprise a combination of silt, sand, and gravel and are Holocene in age. Based on the results from the environmental grab samples, sand is the predominant main soil type with gradual changes in grain size across the route. Bedrock is observed outcropping at the seafloor in nearshore areas including at the landfall zones. The surficial Holocene sediments are generally between 0m to 1m thick. However, they reach a thickness of >5m in places.

6.6.1.11 Maximum water depths reach more than -120m LAT along the offshore export cable corridor, with minimum water depths (of close to 0m LAT) found at the landfall zones. Average seabed gradients are gentle (~1°), with a maximum gradient of ~76° observed in an area of outcropping bedrock close to the coast. A range of relict bedforms have been identified including eskers, glacial moraines and pockmarks, the latter having formed from the escape of fluid or gas from the seabed.

6.6.1.12 Large-scale flow-transverse bedforms including ripples, megaripples and sand waves are observed from approximately 40 kilometres (km) offshore to nearshore areas. Current speeds are sufficiently high for bedform migration to occur in these nearshore areas although clear and unambiguous evidence of this is not observed through comparison of the project geophysical survey data with older bathymetry data available from UKHO. Beyond a distance of approximately 40km from the coast, in the offshore half of the offshore export cable corridor (and in all of the OAA), tidal current speeds are normally insufficient, and the water depth too large for waves to cause sediment mobility on a regular basis.

Landfall zones

6.6.1.13 It has been necessary to present multiple landfall options to provide the Project with flexibility with regard to securing sufficient space, in appropriate locations, to construct the landfall and associated onshore and offshore export cables necessary to facilitate a 3GW Project. The landfall options assessed are:

- Option 1: Lunderton – all export cable cables would make landfall at Lunderton, based on the following scenarios:
  - Option 1a: all export cable cables make landfall at Lunderton North; or
  - Option 1b: all export cable cables would make landfall at a combination of Lunderton North and Lunderton South ;
- Option 2: Scotstown and Lunderton – export cable cables would make landfall at a combination of Lunderton (North and/or South) and Scotstown.

6.6.1.14 Scotstown is an exposed sandy beach located in Rattray Bay, which extends about 5km north to south between Rattray Head and the rock / stony headland at Scotstown Head (**Volume 2, Figure 6.3: The landfall at Scotstown**). The beach is approximately 300m wide, flanked by dunes. At the southern end of the beach there is an indistinct headland with bedrock (Peterhead granite) outcropping on the mid shore. Boulders and cobbles of a range of sizes surround the rock on all sides. Sand and dunes extend behind the outcrop on the mid and upper shore.

6.6.1.15 Lunderton is an exposed sandy beach, about 2km long extending north to south between two ill-defined rocky promontories (**Volume 2, Figure 6.4: The landfall at Lunderton**). Most of the landfall zones comprises a shallow sandy bay with gently sloping smooth or rippled clean sand on the mid to lower shore, about 300m wide. Sand dunes flank the upper shore along the entire length of the beach. The northernmost rocky promontory is low and comprised medium boulders. The southernmost promontory, adjacent to Peterhead Golf Course, extends on to the upper shore almost to the dunes, with only a narrow strip of upper shore sand between the stones and dunes. It included some moderately high bedrock outcrops

6.6.1.16 The cross-shore exchange of sediment between the beach areas and shallow sub-tidal areas by wave action may also result in episodic or seasonal variation of the beach and seabed level in the order of up to a few metres (this is not directly visible in the available data, but is a reasonable assumption based on normal beach processes).

6.6.1.17 The available evidence indicates a relatively stable regime, at present, in terms of net longshore drift. This is supported by available historic mapping evidence. Cyclic seasonal effects of frontal dune undercutting and beach lowering under storm wave conditions and re-accretion due to swell wave and wind action are evident along this stretch of coastline.

6.6.2 Future baseline

6.6.2.1 The baseline is expected to evolve in response to natural variation (for example, lunar nodal cycle, North Atlantic Oscillation etc), wider changes in climate expected over the lifetime of the project, and anthropogenic management of the coast.

6.6.2.2 By 2080, relative sea level may have risen by approximately 0.55m above baseline (2025) levels (Representative Concentration Pathway 8.5)) (Palmer *et al*., 2018). A rise in sea level may allow larger waves, and therefore more wave energy, to reach the coast in certain conditions and consequently result in an increase in local rates or patterns of erosion and the equilibrium position of coastal features. Notwithstanding this, negligible recession in the position of the MHWS contour is predicted by 2060 at Scotstown, even under a high sea level rise scenario. Up to c.15m of recession is predicted in places at Lunderton over the same time period although most areas at Lunderton are expected to see very little change.

6.6.2.3 Some of the shoreline adjacent to the project is defended. This includes parts of the coastline around Peterhead and Fraserburgh. The future evolution of the coastline in these areas will depend to some extent on any changes to the existing management strategies.

6.6.2.4 The UK Climate Impacts Programme dataset ‘UKCP18’ provides projections of changes to storm surge magnitude in the future as a result of climate change. These projections of change in extreme coastal water levels are dominated by the increase in mean sea level with only a minor (<10 per cent) additional contribution due to atmospheric storminess changes over the 21st Century (Palmer *et al*., 2018).

6.6.2.5 The stratification dynamics in the North Sea are expected to undergo significant changes due to the changing climate. The timing of stratification is influenced by the interplay between solar heating and tidal mixing, with a smaller but notable contribution from wind-driven mixing. Global warming and changes to meteorological conditions is likely to alter

the timing of spring stratification, and subsequently the timing of the spring phytoplankton bloom.

6.6.2.6 Model projections suggest that by 2100, the thermal stratification period in UK shelf seas will extend by approximately two weeks (Sharples *et al*., 2025), with stratification occurring about one week earlier and breaking down five to ten days later than present (Sharples *et al*., 2022). Model projections also suggest that seas across the north-west European shelf, including the northern North Sea, will experience greater surface-to-bottom temperature differences as the seasonal heating cycle intensifies (Tinker *et al*., 2016), resulting in stronger stratification. Alongside the strengthening stratification there will be small shifts in the position of tidal mixing fronts as thermal stratification pushes into shower waters and / or stronger tidal regions.

6.7 Basis for the EIA Report

6.7.1 Maximum design scenario

6.7.1.1 The process of 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 planning application, marine licences applications and s.36 consent.

6.7.1.2 The assessment of the maximum adverse scenario for each receptor establishes the maximum potential adverse effect and as a result effects of greater adverse significance would not arise should any other scenario (as described in **Chapter 4: Project Description**) to that assessed within this Chapter be taken forward in the final Project design.

6.7.1.3 The maximum design scenario parameters that have been identified to be relevant to marine geology, oceanography and physical processes are outlined in **Table 6.6** and are in line with the project design envelope (**Chapter 4: Project Description**).

Table 6.6 Maximum design scenario for impacts on marine geology, oceanography and physical processes

Impact / activity	Maximum design scenario parameter	Justification
Construction		
Impact C1: Potential changes to SSC, bed levels and sediment type from: • **seabed preparation for anchors** • **seabed installation activities for array cables** • **seabed preparation for subsea distribution centre (SDCs)** • **seabed preparation subsea substation** • **drilling for substation foundation installation** • **seabed preparation activities (levelling, sandwave clearance) which may lead to a requirement for spoil disposal elsewhere creating elevated suspended sediment and potential smothering deposition** • **seabed installation activities for export cables**	**Seabed preparation for wind turbine anchors** • 225 WTGs each with 8 anchors, total of 1,800 anchors; • Anchor type: driven pile anchor; and • bedform clearance (for example sandwaves). **Seabed preparation for array cables** • Bedform clearance (or example sandwaves). **Installation activities for array cables** • Jet trenching up to 530km of array cables with trench dimensions of 30m wide, 2m deep. **SDCs** • 45 SDCs; and • bedform clearance (or example sandwaves). **Seabed preparation for subsea substation** • 4 subsea substations; and • bedform clearance (or example sandwaves). **Seabed preparation for offshore substations** • 4 offshore substations; and • bedform clearance (or example sandwaves). **Piling for substation foundation installation** • 56 drilled piles (12 driven piles per offshore substation and 4 driven piles per reactive compensation platform (RCP)) with 94.5m drill penetration depth and 3m drill diameter, creating 667.7m^3 of drill arisings per pile.	The maximum design scenario corresponds to (a combination of) the greatest amount of material disturbed and the greatest geographical extent of the impact. **Seabed preparation** Seabed preparation, specifically sandwave clearance / levelling, may be undertaken using a range of techniques – MFE and suction hopper dredging are considered the worst case. Dredge spoil release is assumed to be an instantaneous release at the water surface, with 10% of the hopper volume (typically 11,000m^3) assumed to form the passive phase of the sediment plume. Other seabed preparation such as boulder clearance does not represent the maximum design scenario in terms of potential increases in SSC and associated changes to seabed substrate. **Installation activities for cables** Pre-lay trenching may be undertaken using a range of techniques – jetting, ploughing and trenching. Jetting will give maximum design scenario for sediment disturbance. 100% fluidisation of material expelled from trench is conservatively assumed. In reality, pre-lay jetting will move a proportion of material rather than bringing it fully into suspension.

Impact / activity	Maximum design scenario parameter	Justification
• **landfall installation activities inc. release of drilling fluid**	**Seabed preparation for offshore export cables** • bedform clearance (or example sandwaves); and • 35,000m^3 of sandwave clearance from the offshore export cable. **Installation activities for export cables** • Jet trenching up to 5 offshore export cable trenches, with trench dimensions of 30m wide, 2m deep, along 140km offshore export cable corridor length. **Landfall installation activities** • 8 horizontal directional drill (HDD) cable bore exit pits and ducts with sub-tidal location for punch-out; and • 1,500m HDD duct length.	**Piling** Based on the greatest amount of material disturbed in a drilling event, considering the largest driven pile dimension and largest driven pile penetration depth. **Landfall installation activities** Other stages of drilling (pilot hole drilling and stages of reaming) may result in smaller release events separated in time. But the maximum design scenario is considered as a release of drilling mud (Bentonite) from a single conduit.
Impact C2: Potential impacts to seabed morphology from: • **seabed preparation for anchors** • **seabed installation activities for array cables** • **seabed preparation for SDC** • **seabed preparation subsea substation** • **drilling for substation foundation installation** • **seabed preparation activities (levelling, sandwave clearance) which may lead to a requirement for spoil disposal elsewhere**	**Seabed preparation for wind turbine anchors** • 225 WTGs; • pre-lay grapnel run across entire length or all cables; • boulder clearance campaign; and • bedform clearance (e.g. sandwaves). **Seabed preparation for array cables** • pre-lay grapnel run across entire length or all cables; • boulder clearance campaign; and • bedform clearance (e.g. sandwaves). **Installation activities for array cables** • jet trenching up to 530km of array cables with trench dimensions of 30m wide, 2m deep; and • 1,122,000m^3 of rock placement or 22,666 mattresses or combination of both for cable protection. **Seabed preparation for SDCs** • 45 SDCs; • boulder clearance campaign; and	Sets out construction activities that give rise to the greatest (direct) disturbance to the seabed. **Seabed preparation** Sandwave clearance activities may be undertaken using a range of techniques – MFE and suction hopper dredging. Dredged spoil release creates disposal mounds through the active phase of the plume, assumed to be 90% of the material released.

Impact / activity	Maximum design scenario parameter	Justification
creating elevated suspended sediment and potential smothering deposition • **seabed installation activities for export cables** • **landfall installation activities**	• bedform clearance (e.g. sandwaves). **Seabed preparation for subsea substation** • 4 subsea substations; • boulder clearance campaign; and • bedform clearance (e.g. sandwaves). **Seabed preparation for offshore substations** • 4 offshore substations; • boulder clearance campaign; and • bedform clearance (e.g. sandwaves) **Drilling for substation foundation installation** • Refer to Impact C1. **Seabed preparation for export cables** • pre-lay grapnel run across entire length or all cables; • boulder clearance campaign; and • bedform clearance (e.g. sandwaves). **Installation activities for export cables** • jet trenching up to 5 export cable trenches, with trench dimensions of 30m wide, 2m deep, along 140km offshore export cable corridor length; and • rock placement used for cable protection with dimensions of 2m high (above sea level (ASL)) and 7m wide. **Landfall installation activities** • 8 HDD exit pits and ducts with sub-tidal punch-out locations; and • rock placement, with dimensions of 2m high (ASL) and 7m wide, used for cable protection. Installation duration will be: • up to 1 year for Phase 1; • up to 1 year for Phase 2; and	

Impact / activity	Maximum design scenario parameter	Justification
	• up to 1 year for Phase 3.	
Impact C3: Potential impacts to landfall morphology	**Landfall installation activities** • 8 HDD exit pits and ducts with sub-tidal punch-out locations; and • rock placement, with dimensions of 2m high (ASL) and 7m wide, used for cable protection. Installation duration will be: • up to 1 year for Phase 1; • up to 1 year for Phase 2; and • up to 1 year for Phase 3.	Sets out construction activities that give rise to the greatest (direct) disturbance to the coast and provide the greatest potential to interact with coastal processes responsible for maintaining the baseline form and function of the coast.
Operation and maintenance		
Impact O1: Potential changes to the tidal regime	**Operation and maintenance of:** • 225 WTGS with minimum separation between each WTG of 800m; • 225 floating units with surface dimensions of 100m x 120m; • 8 mooring lines per floating unit with a diameter of 250mm; • 225 array cables with a diameter of 194mm; • 4 offshore substations with below surface dimensions of 80m x 60m; • 2 RCPS with below surface dimensions of 35m x 35m; • 8 export cables with 2m high (ASL and 7m) wide cable protection; and • Up to 22 cable crossings within the offshore export cable corridor and 6 in the OAA requiring cable protection.	The maximum design scenario for changes to the tidal regime is given by the greatest depth-average blockage width for the project as a whole. This considers the number of foundations, floating substructure type (assumes a solid structure), mooring configuration and electrical cabling.
Impact O2: Potential changes to the wave regime	**Operation and maintenance of:** • 225 WTGS with minimum separation between each WTG of 800m; • 225 floating units with surface dimensions of 100m x 120m; • 4 offshore substations with below surface dimensions of 80m x 60m; and • 2 RCPS with below surface dimensions of 35m x 35m.	The maximum design scenario for changes to the wave regime is given by the greatest near-surface blockage width for the project as a whole. This considers the foundations presenting the greatest blockage in the upper water column (for instance, at / close to the sea surface) and the greatest number of foundations.

Impact / activity	Maximum design scenario parameter	Justification
Impact O3: Potential changes to the sediment transport regime	• Refer to Impact O1.	Sediment transport is driven by the combination of waves and tides. The relative contribution of these driving processes will vary spatially and temporally in response to, amongst other things, variation in water depth, tidal strength and meteorological events.
Impact O4: Potential impacts to seabed morphology	**Cable protection** • 1,122,000m^3 of array cable protection volume (rock placement); • 1,155,000m^3 of export cable protection volume for five trenches (rock placement); • 20% of export cable length requires protection; and • 2m high (ASL and 7m) wide cable protection. **Operation and maintenance of:** • 45 SDCs with dimensions of 18m x 8m x 5m; and • 4 subsea substations with dimensions of 22m x 20m x 16m.	Direct changes to seabed morphology through the presence of cable protection. Secondary scour will be highly localised and within the maximum design scenario assessed for primary scour.
Impact O5: Potential impacts to coastal morphology	**Cable protection (nearshore)** • 8 export cables with 2m high (ASL and 7m) wide cable protection.	Direct changes to coastal morphology through the presence of nearshore cable protection. The blockage of waves also has the potential to change of coastal morphology (Impact O5).
Impact O6: Scour	**Operation and maintenance of:** • 225 WTGs with each WTG foundation including 8 suction anchors with a diameter 6.5m and height (ASL) 0.5m; • 4 offshore substations with a base dimension of 110m x90m and each foundation including 12 suction caissons with a diameter 6.5m and height (ASL) 0.5m; and • 2 RCPS with a base dimension of 35m x 35m each foundation including 4 suction caissons with a diameter 6.5m and height (ASL) 0.5m.	Each foundation type and anchor arrangement may produce different scour patterns. The foundation and anchor type, size and number producing the greatest area and / or volume of influence is defined based on the outputs of the scour assessment. Scour protection may be used to protect the stability of foundations if necessary. Where scour protection is used, primary scour is unlikely to occur, although a small amount of secondary scour may develop at the edges of

Impact / activity	Maximum design scenario parameter	Justification
		the scour. However, the extent and volume of secondary scour will be considerably less than that described for the jacket foundations.
Impact O7: Potential changes to stratification and frontal systems	Refer to Impact O1.	The maximum design scenario for impacts to stratification and frontal systems is associated with the largest hydrodynamic blockage. This considers the number of foundations, floating substructure type (assumes a solid structure), mooring configuration and electrical cabling.
Decommissioning		
Impact D1: Potential changes to SSC bed levels and sediment type	• The approach for decommissioning is yet to be determined, however, for the purposes of this maximum design scenario total removal of all infrastructure including buried cables and cable protection has been assumed.	The maximum design scenario for sediment disturbance during decommissioning will be no greater than that set out for the construction stage of the Project.
Impact D2: Potential impacts to seabed morphology	Refer to Impact D1.	The coastal and seabed morphology could evolve to a new equilibrium state including the influence and presence of infrastructure. Removal of structures which have been in place for a long time could lead to changes in morphodynamics.
Impact D3: Potential impacts to landfall morphology	Refer to Impact D1.	The coastal and seabed morphology could evolve to a new equilibrium state including the influence and presence of infrastructure. Removal of structures which have been in place for a long time could lead to changes in morphodynamics.

6.7.2 Embedded environmental measures

6.7.2.1 As part of the Project design process, a number of embedded environmental measures have been adopted to reduce the potential for adverse impacts on marine geology, oceanography and physical processes. These embedded environmental measures have evolved over the development process as the EIA has progressed and in response to consultation.

6.7.2.2 These measures also include those that have been identified as good or standard practice and include actions that will be undertaken to meet existing legislation requirements. As there is a commitment to implementing these embedded environmental measures, and also to various standard sectoral practices and procedures, they are considered inherently part of the design of the Project and are set out in the EIA Report.

6.7.2.3 **Table 6.7** sets out the relevant embedded environmental measures within the design and how these affect the marine geology, oceanography and physical processes assessment.

6.7.2.4 Further detail on the embedded environmental measures in **Table 6.7** is provided in the **Volume 3, Appendix 5.2**, which sets out how and where particular embedded environmental measures will be implemented and secured.

Table 6.7 Relevant marine geology, oceanography and physical processes embedded environmental measures

ID	Environmental measure proposed	Project stage measure introduced	How the environmental measures will be secured	Relevance to marine geology, oceanography and physical processes assessment
M-005	To reduce the environmental impact of the landfall(s), a trenchless solution is to be implemented to install ducts. Determination of the most suitable trenchless landfall crossing method will be undertaken during the detailed design stage of the Project, following geotechnical investigation of the onshore and nearshore areas.	Scoping Amended at EIA Report.	**Volume 4: Outline Construction Environmental Management Plan**, description of Project and planning conditions.	Landfall installation methodology will avoid direct impacts to the intertidal area.
M-028	An **Outline Scour Protection Plan** has been submitted within this Application (**Volume 4**), and includes details of the need, type, quantity and installation methods for scour protection. A Final Scour Protection Plan will be completed prior to construction commencing and will include measures during the O&M stage such as periodic inspection and maintenance requirements and will be submitted to MD-LOT for approval.	Scoping Amended at EIA Report.	Section 36 (s.36) conditions and marine licences conditions.	Following the completion of a scour assessment, where there is the potential for scour to develop around Project infrastructure the appropriate scour protection will be put in place.
M-054	A detailed Cable Burial Risk Assessment (CBRA) will be undertaken to enable informed judgements about burial depth. This should reduce the risk of buried cables reemerging whilst also limiting the amount of sediment disturbance to that which is necessary. The array and export cables will typically be buried at a target burial depth between 1m to 2m below the seabed surface. The final depth of the cable will be dependent on the seabed mobility and CBRA. The CBRA will manage and mitigate risks from loading and sediment transport across the seabed. The CBRA will be included within the Final Cable Plan.	Scoping Amended at EIA Report.	s.36 conditions and marine licences conditions.	Cable burial will minimise the potential for interaction with seabed processes.

ID	Environmental measure proposed	Project stage measure introduced	How the environmental measures will be secured	Relevance to marine geology, oceanography and physical processes assessment
M-106	The development of and adherence to a Decommissioning Programme. The Decommissioning Programme will outline measures for the decommissioning of the Project. The Decommissioning Programme would be submitted prior to construction commencing to MD-LOT and approved by Scottish Ministers prior to construction.	Scoping Amended at EIA Report.	Required under Section 105 (Energy Act 2004) and marine licences conditions.	As the decommissioning stage will be a similar process to the construction stage but in reverse order the embedded environmental measure will be similar to those for the construction stage.
M-120	An **Outline Construction Method Statement** (CMS) has been submitted with this Application (**Volume 4**). The Final CMS will be completed prior to construction commencing and submitted to MD-LOT for approval. The Final CMS will include: a) details of the commence dates, duration and phasing of key elements of construction, working areas, the construction procedures and good working practices; b) details of the roles and responsibilities; and c) details of how the construction related mitigation step proposed are to be delivered.	EIA Report.	s.36 conditions and marine licences conditions.	Will specify the Project's construction methods, setting out good practice construction measures and how agreed embedded environmental measures from the Offshore EIA Report, will be implemented during construction.
M-121	An **Outline Environmental Management Plan** (EMP) has been submitted with this Application (**Volume 4**) and includes the following Appendix: - **Outline Marine Pollution Contingency Plan**. The Final EMP will be completed prior to construction commencing and submitted to MD-LOT for approval. The Final EMP will be implemented by the contractor(s). The contractor(s) will ensure that the relevant environmental measures within the EMP and health and safety procedures are implemented. The Final EMP will identify the project management structure roles and responsibilities with regard	EIA Report.	s.36 conditions and marine licences conditions.	Will set out procedures to ensure all activities with the potential to affect the environment are appropriately managed.

ID	Environmental measure proposed	Project stage measure introduced	How the environmental measures will be secured	Relevance to marine geology, oceanography and physical processes assessment
	to managing and reporting on the environmental impact of the construction and O&M stages. Other measures that feed into the EMP include: - A Waste Management Plan (WMP) will be developed as an Appendix of the EMP post-submission to manage all waste generated during the construction and operation stages of the Project. The WMP will be appended to the Environmental Management Plan. The WMP will follow the principles of the waste hierarchy (Department for Environment, Food & Rural Affairs, 2001) which consists of: prevention, re-use, recycle, other recovery and disposal. - The Final Environmental Management Plan will include a Chemical Risk Assessment to identify, evaluate and mitigate potential environmental and health risks associated with the use, storage and disposal of hazardous substances during O&M and decommissioning stages of the Project. The EMP will be the securing mechanism for many measures.			
M-123	Ensure appropriately qualified offshore Ecological Clerk of Works will be appointed by the Project before pre-construction monitoring requirements commence.	EIA Report.	s.36 conditions and marine licences conditions.	Will set out procedures to ensure all activities with the potential to affect the environment are appropriately managed.

6.8 Methodology for EIA Report

6.8.1 Introduction

6.8.1.1 The project-wide approach to assessment is set out in **Chapter 5: Approach to the EIA.** Whilst this has informed the approach that has been used in this marine geology, oceanography and physical processes assessment, it is necessary to set out how this methodology has been applied, and adapted as appropriate, to address the specific needs of the marine geology, oceanography and physical processes assessment.

6.8.2 Assessment techniques

6.8.2.1 In order to assess the potential changes to marine geology, oceanography and physical processes, relative to the existing baseline, a combination of analytical methods have been used. These methods are discussed with respect to the each of the potential impacts, and pathways of effects, in the assessment Sections, but can be summarised as:

- numerical modelling of wave blockage from the Project infrastructure (notably the WTG floating units);
- standard empirical equations describing the potential for:
  - WTG floating units and offshore platforms to change turbulent kinetic energy (TKE) and therefore water column stratification;
  - scour development around vertical structures (for example, jacket structures and suction anchors), cables and berms (for example, Whitehouse, 1998);
- semi-quantitative assessments of sediment transport blockages from the Project infrastructure, also with reference to spatial maps of baseline sediment transport pathways from a high-resolution numerical sand transport model;
- spreadsheet based tools for extent and concentration of sediment plumes produced from installation activities and associated changes in bed level;
- analytical assessments of project-specific data; and
- evidence from analogous projects including other offshore wind farms and subsea cables.

6.8.2.2 The assessments consider likely naturally occurring variability in, or long-term changes to, marine geology, oceanography and physical processes over the lifetime of the Project (to 2080) due to natural cycles and / or climate change (for example, sea level rise). This is important as it enables a reference baseline level to be established, against which the potentially modified marine and coastal processes can be compared, throughout the Project lifespan.

6.8.3 Significance evaluation methodology

Overview

6.8.3.1 The significance level attributed to each effect has been assessed based on the value of the affected receptor and the magnitude of change resulting from the Project. The level of significance has then been determined by the combination of value and magnitude.

Value of receptor

6.8.3.2 The criteria for defining the value (or sensitivity) in this Chapter are outlined in **Table 6.8**. The value / sensitivity of each receptor has been assessed using expert judgement on a standard semantic scale and is closely guided by the conceptual understanding of regional-scale physical processes, developed during the baseline characterisation process (**Volume 3, Appendix 6.3**).

Table 6.8 Value or sensitivity criteria

Value of receptor	Definition
High	Very low or no capacity to accommodate the proposed form of change; and / or receptor designated and / or of international level importance. Likely to be rare with minimal potential for substitution. May also be of very high socioeconomic importance.
Medium	Moderate to low capacity to accommodate the proposed form of change; and / or receptor designated and / or of regional level importance. Likely to be relatively rare. May also be of moderate socioeconomic importance.
Low	Moderate to high capacity to accommodate the proposed form of change; and / or receptor not designated but of district level importance.
Very low	High capacity to accommodate the proposed form of change; and / or receptor not designated and only of local level importance.

Magnitude of changes

6.8.3.3 The magnitude of impact describes the extent or degree of change that is predicted to occur to a receptor, in terms of the spatial extent, duration, frequency and reversibility of change. It has been assessed using expert judgement and described qualitatively with a standard semantic scale. Definitions for each term are provided in **Table 6.9**. These expert judgements regarding the magnitude of effect relative to baseline conditions have been made by experienced marine physical process specialists and formed following consideration of the information sources previously set out in **Table 6.4** and **Table 6.5** and the assessment findings set out in **Volume 3, Appendix 6.1**.

Table 6.9 Magnitude criteria

Magnitude of impact	Definition
High	Permanent changes across the near- and large parts of the far-field to key characteristics or features of the particular environmental aspect's character or distinctiveness.
Medium	Permanent changes, over the near- and parts of the far-field, to key characteristics or features of the particular environmental aspect's character or distinctiveness.

Magnitude of impact	Definition
Low	Noticeable, temporary (for part of the project duration) change, or barely discernible change for any length of time, restricted to the near-field and immediately adjacent far-field areas, to key characteristics or features of the particular environmental aspect's character or distinctiveness.
Very low	Changes which are not discernible from background conditions.

Significance evaluation

6.8.3.4 During the assessment of effects for each identified receptor, the value in **Table 6.8** will be combined with the magnitude of change from **Table 6.9** to produce an overall significance rating based on the evaluation matrix shown in **Table 6.10**. As a general rule, **Major** and **Moderate** effects are considered to be **Significant** and **Minor** and **Negligible** effects are considered to be **Not Significant**. However, professional judgement is applied, where appropriate, to determine significance of effect. Where effects are assessed, according to the matrix in **Table 6.10** to be **Potentially Significant** in EIA terms, professional judgement is applied to determine whether they are **Significant** or **Not Significant**.

6.8.3.5 It is noted here that a distinction is made throughout the assessment between the magnitude, extent and duration of impacts or changes and the resulting significance of the effects upon marine geology, oceanography and physical processes receptors. Various actions may result in impacts: for instance, the installation of the export cable in the landfall zones, causing a localised and short-term change to intertidal morphology (which is defined as a marine geology, oceanography and physical processes receptor).

Table 6.10 Matrix to determine effect significance

		Magnitude of change			
		High	**Medium**	**Low**	**Very Low**
Value / Sensitivity	**High**	**Major (Significant)**	**Major (Significant)**	**Moderate (Potentially Significant)**	**Minor (Not Significant)**
	Medium	**Major (Significant)**	**Moderate (Potentially Significant)**	**Minor (Not Significant)**	**Minor (Not Significant)**
	Low	**Moderate (Potentially Significant)**	**Minor (Not Significant)**	**Minor (Not Significant)**	**Negligible (Not Significant)**
	Very Low	**Minor (Not Significant)**	**Minor (Not Significant)**	**Negligible (Not Significant)**	**Negligible (Not Significant)**

6.9 Assessment of effects: construction stage

6.9.1 Introduction

6.9.1.1 This Section provides an assessment of the effects for marine geology, oceanography and physical processes from the construction of the offshore elements of the Project.

6.9.1.2 The assessment methodology set out in **Section 6.8** has been applied to assess effects to marine geology, oceanography and physical processes from the Project.

6.9.2 Impact C1: potential changes to suspended sediment concentrations, bed levels and sediment type

Overview

6.9.2.1 This Section provides a description of the realistically possible combinations of magnitude and extent of impact for local increases in SSC and seabed deposition, due to sediment disturbance potentially caused by:

- drilling for offshore substation foundation installation;
- seabed preparation by dredging for floating unit anchors, SDCs, subsea substations and offshore substation jacket foundations;
- sandwave clearance prior to cable burial;
- cable burial; and
- drilling fluid release during HDD at the landfall zones.

6.9.2.2 A full assessment of the above, including the methodological approach used to assess the characteristics of sediment plumes and associated changes in bed level arising from settling of material is set out in **Volume 3, Appendix 6.1**. Summary findings are set out below.

6.9.2.3 The maximum assessment scenario relating to potential changes to SSCs, bed levels and sediment type are presented in **Table 6.6**.

Sensitivity or value of receptor

6.9.2.4 All of the changes described in this Section are to 'pathways' as opposed to receptors and therefore sensitivity ratings have not been assigned.

Magnitude of impact

6.9.2.5 Potential change to SSCs, bed levels and sediment type is considered to be a pathway of effect, rather than an impact on receptors, and as such, it is not appropriate to carry out an assessment of significance which determines the magnitude of effect to them. Instead, this Section focuses on describing the spatial and temporal nature, with the potential for associated impacts to marine biodiversity assessed in other chapters (see **paragraph 6.9.2.11**).

6.9.2.6 The actual magnitude and extent of change in SSC and bed levels will depend in practice on a range of factors, such as the actual total volumes and rates of sediment disturbance, the local water depth and current speed at the time of the activity, the local sediment type and grain size distribution, the local seabed topography and slopes, etc. There will be a wide range of possible combinations of these factors and so it is not possible to predict

specific dimensions with complete certainty. To provide a robust assessment, a range of realistic combinations have been considered, based on conservatively representative location (environmental) and project maximum design scenario specific information, including a range of water depths, heights of sediment ejection / initial resuspension, and sediment types.

6.9.2.7 This wider range of results can be summarised broadly in terms of four main zones of effect, based on the distance from the activity causing sediment disturbance. These zones are entirely consistent with the results of observational (monitoring) evidence and numerical modelling of analogous activities (for example, BERR, 2008; Thames Estuary Dredging Association (TEDA), 2012; Navitus Bay Development Ltd, 2014; Vattenfall, 2018; Ørsted, 2018; Blue Gem Wind, 2022; Awel y Môr Offshore Wind Farm Ltd, 2022; and Five Estuaries Offshore Wind Farm Ltd, 2024):

- 0m to 5m – zone of highest SSC increase and greatest likely thickness of deposition. All gravel sized sediment likely deposited in this zone, also a large proportion of sands that are not resuspended high into the water column, and also most or all dredge spoil in the active phase. Plume dimensions and SSC, and deposit extent and thickness, are primarily controlled by the volume of sediment released and the manner in which the deposit settles:
  - At the time of active disturbance – very high SSC increase (tens to hundreds of thousands of milligrams per litre (mg/l)) lasting for the duration of active disturbance plus up to 30 minutes following end of disturbance; sands and gravels may deposit in local thicknesses of tens of centimetres to several metres; fine sediment is unlikely to deposit in measurable thickness.
  - More than one hour after the end of active disturbance – no change to SSC; no measurable ongoing deposition.
- 25m to 250m – zone of measurable SSC increase and measurable but lesser thickness of deposition. Mainly sands that are released or resuspended higher in the water column and resettling to the seabed whilst being advected by ambient tidal currents. Plume dimensions and SSC, and deposit extent and thickness, are primarily controlled by the volume of sediment released, the height of resuspension or release above the seabed, and the ambient current speed and direction at the time:
  - At the time of active disturbance – high SSC increase (hundreds to low thousands of mg/l) lasting for the duration of active disturbance plus up to 30 minutes following end of disturbance; sands and gravels may deposit in local thicknesses of up to tens of centimetres; fine sediment is unlikely to deposit in measurable thickness.
  - More than one hour after end of active disturbance – no change to SSC; no measurable ongoing deposition.
- 250m to the tidal excursion buffer distance – zone of lesser but measurable SSC increase and no measurable thickness of deposition. Mainly fines that are maintained in suspension for more than one tidal cycle and are advected by ambient tidal currents. Plume dimensions and SSC are primarily controlled by the volume of sediment released, the patterns of current speed and direction at the place and time of release and where the plume moves to over the following 24 hours:
  - at the time of active disturbance – low to intermediate SSC increase (tens to low hundreds of mg/l) as a result of any remaining fines in suspension, only within a narrow plume (tens to a few hundreds of metres wide, SSC decreasing rapidly by dispersion to ambient values within one day after the end of active disturbance; fine sediment is unlikely to deposit in measurable thickness.

  - One to six hours after end of active disturbance – decreasing to low SSC increase (tens of mg/l); fine sediment is unlikely to deposit in measurable thickness.
  - Six to 24 hours after end of active disturbance – decreasing gradually through dispersion to background SSC (no measurable local increase); fine sediment is unlikely to deposit in measurable thickness. No measurable change from baseline SSC after 24 hours to 48 hours following cessation of activities.
- Beyond the tidal excursion buffer distance or anywhere not tidally aligned to the active sediment disturbance activity – there is no expected impact or change to SSC nor a measurable sediment deposition.

6.9.2.8 **Volume 2, Figure 6.5 Spring tidal excursion buffer, 25m and 250m buffers outside of the OAA and offshore export cable corridor** provides a summary of the spatial extent of these zones in relation to the OAA and offshore export cable corridor. Designated nature conservation sites within the study area are also shown. **Volume 2, Figure 6.6 Sediment deposition footprints associated with a single disturbance activity at an example location in the OAA** illustrates sediment deposition footprints associated with a single disturbance at an indicative location in the southern OAA.

6.9.2.9 If multiple activities causing sediment disturbance (such as dredging, drilling or cable installation) are undertaken simultaneously at two or more locations that are aligned in relation to the ambient tidal streams, then there is potential for overlap between the areas of change in SSC and sediment deposition. The effect on SSC is locally additive in the area of overlap. Plumes that overlap subsequently through lateral diffusion are not an additive effect on SSC and will not exceed the values quoted for individual plumes. The total sediment thickness deposited is locally additive in the area of overlap. It is noted that measurable thicknesses of deposition are only expected within relatively small distances (tens of metres) from the site of the activity, extending in the direction of tidal current at the time of the work. Therefore, there is a very low likelihood of a large total area of overlapping measurable local thicknesses of deposition resulting from overlapping plume effects.

6.9.2.10 The embedded environmental measures M-120 and M-121 from **Table 6.7** means a construction method statement and environmental management plan will be produced as part of the Project, ensuring construction methods align with good practice, implement agreed embedded environmental measures and are appropriately managed.

Significance of residual effect

6.9.2.11 The assessment set out in this Section has considered potential changes to a pathway, rather than impacts on receptors. Accordingly, no assessment of significance is provided. However, the potential for these changes to impact other EIA receptor groups are considered elsewhere within the EIA, in particular:

- **Chapter 7: Marine Water and Sediment Quality**;
- **Chapter 10: Benthic, Epibenthic and Intertidal Ecology**;
- **Chapter 11: Marine Mammals**;
- **Chapter 12: Offshore and Intertidal Ornithology**;
- **Chapter 13: Fish Ecology**; and
- **Chapter 16: Marine Archaeology and Cultural Heritage**.

6.9.3 Impact C2: potential impacts to seabed morphology

Overview

6.9.3.1 Cable installation, as well as the installation (and subsequent presence) of cable protection measures, offshore substation platforms, RCPs and anchoring structures all have the potential to impact seabed morphology. This impact will commence when offshore construction begins, increasing incrementally up to the Maximum Design Scenario, which is represented by the fully operational Project. Morphological change arising from the presence of these structures will be no greater than that identified for the operational stage and, therefore, is discussed in **Section 6.10.5** and not considered further here.

6.9.3.2 In addition to the above, some levelling of sandwaves may be necessary during the construction stage, which has the potential to alter the local seabed morphology within the OAA and offshore export cable corridor. This will be achieved by MFE or dredging (**Table 6.6**), although it is noted that any sediment removed from the seabed will, preferentially, be deposited in close proximity to the dredge location. The potential extent of change and likely timescales over which sandwave feature recovery may occur is considered further in this Section. It is noted here that levelling of moraines (including within the Southern Trench MPA) cannot be ruled out; however the potential location, footprint and volume of any dredging activity is unknown at this stage.

6.9.3.3 Finally, where dredging is required, material will be disposed of nearby on the seabed. These disposal events may leave mounds which locally change the morphology of the seabed and (depending on the nature of the material and local hydrodynamic setting) may persist in time. The persistence and evolution of these mounds is considered in this Section.

Sensitivity or value of receptor

6.9.3.4 The offshore export cable corridor passes through the Southern Trench NCMPA and cable installation (possibly as well as sandwave levelling) will be undertaken inside the boundary of the NCMPA. The site is high value / importance (since it forms part of Scotland's NCMPA network) and the geodiversity features of interest are relict (subglacial tunnel valleys, moraines and scars evidencing mass movement) with no ability to recover from impact. Accordingly, the site is assessed to be of **high** sensitivity.

Magnitude of impact

Installation of cables

6.9.3.5 Cables may be buried into surficial sediments or more consolidated Quaternary material. Once buried, the cables will not have any potential to impact seabed morphology unless exposed. Should this occur, the maximum depth of scour will be between one and three times the cable diameter (for instance, up to ~1m) and the maximum horizontal extent of any scour effect will be up to 50 times the cable diameter for instance, up to about 15m).

6.9.3.6 In theory, cables may be installed into moraines and tunnel valleys which are protected geodiversity features within the Southern Trench NCMPA. Based on existing mapping of geodiversity features within the Southern Trench NCMPA (NatureScot, 2025), a moraine feature is understood to be present, located around 10km to 12km offshore of the Scotstown landfall, whilst a north to south trending tunnel valley is present around 16km offshore (see Figure 5 in **Volume 3, Appendix 6.3**).

6.9.3.7 The designated moraine feature is not covered by the Project-specific survey and is not clearly apparent in the available UKHO 8m resolution bathymetry data (This may relate to

the comparatively low resolution nature of the UKHO bathymetry or, more likely, the low resolution of the feature mapping presented in NatureScot (2025)). The tunnel valley is also not resolved in available bathymetric survey data: this may be because the feature is infilled or it may be due data resolution / feature mapping accuracy. Regardless, even if moraines and tunnel valleys are found to be present, the localised nature of any works will be small relative to the size and extent of features and overall favourable condition should be maintained, according to the criteria set out in **Section 6.4.4**. A full assessment of the potential significance of effect on the Conservation Objectives of the Southern Trench NCMPA designation is assessed in the **Nature Conservation Marine Protected Area Assessment**.

6.9.3.8 The magnitude of impact to the designated seabed features (moraines and tunnel valleys) resulting from cable trenching activities would be **very low**. This is because although it is recognised that impacts would be permanent, they would be extremely localised and impact only a small proportion of the total footprint of the feature. As such, the impact does not threaten the long-term viability of the Southern Trench NCMPA.

Sandwave levelling

6.9.3.9 Whilst no sandwaves are understood to be present in the OAA, up to 35,000m^3 of material may require removal from the offshore export cable corridor. The volume of material to be displaced from individual sandwaves will vary according to the local dimensions of the sandwave (height, length and shape) and the level to which the sandwave must be reduced (also accounting for stable sediment slope angles and the capabilities and requirements of the cable burial tool being used). Based on the available geophysical data, it is anticipated that the bedforms requiring localised levelling may exceed 3m in height. Indicative locations of sandwave fields within the Offshore Development Area are shown in Figure 9 in **Volume 3, Appendix 6.3**; the exact location of sandwaves which may require levelling is not yet known.

6.9.3.10 The sediments comprising the sandwave features will be predominantly sand, although a small proportion of fines and gravel may, potentially, also be present. Individual sandwaves will require removal via MFE or by multiple dredging cycles to complete the required corridor. If dredging is undertaken, the preference is for the dredge spoil to be returned to the seabed in the vicinity of the dredged area. Given that surficial sediment cover is limited in many areas, maintaining the local total sediment volume will enable levelled sandwaves to reach a new equilibrium which is as similar as possible to the pre-levelled feature. The equilibrium position should also be reached more quickly than if the material was removed from the system.

6.9.3.11 The tidal current regime (peak current speeds on a mean spring tide of 0.6m/s or more in areas along the offshore export cable corridor where sandwaves are present) is sufficiently strong to cause mobility of sand on a regular basis. The tidal current regime will not measurably change as a result of the localised levelling, or as a result of any other aspect of the Project. The volume of sediment available in each local system will be locally redistributed by the local levelling (via MFE) and / or dredging, and disposal of removed material back into the water column nearby, but will not change in an overall net sense . As the controlling factors will also not change, the levelled areas and sandwave features will recover in time to a new (dynamically evolving) natural state.

6.9.3.12 The levelled area is considered to be ‘recovered’ in terms of form and function once the local crest level has re-established to a form that is within the range of natural variability observed in the other similarly sized surrounding bedforms, which may be of different dimensions and location than the original feature pre-levelling.

6.9.3.13 The rate and timescale of recovery will vary in proportion to the rate of sediment transport and accumulation. Faster infill and recovery rates will be associated with periods of higher

local flow speeds and more frequent wave influence at the seabed. The following factors will all influence the rate of recovery:

- the local rates of sand transport;
- the amount of material dredged at each sandwave location which will be determined by:
  - the width of the dredged corridor; and
  - the height and wavelength of the dredged features.

6.9.3.14 Where the dredge spoil is returned to the seabed in the vicinity of the dredged area, the volume and supply of sediment in the local system will not be changed.

6.9.3.15 The exact timescale for recovery cannot be calculated with certainty. Based only on the overall rate of observed bedform migration (which is not the main or only mechanism for recovery and is proportional to the long-term net sediment transport rate), the timescale for recovery may be in the order of many decades as minimal migration is observed to have occurred over the past decade or so. However, short-term sediment mobility will also contribute to local sandwave recovery, and these rates are expected to be higher than negligible in these areas.

6.9.3.16 A shorter estimated timescale is obtained when considering the instantaneous rate of transport during higher flow periods. As shown by the detailed sand transport modelling presented in **Volume 3, Appendix 6.3**, instantaneous transport rates (increasing with proximity to the coast) of between approximately 0.05 to 3.5 cubic metres per meter per hour ($m^3/m/hr$) may be active up to four times per day (peak flood and ebb) for a few days either side of the peak of spring tides. At a representative rate of $0.5m^3/m/hr$, and assuming a representative 50m wide corridor and a nominal volume of $15,000m^3$ sediment displaced for an individual sandwave, it could take in the order of ($15,000m^3$ / [$0.5m^3/m/hr$ x 50m x 4hr/day x 4 days]) 37.5 spring tidal cycles (~1.5 years) to move the displaced volume of sediment back into the levelled area. The overall rate of recovery would also vary in proportion to the volume displaced (relative to the representative value of $15,000m^3$).

6.9.3.17 The recovery may be gradual or episodic. Rates of sandwave bedform recovery are likely to be relatively faster closer to the coast (higher current speeds and shallower depths lead to greater and / or more frequent sediment mobility). Varying states of partial recovery will be achieved in a shorter timescale. As the recovery is due to natural processes of sediment transport, the nature of the seabed surface sediments in the recovering area will not be measurably different to that on the surrounding seabed and adjacent sections of undisturbed sandwave. In all locations, surficial sediments will continue to be mobilised at the natural ambient rate and direction under sufficiently energetic current and wave conditions, with the associated development and migration of smaller (for example, ripple and megaripple) bedforms.

6.9.3.18 The final shape of the bedform following recovery may be similar to its original condition (for example, rebuilding a single crest feature, although likely displaced in the direction of natural migration) or it might change (for example, a single crest feature might bifurcate or merge with another nearby bedform). All such possible outcomes are consistent with the natural processes and bedform configurations that are already present in the study area and would not adversely affect the onward form and function of the individual bedform features.

6.9.3.19 The levelled areas are not considered likely to create a barrier to onward sediment transport. Evidence from aggregate dredging activities indicates that if any changes occur to the flow conditions or wave regime, these are localised in close proximity to the dredge pocket (with widths and lengths of several kilometres) (for example, AODA, 2011; TEDA, 2012). The proposed works will be at a much smaller scale and footprint, with trench widths expected to be in the order of up to a few tens of metres. This means there is likely to be little to no

influence on the flow or wave regime in the surrounding area which, in turn, means little to no change to the regional scale sediment transport processes across the offshore export cable corridor.

6.9.3.20 The magnitude of impact to moraines and tunnel valleys within the Southern Trench NCMPA as a result of any sandwave levelling is also considered to be **very low**. This is because partial removal of sandwaves would not disturb the underlying designated features upon which they would be located. As such, the impact does not threaten the long-term viability of the Southern Trench NCMPA.

Disposal mounds

6.9.3.21 Levelling of sandwaves (and potentially moraines) via dredging are likely to be associated with the formation of disposal mounds adjacent to the dredged areas, following the release of material from the hopper. The persistence and evolution of these disposal mounds in either the OAA or offshore export cable corridor will be dependent upon a range of factors, principally:

- the type of material in the mound;
- the size / shape of the mound; and
- the level of bed shear stress exerted on the mound by tidal currents and waves (water depth being a key determinant of the latter).

6.9.3.22 Arguably the most important of these is the type of material in the mound and this is expected to differ markedly, depending upon whether the dredged material originates from sandwaves (comprising sand) or moraines (likely comprising consolidated bounder clay).

6.9.3.23 It can reasonably be assumed that any disposal mounds comprised of material dredged from moraines (boulder clay) will become semi-permanent or permanent seabed features that persist for the lifetime of the Project and potentially beyond. The actual shape and thickness of disposal mounds resulting from the release of material from the dredger cannot be predicted accurately in advance and in any case is likely to vary. However, any mounds could reasonably be expected to be up to a few metres in height and a few tens of metres in diameter. Over time, it can be expected that fine grained material will be further disaggregated and winnowed away, lowering the profile of the mound. Ultimately, this could result in only (largely immobile) gravel sized material remaining, potentially forming an ‘armoured’ seabed layer.

6.9.3.24 It is noted however, that whilst the disposal mounds might be topographically different from the surrounding seabed, their surficial sediment character may become similar. This is because surficial (sandy) sediment is limited or absent in many areas. This mobile sand would likely be transported onto the disposal mound, creating a similar surficial seabed type and smoothing local topography over time.

6.9.3.25 In those areas where disposal mounds are comprised largely of sandy material (for instance, derived from sandwaves) similar in character to the surrounding seabed, given the prevailing hydrodynamic and wave conditions it can reasonably be expected that the sand will be re-mobilised and re-incorporated into the active sediment regime over time.

6.9.3.26 The magnitude of impact to moraines and tunnel valleys within the Southern Trench NCMPA as a result of any disposal activities is also considered to be **very low**. This is because although it is recognised that the disposal mound(s) on the designated features may be permanent (or persist for a very long period of time), it would be an extremely localised impact covering a small proportion of the total footprint of the feature.

Significance of residual effect

6.9.3.27 Overall, it is predicted that the sensitivity of the receptor (designated seabed features within the Southern Trench NCMPA) is **high**, and the magnitude of all identified impacts is **very low**. The effect is of **Minor** (**Not Significant**) in EIA terms.

6.9.4 Impact C3: potential impacts to landfall morphology

Overview

6.9.4.1 The offshore export cables will make landfall at Scotstown and / or Lunderton (**Volume 2, Figure 6.3** and **Volume 2, Figure 6.4**). Full details of the Maximum design scenario parameters are provided in **Table 6.6**, whilst a full description of coastal characteristics (including observed historic change and existing management policies) are set out in **Volume 3, Appendix 6.3**. The assessment below separately considers the potential for impacts associated with:

- trenchless installation techniques; and
- construction of exit pits.

6.9.4.2 The potential for impacts to coastal morphology arising from the use of cable protection measures during the operational stage is assessed in **Section 6.10.6.**

6.9.4.3 The magnitude of change, and hence the significance of potential effects has been assessed on the assumption that the embedded environmental measures from **Table 6.7** have been implemented as part of the Project.

Sensitivity or value of receptor

6.9.4.4 The coast at the landfall zones is potentially vulnerable to either direct or indirect disturbance from Project-related activities. However, it is not located within any designated nature conservation sites and does not therefore contain any protected geodiversity features. It is typically a dynamic environment which is subject to natural change under baseline conditions. Accordingly, it is assessed to have some capacity to recover from disturbance and accommodate change. The overall sensitivity of the coastline at the landfall zones is therefore considered to be **medium**, reflecting the fact that the receptor is of medium value, medium vulnerability and medium recoverability.

Magnitude of impact

Trenchless installation techniques

6.9.4.5 The coastline within the landfall zones is characterised by the presence of a sandy beach backed by an (undefended) dune complex. The available evidence suggests that the coastline is stable with only very modest erosion anticipated over the lifetime of the Project in response to climate change and sea level rise (**Section 6.6, Volume 2, Figure 6.3** and **Volume 2, Figure 6.4**).

6.9.4.6 The most commonly used form of trenchless installation technique is HDD; this is an established solution for trenchless installation. HDD involves drilling a long borehole underground, using a drilling rig located within the landfall compound. This technique avoids interaction with surface features and is used to install ducts through which cables can be pulled. HDDs can vary in length depending on the ground conditions: although the overall length is unknown at this stage, the punchout location will be in a sub-tidal setting.

6.9.4.7 Trenchless cable installation will cause minimal direct disturbance to the existing coastline because it will not interact directly with, or leave any infrastructure exposed in, the active parts of the beach (between the entry and exit points of the drill) and so will not impact upon littoral processes in these areas. Provided that the cable remains buried beyond the exit point, there is no possibility for it to interact with, or have any effect on, nearshore beach processes or morphology. The design of the trenchless operations will take this into account. Accordingly, it is extremely unlikely that the Loch of Strathbeg SSSI / SPA / RAMSAR (which is located around 4km to the north of the Scotstown landfall) would be impacted by an interruption to coastal processes including changes to sediment transfer.

6.9.4.8 The choice of location for the onshore trenchless operation works and jointing bay will take into consideration projected rates of coastal erosion to ensure that infrastructure is unaffected by the possibility of coastal retreat.

6.9.4.9 The magnitude of impact to coastal morphology at the landfall zones is predicted to be **very low**. This is because trenchless cable installation techniques will be used, meaning that there will be no interaction with the beach and associated littoral transport processes.

Construction of exit pits

6.9.4.10 As the trenchless installation is carried out between a start and end point, entry and exit pits (up to eight) must be excavated at either end of the borehole: one in the landfall compound and one on the offshore side.

6.9.4.11 The exact dimensions of the exit pits are unknown at this stage but are expected to be a few metres wide, a few 10's metres long and a few metres deep, with an excavated volume of a few 1000m^3 per pit.

6.9.4.12 Exit pits will be excavated or dredged to the required depth, and side-cast material for backfilling will be stored adjacent to the exit pit. Once the drilling operation has taken place, the ducts will be pulled through the drilled holes. Once installation is complete, the exit pits will either be backfilled using side-cast material or left to naturally backfill.

6.9.4.13 The potential mechanisms by which the presence of the exit pits could theoretically impact the coast at the landfall zones are principally via the modification of waves and interception of sediment. Potential changes to the wave regime resulting from the presence of exit pits in shallow subtidal areas are summarised as follows:

- Changes to short period, low amplitude wind waves will be largely immeasurable at all states of the tide as the likely depth and footprint dimensions of the temporary changes to water depths will be insufficient to measurably alter short wave characteristics.
- Longer period, higher amplitude storm waves could theoretically be more affected by the presence of the exit pits, possibly resulting in some wave refraction. However, the dimensions of the exit pits will be very small relative to the wavelengths of storm waves, greatly limiting the potential for measurable refraction. Any change to the wave regime will also diminish with increasing distance away from the exit pits and at higher states of the tide when water depths are greater.
- The presence of the exit pits could potentially enable wave energy associated with storm waves to propagate slightly further inshore / up the beach than would have been the case, as larger waves will shoal less, enabling them to remain marginally higher immediately in the lee of the exit pits. However as larger waves travel inshore from the exit pits, the shoreline gradient / water depths will increasingly become the limiting condition on wave form.

6.9.4.14 However, even with the possibility of some (highly localised) wave refraction, it is probable that only some of the waves reaching the beach will have passed across the footprint of the exit pits.

6.9.4.15 The exit pits are expected to be located within the theoretical active shore profile, as defined by the 'Depth of Closure'. This means that during storm events, material removed from the beach may be transported across the location of the exit pits. Given the likely high gradient of the pit side slopes, it is probable that any local material entering the pits could become trapped. This material would then not be available to replenish the beach during calmer conditions (when waves are generally constructive rather than destructive in nature).

6.9.4.16 The extent to which a very small section of beach morphology could potentially be altered by trapping of sediment will be dependent upon the frequency and magnitude of storms during the operational period of the exit pits, and their dimensions. If an exit pit were to be entirely infilled, this would represent up to only a few thousand m^3 of material temporarily 'lost' from the local subtidal sedimentary system and beach. However, this is unlikely to happen given the relatively short duration of time that the exit pits will be open and operational, and their distance from the beach.

6.9.4.17 Given that winter storms may occur during the operational period of the exit pits, it is theoretically possible that some maintenance dredging may be required prior to further access. Should this be required, any dredged material is likely to be deposited in reasonably close proximity to the exit pits. Accordingly, no mobile beach material will be lost from the local system but will instead remain available for beach resupply.

6.9.4.18 The Loch of Strathbeg SSSI / SPA / RAMSAR is located around 4km to the north of the Scotstown landfall but is too distal to be impacted by an interruption to coastal processes including changes to sediment transfer.

6.9.4.19 The embedded environmental measure M-120 from **Table 6.7** means a construction method statement will be produced as part of the Project, ensuring construction methods align with good practice, implement agreed embedded environmental measures and are appropriately managed.

6.9.4.20 The magnitude of impact to coastal morphology at the landfall zones is predicted to be **low**. This is because any impact to beach morphology would be localised and temporary.

Significance of residual effect

6.9.4.21 The embedded environmental measures (as shown in **Table 6.7**) include the use of trenchless techniques to avoid direct impacts to inter-tidal areas (embedded environmental measure M-005) alongside adherence to the construction method statement (embedded environmental measure M-120) and environmental management plan (embedded environmental measure M-121). Overall, it is predicted that the sensitivity of the receptor is **medium**, and the magnitude of all identified impacts is no greater than **low**. The effect is therefore of **Minor** (**Not Significant**) in EIA terms.

6.10 Assessment of effects: operation and maintenance stage

6.10.1 Introduction

6.10.1.1 This Section provides an assessment of the effects for marine geology, oceanography and physical processes from the O&M of the offshore elements of the Project.

6.10.1.2 The assessment methodology set out in **Section 6.8** has been applied to assess effects to marine geology, oceanography and physical processes from the Project.

6.10.2 Impact O1: potential changes to the tidal regime

Overview

6.10.2.1 The interaction between the tidal regime and the WTG floating units and offshore platforms in the OAA will result in a slight reduction in current speed and an increase in levels of turbulence in a narrow, localised wake due to frictional drag and the shape of the structure. Changes to the tidal regime may indirectly impact seabed morphology (including bedforms) in several ways. There exists a close relationship between flow speed and bedform type (Belderson *et al*., 1982) and thus any changes to flows have the potential to alter seabed morphology over the lifetime of the Project.

6.10.2.2 Within the extent of the OAA, the effect on tidal currents will be evident as a series of narrow and discrete wake features extending downstream along the tidal axis from each foundation. For structures such as WTG floating units, the wake signature is expected to naturally dissipate within a distance in the order of ten to twenty obstacle diameters downstream (for example, Li *et al*., 2014; Cazaneve *et al*., 2016; Rogan *et al*., 2016). This wake length distance will be much less than the corresponding ~5km spring tidal excursion distance in the OAA – the distance over which water is displaced during each flood or ebb tide.

6.10.2.3 An array comprising 225 WTGs on floating units (maximum dimension of 120m), four offshore substations on fixed foundations (maximum dimension of 80m) and two RCPs on fixed foundations (maximum dimension of 35m) represents the Maximum design scenario for changes to the tidal regime. Further details regarding the Maximum design scenario are provided in **Table 6.6**.

Sensitivity or value of receptor

6.10.2.4 All of the changes described in this Section are to 'pathways' as opposed to receptors and therefore sensitivity ratings have not been assigned.

Magnitude of impact

6.10.2.5 Potential change to the tidal regime is considered to be a pathway of effect, rather than an impact on receptors, and as such, it is not appropriate to carry out an assessment of significance which determines the magnitude of effect to them. Instead, this Section focuses on describing the spatial and temporal nature of change, with the potential for associated impacts to sediment transport pathways, seabed morphology and coastal morphology assessed in **Section 6.10.4, Section 6.10.5** and **Section 6.10.6** respectively. The potential for associated impacts to marine biodiversity is assessed in other chapters (see **paragraph 6.10.2.11**).

6.10.2.6 The effect of the WTG foundations on tidal currents within the OAA will be to locally reduce current speed and increase turbulence in a narrow wake behind the cross section of each WTG floating unit (maximum width of 120m). The wake features / effects will recover rapidly with distance downstream, likely becoming not measurable within a few hundreds of metres (less than the distance between the WTG floating units which will be a minimum of 800m apart). The maximum distance to which any (cumulative) effect might propagate from the OAA is, in any case, limited to one tidal excursion distance (the distance over which water is displaced during one flood or ebb tidal cycle), approximately 5km under mean spring conditions for the OAA. Wakes would extend in the ebb or flood direction, depending on the state of the tide. Due to the limited number and dimensions of offshore substations and RCPs, changes are likely to be of further limited scale and extent.

6.10.2.7 Currents passing underneath the WTG floating units will not be directly affected but will interact to a much lesser extent with the very small blockage presented by the mooring lines (up to eight per foundation, 250 millimetres (mm) diameter) and cables (one per foundation, up to 194mm diameter) between the base of each WTG floating unit and the seabed. The main body of any anchors will be buried and so will not interact with currents. It is the case that the top of some anchors could project above the seabed and so may theoretically interact with currents locally. However, they are individually of relatively small scale and so are unlikely to cause a change in overall patterns of flow or sediment transport through the OAA. Any associated seabed scour is also expected to be very limited (**Section 6.10.8**).

6.10.2.8 Measurable effects on currents are therefore likely to only be associated with the WTG floating units and so largely confined to surface and near surface waters. Accordingly, any change to currents caused by individual substructures or the array as a whole will have no consequential effect on the overall rate or direction of sediment transport at the seabed.

6.10.2.9 Within the OAA, up to 20 per cent (or 136km) of array cables may require protecting by rock or mattresses. Up to 20 per cent of the offshore export cables between the OAA and the landfall zones may also require rock protection to be installed. Up to 16 known crossings and an additional 6 (to take account of other developers export cables) within the offshore export cable corridor and 6 assumed crossings within the OAA may require rock protection. Rock berms have a trapezoidal profile with a height of 2m above seabed and a base width of up to 7m.

6.10.2.10 Water depths are between approximately 70 metres referenced to mean sea level (MSL) and 130mMSL within the OAA and along the offshore export cable corridor (seaward of 12 nautical miles (nm)). The long axis of any potential berm may be aligned to, or perpendicular to, the main tidal current axis, depending on exact location within the OAA or along the offshore export cable corridor. However, the cable protection height (maximum 2m) is a very small proportion of the total water depth and so, together with the sloped sides of the berm, will present a minimal obstruction to tidal currents (no measurable effect more than a few tens of metres from the berm and restricted only to the near-bed).

Significance of residual effect

6.10.2.11 The assessment set out in this Section has considered potential changes to a pathway, rather than impacts on receptors. Accordingly, no assessment of significance is provided. However, the potential for these changes to impact other EIA receptor groups are considered elsewhere within the EIA, in particular:

- **Chapter 10: Benthic, Epibenthic and Intertidal Ecology**;
- **Chapter 11: Marine Mammals**;
- **Chapter 12: Offshore and Intertidal Ornithology**;
- **Chapter 13: Fish Ecology**; and
- **Chapter 16: Marine Archaeology and Cultural Heritage**.

6.10.3 Impact O2: potential changes to the wave regime

Overview

6.10.3.1 The interaction between waves and the foundations of the Project infrastructure may result in a reduction in wave energy locally around foundations. The combined changes arising from all foundations may give rise to an array-scale change that could extend outside of the OAA and into the wider study area. Where the wave climate is important to local processes

and is persistently modified, these changes may potentially alter the frequency or pattern of sediment transport and therefore seabed morphology in affected offshore areas, and / or the rate and direction of longshore sediment transport and therefore coastal morphology on affected coastlines.

6.10.3.2 An array comprising 225 WTGs on floating units (maximum dimension of 120m), four offshore substations on jacket foundations (maximum dimension of 80m) and two RCPs on jacket foundations (maximum dimension of 35m) represents the maximum design scenario for the blockage of waves through the Project. Further details regarding the maximum design scenario are provided in **Table 6.6**.

6.10.3.3 Cumulative blockage to the wave regime arising from operation of the Project with other planned and operational wind farms in the study area are considered separately, in **Section 6.15**.

Sensitivity or value of receptor

6.10.3.4 All of the changes described in this Section are to 'pathways' as opposed to receptors and therefore sensitivity ratings have not been assigned.

Magnitude of impact

6.10.3.5 Potential change to the wave regime is considered to be a pathway of effect, rather than an impact on receptors, and as such, it is not appropriate to carry out an assessment of significance which determines the magnitude of effect to them. Instead, this Section focuses on describing the spatial and temporal nature of change, with the potential for associated impacts to sediment transport pathways, seabed morphology and coastal morphology assessed in **Section 6.10.4, Section 6.10.5** and **Section 6.10.6**, respectively. The potential for associated impacts to marine biodiversity is assessed in other chapters (see **paragraph 6.10.3.15**).

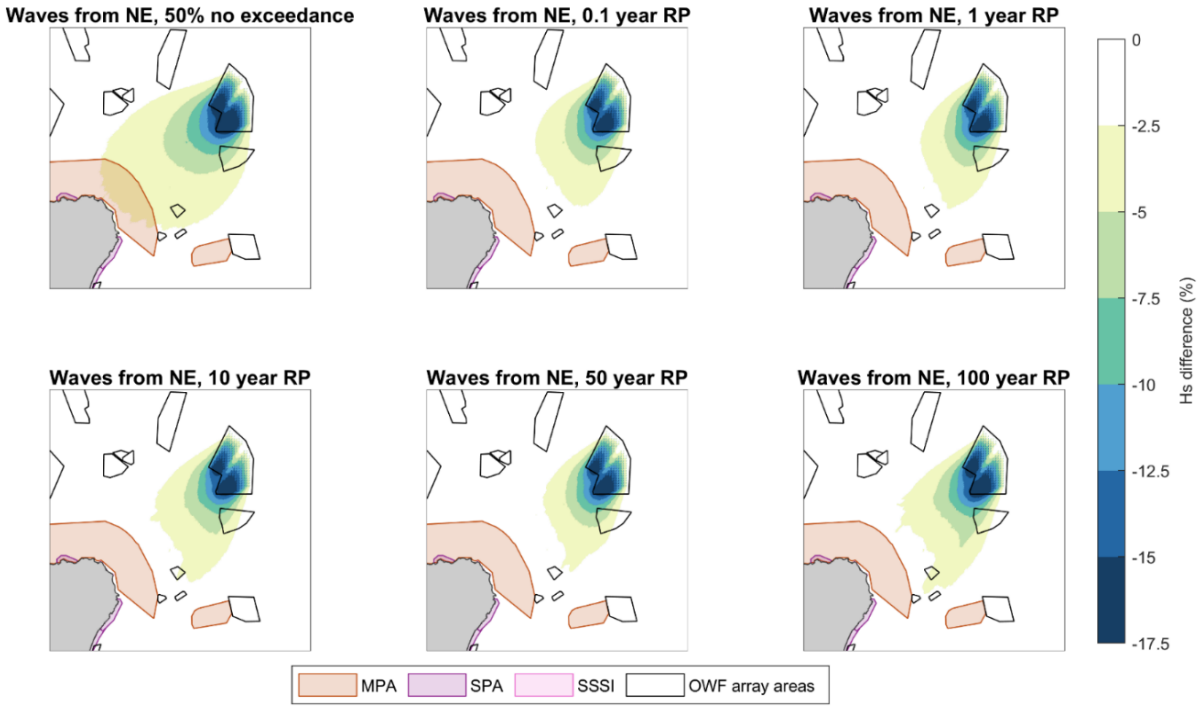
6.10.3.6 The Project has the potential to impact on the wave regime as individual waves interact with the foundation structures. The blockage caused by the foundation structures has the potential to impact on the following wave characteristics:

- wave height;
- wave period; and
- wave direction.

6.10.3.7 To quantify the likely magnitude and extent of interaction between the O&M stage and the wave regime, a numerical wave model has been developed (**Volume 3, Appendix 6.1**).

6.10.3.8 The assessment of potential changes to the wave regime has been undertaken for a series of frequently occurring and extreme return period conditions with and without the Project foundations in place, in order to obtain a generic measure of the extent and magnitude of any change likely to occur during the lifetime of the Project. These are presented in terms of the difference between the baseline wave environment and that predicted to occur with the Project in place. The full set of results is presented in **Volume 3, Appendix 6.1**, with a subset of results (associated with a range of frequently occurring and extreme return period conditions for northeast waves – the direction which aligns with the shortest distance to the coast) shown in **Plate 6.1**. (The 50 per cent no exceedance condition refers to a wave height that has a 50 per cent probability of not being exceeded within any given year, based on analysis of a 45-year hindcast dataset).

Plate 6.1 Percentage difference in significant wave height (scheme minus baseline as a proportion of baseline values), waves from the northeast, all return periods. O&M stage maximum design scenario for the Project



6.10.3.9 The assessment is informed by the ABPmer SEASTATES wave hindcast database (seastates.net), which provides hourly timeseries and derivative climatic statistics for the period January 1979 to near-present. Typically, at least 30 years of hourly data are used to describe the long-term wind and wave climate. The hindcast model is validated using historical measured wave data from ~20 coastal and offshore locations around the UK. The validity of the model (and therefore the data it produces) is not affected by the age of the historical data used for validation – only the quality and quantity of that data, which is considered sufficient.

6.10.3.10 Potential impacts of the Project on the wind and therefore the wave field downwind of the OAA are normally considered to be a very low magnitude change. This is based on general understanding of the nature of the impact on the wind field, a small number of observational studies demonstrating no measurable impact (Cefas, 2007), and consistent with reasonable theoretical consideration. As such this is not normally identified or scoped into marine geology, oceanography and physical processes studies for windfarm EIA as a realistically relevant potential impact.

6.10.3.11 From the outset, it is noted that changes of less than 5 per cent of the baseline wave height would be indistinguishable from natural variability both within the seastate (difference between individual waves) and compared to normal rates of change (over timescales of one hour or less); such small differences would not be measurable in practice. Changes less than 2.5 per cent are also less than the reasonably expected accuracy of the model and so are excluded from the **Plate 6.1** colour scale.

6.10.3.12 On the basis of the modelling results summarised in **Plate 6.1** and discussed in more detail in **Volume 3, Appendix 6.1**, it is found that:

- Due to interaction with consecutive foundations, wave height progressively decreases with distance through the OAA measured in the direction that the waves are traveling.

As a result, the maximum reduction in wave height is found downwind of individual wind turbines in the central downwind part of the OAA (15 per cent to 17.5 per cent).

- Regions of larger relative change (>15 per cent) are restricted to confined areas within or immediately neighbouring the OAA, with the magnitude of change decreasing with distance from the OAA. The majority of the footprint of influence outside the OAA is defined by a reduction of less than 10 per cent.
- The scale of the change is dependent on the nature of the wave height / period condition, and the main direction of the wave energy with respect to the shape / thickness of the array and the alignment of the foundations.
- The maximum corresponding changes to wave period and wave direction (not shown) are less than 0.1s and 3° respectively, at all locations, in all cases.
- In the area where changes to wave height are greatest (typically within and immediately to the west through to south of the OAA), water depths are also relatively large (~100mMSL). In such water depths, a minimum wave period (approximately 12s and larger in 100m depth) is required to penetrate deeply enough to cause any water movement at the seabed and contribute to sediment transport. As the wave period will not be affected (by more than 0.1s), the ability of individual waves to reach the seabed will be unaffected.
- Wave height begins to recover immediately downwind of the OAA. Recovery occurs mainly due to lateral wave energy spreading from areas to the side of the OAA where waves are less or completely unaffected by interaction with the wind farm. For smaller seastates, recovery of the dominant wave condition can also occur more rapidly as a result of ongoing wind energy input.
- For waves coming from the north, where wave pass through the OAA before reaching Turbot Bank MPA, no observable difference in wave height is predicted within the designated area (<5 per cent).
- For waves coming from the north-east, where wave pass through the OAA before reaching the Rosehearty to Fraserburgh Coast Site of SSSI and Southern Trench NCMPA, no observable difference in wave height is predicted within the designated areas (<5 per cent).

6.10.3.13 Within the OAA, up to 20 per cent (or 136km) of array cables may require protecting by rock or mattresses. Up to 20 per cent of the offshore export cables between the OAA and the landfall zones may also require rock protection to be installed. Up to 16 cable / pipeline crossings along the offshore export cable and six crossings in the OAA may require rock protection. Rock berm have a trapezoidal profile with a height of 2m above seabed and a base width of up to 7m.

6.10.3.14 Water depths are between approximately 70mMSL and 130mMSL within the OAA and along the offshore export cable corridor (seaward of 12nm). On the few occasions, during large storm events, when waves are sufficiently large to interact at all with the berm, it is very unlikely that the berm will present a sufficient obstacle to cause changes to their size or direction.

Significance of residual effect

6.10.3.15 The assessment set out in this has considered potential changes to a pathway, rather than impacts on receptors. Accordingly, no assessment of significance is provided. However, the potential for these changes to impact other EIA receptor groups are considered elsewhere within the EIA, in particular:

- **Chapter 10: Benthic, Epibenthic and Intertidal Ecology**;
- **Chapter 11: Marine Mammals**;
- **Chapter 12: Offshore and Intertidal Ornithology**;
- **Chapter 13: Fish Ecology**; and
- **Chapter 16: Marine Archaeology and Cultural Heritage.**

6.10.4 Impact O3: potential changes to the sediment transport regime

Overview

6.10.4.1 Modification of existing sediment transport pathways could occur in response to changes in the wave and tidal regimes resulting from the presence of

- WTG floating units and offshore platforms; and / or
- cable protection measures.

6.10.4.2 The above changes could potentially occur over a range of timescales, depending on location and the specific project infrastructure that is interacting with the sediment transport regime.

6.10.4.3 The maximum design scenario with respect to the potential for changes to the sediment transport regime is set out in **Table 6.6**.

Sensitivity or value of receptor

6.10.4.4 All of the changes described in this Section are to 'pathways' as opposed to receptors and therefore sensitivity ratings have not been assigned.

Magnitude of impact

6.10.4.5 Potential change to the sediment transport regime is considered to be a pathway of effect, rather than an impact on receptors, and as such, it is not appropriate to carry out an assessment of significance which determines the magnitude of effect. Instead, this Section focuses on describing the spatial and temporal nature of change, with the potential for associated impacts to seabed morphology and coastal morphology assessed in **Section 6.10.5** and **Section 6.10.6,** respectively. The potential for associated impacts to marine biodiversity is assessed in other chapters (see **paragraph 6.10.4.20**).

WTG floating units and offshore platforms

6.10.4.6 The effect of the WTG floating units and (fixed bottom foundation) offshore platforms on tidal currents within the OAA will be to locally reduce current speed and increase turbulence in a narrow wake behind each structure. The WTG floating units are up to 120m wide, whilst the offshore platforms are up to 80m wide.

6.10.4.7 Currents passing underneath the WTG floating units will not be directly affected by the main structure but will interact to a much lesser extent with the relatively small local blockage presented by the mooring lines (up to eight per foundation, 250mm diameter) and electrical cables (194mm diameter) between the base of each WTG floating unit and the seabed. Anchors will mostly be buried although where they protrude above the bed, they may interact locally with currents, potentially causing very localised scour (**Section 6.10.8**).

6.10.4.8 There will only be a maximum of six offshore platforms (on fixed foundations) and overall blockage associated with these structures will be extremely small. Measurable effects on currents at the scale of the OAA is therefore, likely to only be associated with the main WTG floating units, and so largely confined to surface and near surface waters. These changes will have no consequential effect on the overall rate or direction of sediment transport at the seabed within the OAA.

6.10.4.9 The surface and upper water column wake features behind each column of the WTG floating substructures may remain separate or may coalesce depending on the relative angle of the current to the foundations individually, and to the OAA as a whole. Overlapping wake features may become slightly more pronounced, but will recover in the same manner and will also have a smaller overall extent. The wake features / effects will recover rapidly with distance downstream, likely becoming not measurable within a few hundreds of metres (less than the distance between the WTG floating units, which will be a minimum of 800m apart). The maximum theoretical distance to which any (cumulative) effect might propagate from the OAA is, in any case, limited to one tidal excursion distance (the distance over which water is displaced during one flood or ebb tidal cycle, approximately 5km in the OAA on a mean spring tide, or half this distance on a mean neap tide), as shown in **Volume 2, Figure 6.1**. In reality, measurable change to currents will be restricted to a far smaller area than this (likely extending no more than a few hundreds of metres outside of the boundary of the OAA.

6.10.4.10 Reduction in significant wave height reaches a maximum of around 15 per cent in the OAA and approximately 12.5 per cent in areas located immediately outside of the OAA (**Section 6.10.3**. and **Plate 6.1**). In these areas where changes to wave height are greatest, water depths are also relatively large (~80mMSL or more). In such water depths, a minimum wave period (approximately 10s and larger in 80m depth) is required to penetrate deeply enough to cause any water movement at the seabed. Even longer waves in conjunction with a sufficient wave height are needed to cause sufficient motion at the seabed to contribute to sediment transport. Given that very low to no sediment mobility occurs under baseline conditions within the OAA (**Volume 2, Figure 6.2: Conceptual understanding of physical processes within the study area**), the absolute change in magnitude of sediment transport potentially associated with a modest decrease in wave height will be extremely small and almost certainly immeasurable.

6.10.4.11 At a distance of a few kilometres (or more) from the OAA, the differences in wave height, period and direction are small in absolute and relative terms (**Plate 6.1**) and (as a small additional contribution to the tidally dominated transport) could only cause an even smaller change to overall instantaneous sediment transport rates or directions. Any differences would not be measurable in practice and are easily within the range of natural variability in wave height from wave to wave, from hour to hour during the passage of a storm, and in the context of seasonal and interannual variation of wave climate.

6.10.4.12 Finally, it is noted that on the basis of the numerical wave modelling, measurable changes to wave height (as well as period and direction) will not extend to adjacent coastlines (**Plate 6.1**). Accordingly, there will be no associated change in wave driven longshore sediment transport.

Cable protection measures

6.10.4.13 Installation of cable protection could result in a local increase in the elevation of the seabed (**Table 6.6**). Cable protection would be placed onto the seabed surface above the cable and therefore could directly trap sediment, locally impacting down drift locations.

6.10.4.14 The monitoring data reviewed in The Crown Estate (2019) presented little or no information on the effects of cable protection either on the seabed or on associated benthic ecology communities (for example, colonisation of installed protection measures). However,

research initiatives are currently underway which should help address this data gap (ABPmer, 2025).

6.10.4.15 Following installation and under favourable conditions, an initial period of sediment accumulation would be expected to occur against cable protection measures which could have a height of up to 2m above the bed (**Table 6.6**). This accumulation would likely create a smooth slope against the cable protection. The process of wedge formation may take place over a period of a few weeks to months, depending on rates of sediment transport.

6.10.4.16 Sandy sediments are transported in two modes: bedload and saltation. Saltation is the process by which sands are moved up into the water column. These suspended sands would be expected to move relatively freely over the top of the armour although to begin with would regularly be deposited upon it, filling void spaces. Once any void spaces have been infilled, saltation is expected to be largely unaffected by the presence of the cable protection such that existing transport process (including bed form migration) will remain unaffected.

6.10.4.17 The process of void infilling is expected to occur relatively quickly (in the order of a few months). This is due to saltation as well as the anticipated high rates of transport in areas of mobile seabed (which is where much of the cable protection is anticipated).

6.10.4.18 Bedload is the process by which sands move while still in contact with the seabed. Bedload will be temporarily affected up until such time that the armour is covered by sand and the slope gradient either side has been reduced in response to the accumulation of a sediment wedge with stable slope angles (approximately 30°). Following this, bedload will continue because the slope angle presented by sections of protected cable would be within the natural range of bed slope angles associated with bed forms mapped within the offshore export cable corridor.

6.10.4.19 Accordingly, for all areas in which cable protection is used, it is not expected that the presence of the cable protection devices will continuously affect patterns of sediment transport following the initial period of accumulation. It follows that any changes on seabed morphology away from the cable protection will also be very small. The extent of the cable protection measures does not constitute a continuous blockage along the offshore export cable corridor.

Significance of residual effect

6.10.4.20 The assessment set out in this Section has considered potential changes to a pathway, rather than impacts on receptors. Accordingly, no assessment of significance is provided. However, the potential for these changes to impact other EIA receptor groups are considered elsewhere within the EIA, in particular:

- **Chapter 10: Benthic, Epibenthic and Intertidal Ecology**;
- **Chapter 11: Marine Mammals**;
- **Chapter 12: Offshore and Intertidal Ornithology**;
- **Chapter 13: Fish Ecology**; and
- **Chapter 16: Marine Archaeology and Cultural Heritage**.

6.10.5 Impact O4: potential changes to seabed morphology

Overview

6.10.5.1 This Section describes potential impacts to the morphology of designated areas of seabed, based on the Maximum design scenario set out in **Table 6.6**. The offshore export cable corridor passes through the Southern Trench NCMPA. The next closest NCMPA to the Project is Turbot Bank NCMPA, which is located approximately 25km to the south of the offshore export cable corridor and around 60km to the south of the OAA (**Volume 2, Figure 6.1**).

6.10.5.2 Impacts to the morphology of designated seabed areas could potentially be caused by the presence of:

- cable protection; and
- WTG floating units (and associated mooring / anchoring systems) and offshore platforms.

6.10.5.3 These could indirectly cause change to the tidal regime (discussed separately in **Section 6.10.2**), wave regime (discussed separately in **Section 6.10.3**) and sediment transport regime (discussed separately in **Section 6.10.4**).

6.10.5.4 The magnitude of change, and hence the significance of potential effects has been assessed on the assumption that the embedded environmental measures from **Table 6.7** have been implemented as part of the Project.

Sensitivity or value of receptor

6.10.5.5 The Southern Trench NCMPA and Turbot Bank NCMPA are both sites of high value / importance (since they form part of Scotland's NCMPA network). The geodiversity features of interest in the Southern Trench NCMPA are relict (subglacial tunnel valleys, moraines and scars evidencing mass movement) with no ability to recover from impact. The seabed within the Turbot Bank NCMPA is understood to be relatively immobile meaning it too is potentially sensitive to change baseline marine physical processes. Accordingly, both sites is assessed to be of **high** sensitivity.

Magnitude of impact

Cable protection

6.10.5.6 The presence of cable protection berms during the O&M stage has the potential to cause changes to the local seabed level as a result of local flow interaction between the body and surface of the berm, and any near-bed current and wave action. The potential for cable protection to cause larger scale changes to the tidal, wave or sediment transport regimes is very limited, far less than the effects of the WTG floating units and offshore platforms.

6.10.5.7 The purpose of cable protection is to maintain stable cover over the lifetime of the Project. By design, it aims to minimise the risk of scour associated with both the offshore export cables and the protection itself. The maximum berm dimensions (7m base width x 2 m height) result in relatively low angle slopes and a low overall height relative to the water depth, which limits the potential for form-related flow disturbance and scour, even when flows are perpendicular to the berm.

6.10.5.8 Turbulence may become locally elevated in water flowing close to the surface of the berm, which may result in a limited depth and extent of secondary scour (order of a few tens of

centimetres deep and up a few metres from the berm). The seabed surface in the scoured area will generally be similar to the surrounding seabed but the texture may coarsen due to preferential winnowing of finer sediment grains.

6.10.5.9 Based on the above, the magnitude of impact to designated seabed areas is predicted to be **very low**.

Presence of WTG floating units and offshore platforms

6.10.5.10 On the basis of the discussion of potential changes to tides (set out in **Section 6.10.2**), waves (set out in **Section 6.10.3** and **Plate 6.1**) and sediment transport (set out in **Section 6.10.4**), there are not expected to be any detectable changes to any of these parameters at the location of designated sites. Indeed, changes to tidal currents will be highly localised to the OAA and immediate surroundings, whilst the reduction in wave height (Hs) is <5 per cent at the locations of designated sites for all scenarios tested. Accordingly, the rate (and direction) of sediment transport at these sites will remain unaltered from baseline conditions and therefore there will be no associated morphological change to the seabed in these areas.

6.10.5.11 Based on the above, the magnitude of impact to designated seabed areas is predicted to be **very low**.

Significance of residual effect

6.10.5.12 Overall, it is predicted that the sensitivity of the receptor (designated seabed areas, namely the Southern Trench NCMPA and Turbot Bank NCMPA) is **high**, and the magnitude of all identified impacts is **very low**. The effect is of **Minor** (**Not Significant**) in EIA terms.

6.10.6 Impact O5: potential impacts to coastal morphology

Overview

6.10.6.1 This Section describes potential impacts to the morphology of the coast. These could arise from:

- blockage of waves by project infrastructure within the OAA, especially WTG floating units and offshore platforms;
- changes to currents, waves and associated sediment transport (or other physical processes) caused by the presence of exposed cables in nearshore areas; and
- changes to currents, waves and associated sediment transport (or other physical processes) caused by the presence of cable protection measures in nearshore areas.

6.10.6.2 The magnitude of change, and hence the significance of potential effects has been assessed on the assumption that the embedded environmental measures from **Table 6.7** have been implemented as part of the Project.

Sensitivity or value of receptor

6.10.6.3 The coastline within the study area is potentially vulnerable to either direct or indirect disturbance from Project-related activities. However, it is typically a dynamic environment which is subject to natural change under baseline conditions. Accordingly, it is assessed to have some capacity to recover from disturbance and accommodate change. The overall sensitivity of the coastline is therefore considered to be **medium**, reflecting the fact that the receptor is of medium to high value, medium vulnerability and medium recoverability.

Magnitude of impact

WTG floating units and offshore platforms

6.10.6.4 On the basis of the discussion of potential changes to waves (set out in **Section 6.10.3** and **Plate 6.1**) and within **Volume 3, Appendix 6.1**, there are not expected to be any detectable changes to the wave regime at the coast. The reduction in Hs is <2.5 per cent at the coast for all scenarios tested. Accordingly, the rate (and direction) of net longshore sediment transport at the coast will remain unaltered from baseline conditions and therefore there will be no associated morphological change to the coast.

6.10.6.5 Based on the above, the magnitude of impact to coastal morphology is predicted to be **very low**.

Exposure of cables

6.10.6.6 As part of the embedded environmental measures for the Project, cables will be buried where possible (embedded environmental measure M-054 in **Table 6.7**). A Cable Burial Risk Assessment will be undertaken to ensure that all cables will be buried to an appropriate depth (or surface laid and protected) to minimise the chance of exposure during the lifetime of the Project. If exposure does occur, cables will be re-buried. However, no protection of greater dimensions (outside that already outlined as the Maximum design scenario in **Table 6.6** and used as the basis for the assessment) will be applied. Where cable protection has been employed during the construction stage, this may be replenished during the operational stage, as necessary.

6.10.6.7 Once the offshore export cables are buried in the (nearshore) seabed, there is no potential for cable related scour to occur. If and where the offshore export cables becomes exposed due to natural seabed erosion, then a small, localised, area of additional scour may occur, as a result of currents interacting with the exposed part of the cable. The exact dimensions of the scour will depend on the height of the offshore export cables relative to the seabed but will be in proportion to the relatively small diameter of the cable (up to a few hundred mm diameter) and no more than described for the cable protection, namely that scour could be up to a few tens of centimetres deep and up to a few metres from the cable protection).

6.10.6.8 Based on the above, the magnitude of impact to coastal morphology is predicted to be **very low**.

Cable protection

6.10.6.9 In nearshore subtidal areas, cable protection could potentially be used to protect the offshore export cables. The exact location of cable protection and orientation relative to the beach is presently unknown. However, given the route of the offshore export cable corridor, it is probable that the long axis of the rock berms will be orientated generally across the main tidal current axis but broadly aligned with the direction of waves as they approach the coast.

6.10.6.10 Cable protection in shallow areas could, theoretically, work in a similar way to a submerged offshore breakwater, affecting wave transformation processes closer to shore. This, in turn, could potentially alter the wave approach to the shore, leading to wave focusing on areas of the beach not presently eroding. This could result in long-term lowering in areas where surficial mobile material is present whilst localised accretion may also occur in other areas, as material is redistributed. If and where exposed bedrock platforms are present, the presence of any cable protection is not expected to lead to enhanced erosion.

6.10.6.11 The structures themselves could also locally intercept sediment being transported by wave and tidal driven currents. However, whilst it can reasonably be expected that there will be some localised change to waves and hydrodynamics in the immediate vicinity of the rock berms, the potential for wider morphological change at the coast at the landfall zones, especially to the upper beach and adjacent dunes, is considered to be very limited. This is primarily due to the fact that any rock berms would be relatively distant from the upper beach and have a relative low profile (<2m), meaning the ability to trap sediment and modify waves would be limited. It is also noted here that Marine Guidance Note (MGN) 654 advises that changes in water depth should not exceed five per cent of charted depths to ensure safety of navigation (Maritime and Coastguard Agency, 2021). This will likely be a limiting factor on cable protection height installed in shallow coastal waters at the Landfall.

6.10.6.12 The Loch of Strathbeg SSSI / SPA / RAMSAR is located around 2km to the north of the offshore export cable corridor but is too distal to be impacted by an interruption to coastal processes – including changes to sediment transfer associated with the presence of cable protection measures.

6.10.6.13 Based on the above, the magnitude of impact to coastal morphology is predicted to be **low**.

Significance of residual effect

6.10.6.14 Overall, it is predicted that the sensitivity of the receptor is **medium**, and the magnitude of all identified impacts is no greater than **low**. The effect is therefore of **Minor** (**Not Significant**) in EIA terms.

6.10.6.15 A summary of the residual effects arising from the construction stage of the Project are provided in **Table 6.14**.

6.10.7 Impact O6: scour

Overview

6.10.7.1 The term scour refers here to the development of pits, troughs, or other depressions in the seabed sediments around the base of WTG and offshore substation foundations. Minor scour might also occur at the edges of scour protection for foundations and cables, including cable crossings. Scour is the result of net sediment removal over time due to the complex three-dimensional interaction between the foundation and ambient flows (currents and / or waves). Such interactions result in locally accelerated mean flow and locally elevated turbulence levels that also locally enhance sediment transport potential. The resulting dimensions of the scour features and their rate of development are, generally, dependent upon the characteristics of the:

- obstacle (dimensions, shape and orientation);
- ambient flow (depth, magnitude, orientation and variation including tidal currents, waves, or combined conditions); and
- seabed sediment (geotextural and geotechnical properties).

6.10.7.2 Scour assessment for EIA purposes is considered here for several foundation types:

- RCP jacket foundations;
- offshore substation jacket foundations; and
- WTG floating unit anchors.

6.10.7.3 The potential concerns include the seabed area that may be modified from its natural state (potentially impacting sensitive receptors through habitat alteration) and the volume and rate of additional sediment resuspension, as a result of scour.

6.10.7.4 The seabed area directly affected by scour may be modified from the baseline or ambient state in several ways, including:

- a different (coarser) surface sediment grain size distribution could develop due to winnowing of finer material by the more energetic flow within the scour pit;
- seabed slopes could be locally steeper in the scour pit; and
- flow speed and / or turbulence would be locally elevated, on average.

6.10.7.5 The scale of change would vary depending upon the foundation type, the local baseline oceanographic and sedimentary environments as well as the type of scour protection implemented. The latter will be set out in the scour protection management plan (embedded environmental measure M-028 in **Table 6.7**) and will be determined following the completion of a scour assessment.

6.10.7.6 In some cases, the modified sediment character within a scour pit may not be so different from the surrounding seabed. However, changes relating to bed slope and elevated flow speed and (near-field) turbulence are still likely to apply. As such, depending upon the sensitivities of the particular ecological receptor, not all scouring necessarily correspond to a loss of habitat. This is discussed further in **Chapter 10: Benthic, Epibenthic and Intertidal Ecology**.

Sensitivity or value of receptor

6.10.7.7 All of the changes described in this Section are to 'pathways' as opposed to receptors and therefore sensitivity ratings have not been assigned.

Magnitude of impact

6.10.7.8 Potential scouring of the seabed is considered to be pathways of effect, rather than an impact on receptors, and as such, it is not appropriate to carry out an assessment of significance which determines the magnitude of effect. Instead, this section focuses on describing the spatial and temporal nature of change, with the potential for associated impacts to marine biodiversity assessed in other chapters (see **paragraph 6.10.7.19**).

6.10.7.9 To quantify the area of seabed that might be affected by scour (either the footprint of scour or scour protection), the following provides an estimate of the theoretical maximum depth and extent of scour. This assessment is based upon empirical relationships described in Whitehouse (1998) and is a summary of a more detailed assessment presented in **Volume 3, Appendix 6.1**. Importantly, these estimates are highly conservative as they assume an unlimited depth of erodible sediment at all final foundation locations. In practice, the more erosion resistant glacial till is at or close to the surface in some areas, which will naturally limit the maximum potential scour depth and volume for foundations located in these areas.

6.10.7.10 Results conservatively assume that the maximum likely (‘equilibrium’) scour dimensions are present around the perimeter of the structures. Derivative calculations of scour extent, footprint and volume assume an angle of internal friction of 32°. Scour extent is measured from the structure's edge. Scour footprint excludes the footprint of the structure. Scour pit volumes for jacket foundation structures are calculated as the sum of the volume of an inverted truncated cone, minus the structure volume, for each of the corner piles. Scour pit

volumes for the WTG floating unit are similarly calculated but as the sum of that predicted for each anchor.

6.10.7.11 The term 'local scour' refers to the local response to individual structure members. 'Global scour' refers to a region of shallower but potentially more extensive scour around or associated with a multi-member foundation resulting from the change in flow velocity through the gaps between members of the structure and turbulence shed by the entire structure. Global scour does not imply scour at the scale of the OAA.

6.10.7.12 Key findings are summarised in **Table 6.11, Table 6.12** and below:

- overall, scour development within the OAA (and offshore export cable corridor for RCPs) is expected to be dominated by the action of tidal currents;
- in practice, the thickness of unconsolidated (and more easily erodible) surficial Holocene sediment is relatively thin (typically less than 0.5m, up to 2.8m thick), or absent;
- for the OAA as a whole, the greatest total foundation local scour footprint is associated with an array of 225 14 megawatts (MW) WTG floating units with suction anchors, four offshore substation 12-legged jacket foundations on suction anchors and two RCP 4-legged jacket foundations on suction anchors (83,513m^2), equivalent to only approximately 0.012 per cent of the total OAA; and
- for the OAA as a whole, the greatest total foundation global scour footprint is associated with an array of 225 14MW WTG floating units with suction anchors, four offshore substation 12-legged jacket foundations on suction anchors and two RCP 4-legged jacket foundations on suction anchors (131,502m^2), equivalent to only approximately 0.019 per cent of the total OAA.

Table 6.11 Summary of predicted maximum scour dimensions for foundation structures

Return Period (years)		RCP – four-legged Jacket on Suction Anchors (35mx35m base, 6.5m diameter)	Offshore substation – 12-legged Jacket on Suction Anchors (80m x 60m base, 6.5m diameter)	WTG – Floating on Suction Anchors (0.5m height, 6.5m diameter)
Equilibrium Scour Depth (m)	Steady current	8.5	8.5	0.5
	Waves	Insufficient for scour.	Insufficient for scour.	Insufficient for scour.
	Waves and current	8.5	8.5	0.5
	Global scour	2.6	2.6	N/A
Extent from foundation* (m)	Local scour	13.5	13.5	0.9
	Global scour	35	100	N/A
Footprint* (m^2)	Structure alone	132.7	398.2	265
	Local scour (excluding structure)	3,403	10,208	159
	Global scour (excluding structure)	3,716	31,018	NA
Volume* (m^3)	Local scour (excluding structure)	11,139	33,418	6
	Global scour (excluding local scour and structure)	9,661	80,646	N/A

Return Period (years)		**RCP – four-legged Jacket on Suction Anchors (35mx35m base, 6.5m diameter)**	**Offshore substation – 12-legged Jacket on Suction Anchors (80m x 60m base, 6.5m diameter)**	**WTG – Floating on Suction Anchors (0.5m height, 6.5m diameter)**
	Total scour (excluding structure)	20,800	114,064	6
	Scour protection	500	500	N/A
* Results assume erodible bed and absence of geological controls **Based upon the scour depth for steady currents. Footprint and volume values are per foundation.				

Table 6.12 Total seabed footprint of all foundation types with and without scour

Maximum number of foundations	225 WTG + four offshore substation + two RCP
Seabed footprint of all foundations	61,588m^2
Proportion of OAA*	0.009%
Seabed footprint of all local scour	83,513m^2
Proportion of OAA*	0.012%
Seabed footprint of all foundations + local scour	145,101m^2
Proportion of OAA*	0.021%
Seabed footprint of all global scour	131,502m^2
Proportion of OAA*	0.019%
Seabed footprint of all scour protection**	3,000m^2
Proportion of OAA*	<0.001%
Seabed footprint of all foundations + scour protection	64,588m^2
Proportion of OAA*	0.009%

* OAA = 683,770,029m^2.
** Assumed scour protection height = 1m.

6.10.7.13 The embedded environmental measures M-028 from **Table 6.7** means a scour protection management plan will be implemented as part of the Project. Following the completion of a scour assessment, where there is the potential for scour to develop around Project infrastructure the appropriate scour protection will be put in place.

6.10.7.14 Where scour protection is used, primary scour is unlikely to occur, although a small amount of secondary scour may develop at the edges of the scour protection in response to the interaction between the scour protection materials and foundation, and the hydrodynamic and sediment transport regimes. However, the extent and volume of secondary scour will be considerably less than that described for the foundations.

6.10.7.15 Scour depth can vary significantly under combined current and wave conditions through time (Harris *et al*., 2010). Monitoring of scour development around monopile foundations in UK offshore wind farm sites suggest that the timescale to achieve equilibrium conditions can be of the order of 60 days in environments where the seabed is mobile (Harris *et al*., 2011). These values account for tidal variations as well as the influence of waves. Near symmetrical scour will only develop following exposure to both flood and ebb tidal directions.

6.10.7.16 Under waves or combined waves and currents an equilibrium scour depth for the conditions existing at that time may be achieved over a period of minutes, whilst typically under tidal flows alone equilibrium scour conditions may take several months to develop.

6.10.7.17 Any elevations in SSC because of scour will be short lived and localised and within the range of natural variability.

6.10.7.18 Finally, highly localised scour may also occur in areas where rock placement is used to protect cables. The raised profile of the protection may cause a limited amount of localised secondary scouring at the edges of the protection in line with the dominant flow or wave direction. The depth and extent of scour will be limited in proportion to the diameter of the individual rocks used (typically graded between 0.05m to 0.5m) which may be reduced by embedment or settling over time.

Significance of residual effect

6.10.7.19 The assessment set out in this Section has considered potential changes to a pathway, rather than impacts on receptors. Accordingly, no assessment of significance is provided. However, the potential for these changes to impact other EIA receptor groups are considered elsewhere within the EIA, in particular:

- **Chapter 10: Benthic, Epibenthic and Intertidal Ecology**; and
- **Chapter 16: Marine Archaeology and Cultural Heritage**.

6.10.8 Impact O7: potential changes to stratification and frontal systems

Overview

6.10.8.1 As currents move water past individual structures, a turbulent wake is formed. Within the turbulent wake, vertical mixing can be enhanced above ambient levels: the >20m draft of WTG floating units, or full depth draft of fixed foundations, is large enough to penetrate the thermocline and directly mix seasonally stratified water passing in close proximity. This increase in turbulence intensity has the potential to contribute to a local reduction in the strength of vertical stratification and position of tidal mixing fronts (for example, Carpenter *et al*., 2016; Cazenave *et al*., 2016; and Dorrell *et al*., 2022).

6.10.8.2 In addition to the potential for direct disturbance of the water column by the Project infrastructure, it has also been suggested that atmospheric wakes associated with WTGs have the potential to affect sea surface currents, altering the temperature and salinity distribution in areas of wind farm operation (Christiansen *et al*., 2022).

6.10.8.3 This Section considers the potential for structures within the OAA to influence regional scale patterns of stratification via the mechanisms outlined above and any resulting change in the location of fronts, including the Buchan Front – a thermal front within the Southern Trench MPA that is designated and could be sensitive to changes in tidal flow (NatureScot, 2025).

6.10.8.4 The assessment approach is similar to that adopted by Carpenter *et al*. (2016) and uses empirical equations to estimate two key timescales: the mixing timescale, which predicts the time required for complete mixing of stratified layers due to increased TKE generated by the foundations, and the advective timescale, which quantifies how long a water parcel remains within the OAA, experiencing enhanced TKE.

6.10.8.5 The maximum assessment scenario relating to the potential changes to stratification and frontal systems are presented in **Table 6.6**. Where predicted effects are identified, an assessment of the magnitude of change for each effect has been completed based on the methodology provided in **Section 6.8.2**. The magnitude of change, and hence the significance of potential effects has been assessed on the assumption that the embedded environmental measures from **Table 6.7** have been implemented as part of the Project.

Sensitivity or value of receptor

6.10.8.6 Frontal systems (including the Buchan Front within the Southern Trench NCMPA) are oceanographic features caused by regional-scale mixing processes. They support high biological primary productivity and biodiversity and as such, are considered to be of high value. However, these features are both highly dynamic and ephemeral and therefore have somewhat limited vulnerability to more localised changes in water column turbulence. Accordingly, the sensitivity of designated frontal systems within the study area is considered to be **medium**, reflecting the fact that the receptor is of high value, medium vulnerability and high recoverability.

Magnitude of impact

6.10.8.7 Stratification and tidal mixing fronts have been described in detail within **Volume 3, Appendix 6.1**. In brief:

- The OAA experiences strong seasonal stratification, with significant tidal, seasonal and interannual variability.
- Stratification typically peaks during mid-summer when warmer surface waters are separated from colder bottom waters by a thermocline (temperature gradient) and associated pycnocline (density gradient).
- The area east of the OAA typically experiences stronger stratification, whereas the western region tends to be more weakly stratified—with coastal waters remaining well mixed throughout the year.
- During summer, elevated chlorophyll-a concentrations - likely associated with a tidal mixing front - are commonly observed west of the OAA. However, their exact positioning varies significantly between years. In years with weaker stratification, the tidal mixing front forms further offshore, resulting in elevated chlorophyll-a levels within the OAA. Conversely, during years of stronger stratification, the front / elevated chlorophyll-a concentrations shift closer to the coast.
- The Buchan Front, associated with the Southern Trench NCMPA, typically forms closer to the coastline, outside of the OAA.
- Model projections suggest that by 2100, the thermal stratification period in UK shelf seas will extend by approximately two weeks, with stratification occurring about one week earlier and breaking down five to ten days later than present (Sharples *et al.*, 2022).

6.10.8.8 The assessment of potential changes to stratification and frontal systems caused by the Project is set out in **Volume 3, Appendix 6.1**. This indicates that the Project will have very limited impacts, with effects falling within the range of natural variability.

6.10.8.9 The installation of WTG and offshore substation foundations will generate additional turbulence alongside naturally occurring turbulence generated at the seabed by tidal currents and the surface by wind / wave action. The foundation induced TKE will enhance vertical mixing in the water column, acting to weaken stratification. However, this mixing effect is expected to be spatially limited, occurring in narrow wakes extending downstream of individual foundations.

6.10.8.10 To assess the impact of offshore infrastructure on water column mixing and stratification, the method outlined by Carpenter *et al.* (2016) was used. This approach uses empirical equations to estimate two key timescales: the mixing timescale, which predicts the time required for complete mixing of stratified layers due to increased TKE generated by flow past the foundation structures, and the advective timescale, which quantifies how long a

water parcel remains within the OAA, experiencing enhanced TKE. These estimates provide insight into the influence of offshore infrastructure on local stratification.

6.10.8.11 Monthly PEA values for the OAA were calculated for the years 2010 to 2024. PEA is widely used in oceanography to assess the strength of stratification in a water body (for instance, the higher the PEA the stronger the water column stratification). Based on these monthly PEA values years representative of relatively weaker, intermediate and stronger stratification in the OAA were identified as 2015, 2010 and 2014, respectively.

6.10.8.12 The estimated mixing timescales for the OAA for weaker (2015), intermediate (2010) and stronger (2014) stratification years are given in **Table 6.13**. The estimated time a water parcel spends within the OAA experiencing enhanced mixing is 45.1 days. This indicates that a parcel of water is not exposed to the elevated TKE from offshore wind farm structures for a sufficiently long time to completely break down the stratification present in the water column, even for more weakly stratified years such as 2015.

Table 6.13 Mixing timescales for stronger (2014), intermediate (2010) and weaker (2015) stratification years

	Stronger stratification year	Intermediate stratification year	Weaker stratification year
Year	**2014**	**2010**	**2015**
T_{mix} (days).	87.7	77.4	67.1
T_{adv} (days).	45.1	45.1	45.1
T_{adv}/T_{mix}	0.51	0.58	0.67

6.10.8.13 To better understand the predicted impact in the context of natural variability, hourly PEA values were calculated for the OAA during a stratified summer month, July 2023. Stratification strength varies considerably over short timescales, with PEA fluctuations of approximately ±20J/m³ within a tidal cycle (12 hours). These natural variations exceed those expected from foundation-induced mixing over similarly short periods (<1 day). This suggests that the weakening of stratification caused by elevated turbulent mixing in the wake of foundation structures remains within the bounds of natural variability in the system.

6.10.8.14 Given the mixing induced by the foundations is unlikely to be strong enough to fully break down stratification within the timescale that water parcels are exposed to the enhanced mixing, the Project is therefore not expected to significantly influence the timing of seasonal stratification. The onset of stratification in spring depends on surface heating overcoming vertical mixing. The foundation-induced mixing could theoretically delay the onset of stratification. Similarly, the breakdown of stratification in autumn may be slightly accelerated by the Project infrastructure's enhanced TKE. However, in years where stratification is naturally weaker, stratification typically develops later and breaks down earlier. Therefore, the Project infrastructure's influence on seasonal timing is expected to be small, falling within the natural variability of the system.

6.10.8.15 Frontal systems typically form at the boundaries between mixed and stratified waters, with their position and intensity influenced by vertical mixing. Turbulence generated by offshore infrastructure is expected to locally weaken – though not completely disrupt stratification within the wakes of foundations. This may lead to small pockets of elevated primary production within the OAA, where nutrient mixing from the foundation wakes enriches the sunlit, nutrient-depleted surface layers of surrounding stratified waters. Such mixing could

also cause a slight offshore shift in frontal systems, effectively extending the well-mixed side of the front if it intersects the OAA. However, these changes are expected to be highly localised and fall within the natural variability of frontal system positioning.

6.10.8.16 The Buchan Front, associated with the Southern Trench NCMPA, typically forms closer to the coast. It lies outside the area directly influenced by elevated mixing within the OAA, with no clear hydrodynamic pathway connecting the two locations.

6.10.8.17 Effects on primary production and the wider ecosystem is expected to be minimal, especially when considering the natural variability and existing patterns of productivity in the region. In terms of the wider ecosystem, the localised mixing effects near the foundation structures are unlikely to affect ecosystem processes beyond the immediate vicinity of the OAA.

6.10.8.18 Finally, some modelling studies provide theoretical evidence for atmospheric offshore wind farm wakes to effect water column stratification through changes in near-surface wind speeds (for example, Christiansen *et al*., 2022). However, these findings are based on the presence of a very large number of offshore windfarms (>50) in relatively close proximity with a large total number of WTGs (>2,500) present within the theoretical scenario study area. The Project is small in comparison and the scale of these changes is expected to be very limited.

6.10.8.19 Whilst Christiansen *et al*. (2022) provides some evidence on the effects of WTGs on near surface wind speeds and water column mixing. It is noted that this work focused on a region of the North Sea that does not strongly seasonally stratify, so is not completely analogous to the location of the OAA. Other literature and methodology focusing on this wind wake effect on mixing and stratification is limited. Therefore, some uncertainty remains regarding the potential impact in the northern North Sea.

6.10.8.20 In conclusion, the magnitude of the impact that O&M activities relating to the Project will have on designated frontal features within the Southern Trench NCMPA is considered to be **low**, indicating that the potential for changes to frontal positioning, and the wider ecosystem it supports, will be unlikely, and if they do occur highly localised and within the natural variability of the positioning of frontal systems. In terms of the Conservation Objectives set out in NatureScot (2025), favourable condition of the NCMPA features will be maintained since:

- the extent, distribution and structure of that feature will be maintained;
- the function of the feature will be maintained – it will continue to support its characteristic biological communities and their use of the site including, but not restricted to, feeding, spawning, courtship or use as nursery grounds; and
- the processes supporting the feature will be maintained.

Significance of residual effect

6.10.8.21 Overall, it is predicted that the sensitivity of the receptor is **medium**, and the magnitude is **low**. The effect is of **Minor** (**Not Significant**) in EIA terms.

6.11 Assessment of effects: decommissioning stage

6.11.1 Introduction

6.11.1.1 This Section provides an assessment of the effects for marine geology, oceanography and physical processes from the decommissioning of the offshore elements of the Project.

6.11.1.2 The assessment methodology set out in **Section 6.8** has been applied to assess effects to marine geology, oceanography and physical processes from the Project.

6.11.2 Impact D1: potential changes to suspended sediment concentrations, bed levels and sediment type

Overview

6.11.2.1 The following decommissioning activities could potentially give rise to increases in SSC and associated deposition of material within the OAA and the offshore export cable:

- removal of foundation structures;
- cutting off of piles at foundation legs / anchors; and
- removal of buried cables and protection.

6.11.2.2 The maximum assessment scenario relating to potential changes to SSCs, bed levels and sediment type are presented in **Table 6.6**.

Sensitivity or value of receptor

6.11.2.3 All of the changes described in this Section are to 'pathways' as opposed to receptors and therefore sensitivity ratings have not been assigned.

Magnitude of impact

6.11.2.4 Potential changes to SSC, bed levels and sediment type are considered to be pathways of effect, rather than an impact on receptors, and as such, it is not appropriate to carry out an assessment of significance which determines the magnitude of effect. Instead, the potential for associated impacts to marine biodiversity assessed in other chapters (see **paragraph 6.11.2.11**).

6.11.2.5 The removal of WTG, offshore substation and RCP foundations is expected to result in some localised seabed disturbance accompanied by temporary increases in SSC. Foundations involving piled solutions would be cut off at or just below, potentially causing a localised disturbance of the bed and a temporary increase in SSC.

6.11.2.6 For the purposes of the EIA it has been assumed that all cables will be removed from the intertidal zone during decommissioning. It is probable that equipment similar to that which is used to install the cables could be used to reverse the burial process and expose the cables. Accordingly, the area of seabed impacted during the removal of the cables would be similar as the area impacted during the installation of the cables.

6.11.2.7 For all of the above, the changes in SSC and accompanying changes to bed levels than those associated with decommissioning activities are expected to be lesser than that associated with construction. Further information is provided in the construction stage assessment (**Section 6.9.2**).

6.11.2.8 The approach for decommissioning array cables and offshore export cables on the seabed is yet to be determined, however, this will be reviewed throughout the lifetime of the Project and best practice guidance at the time of decommissioning will be followed.

6.11.2.9 If multiple activities causing sediment are undertaken simultaneously at two or more locations that are aligned in relation to the ambient tidal streams, then there is potential for overlap between the areas of change in SSC and sediment deposition. The effect on SSC is locally additive in the area of overlap. Plumes that overlap subsequently through lateral

diffusion are not an additive effect on SSC and will not exceed the values quoted for individual plumes. The total sediment thickness deposited is locally additive in the area of overlap. It is noted that measurable thicknesses of deposition are only expected within relatively small distances (tens of metres) from the site of the activity, extending in the direction of tidal current at the time of the work. Therefore, there is a very low likelihood of a large total area of overlapping measurable local thicknesses of deposition resulting from overlapping plume effects.

6.11.2.10 The embedded environmental measure M-106 from **Table 6.7** means a decommissioning programme will be produced as part of the Project, ensuring decommissioning methods align with good practice, implement agreed embedded environmental measures and are appropriately managed.

Significance of residual effect

6.11.2.11 The assessment set out in this Section has considered potential changes to a pathway, rather than impacts on receptors. Accordingly, no assessment of significance is provided. However, the potential for these changes to impact other EIA receptor groups are considered elsewhere within the EIA, in particular:

- **Chapter 7: Marine Water and Sediment Quality**;
- **Chapter 10: Benthic, Epibenthic and Intertidal Ecology**;
- **Chapter 11: Marine Mammals**;
- **Chapter 12: Offshore and Intertidal Ornithology**;
- **Chapter 13: Fish Ecology**; and
- **Chapter 16: Marine Archaeology and Cultural Heritage**.

6.11.3 Impact D2: potential impacts to seabed morphology

Overview

6.11.3.1 Decommissioning activities, such as removal of infrastructure, could also potentially give rise to increases in SSC (**Section 6.11.2**) as well as localised changes to morphology within the OAA and the offshore export cable corridor. However, the potential for wider morphological change to designated seabed areas arising from these activities would be very limited and no greater than that identified for the construction stage.

6.11.3.2 The maximum assessment scenario relating to the potential impacts to seabed morphology during decommissioning is presented in **Table 6.6**. Where predicted effects are identified, an assessment of the magnitude of change for each effect has been completed based on the methodology provided in **Section 6.8.2**. The magnitude of change, and hence the significance of potential effects has been assessed on the assumption that the embedded environmental measures from **Table 6.7** have been implemented as part of the Project.

Sensitivity or value of receptor

6.11.3.3 The offshore export cable corridor passes through the Southern Trench NCMPA and decommissioning activities will be undertaken inside the boundary of the NCMPA. The site is high value / importance (since it forms part of Scotland's NCMPA network) and the geodiversity features of interest are relict (subglacial tunnel valleys, moraines and scars evidencing mass movement) with no ability to recover from impact. Accordingly, the site is assessed to be of high sensitivity.

Magnitude of impact

6.11.3.4 Where some or all cable protection is left in situ during or following the decommissioning process, the potential for changes to local seabed morphology (including within the Southern Trench NCMPA) as well as regionally, within designated areas of seabed within the study area is the same as described and assessed for the presence of cable protection during the O&M stage (**Section 6.10.5**).

6.11.3.5 Any impression left following the removal of infrastructure from the seabed, will be no larger than the original infrastructure and scour footprint. Depressions will become infilled and high points (comprising mobile sediment) will be levelled out by ambient sediment transport over time. The seabed sediment type will either remain or return to the ambient baseline condition within a similar or shorter time period as new sediment is deposited or underlying (previously undisturbed) sediments are exposed.

6.11.3.6 The embedded environmental measure M-106 from **Table 6.7** means a decommissioning programme will be produced as part of the Project, ensuring decommissioning methods align with good practice, implement agreed embedded environmental measures and are appropriately managed.

6.11.3.7 Overall, the magnitude of the impact that decommissioning activities relating to the Project will have on designated areas of seabed is considered to be **very low**, indicating that the impacts will be very small. Any impact is predicted to be highly localised and of short-term duration. These impacts do not threaten the long-term viability of the designated areas of seabed.

Significance of residual effect

6.11.3.8 The embedded environmental measures (as shown in **Table 6.7**) include the production of a decommissioning programme (M-106), to ensure decommissioning methods align with good practice, implement agreed embedded environmental measures and are appropriately managed, therefore minimising the disturbance of designated sites. Overall, it is predicted that the sensitivity of the receptor is **high**, and the magnitude is **very low**. The effect is of **Minor** (**Not Significant**) in EIA terms.

6.11.4 Impact D3: potential impacts to landfall morphology

Overview

6.11.4.1 The offshore export cables will make landfall at Scotstown and / or Lunderton. Both landfall zones include stretches of intertidal sand extending from dunes, through a dry upper shore zone, to mid and lower shore mobile sand. Further details are provided in **Section 6.6** and **Volume 3, Appendix 6.3**.

6.11.4.2 The maximum assessment scenario relating to the potential impacts to seabed morphology during decommissioning is presented in **Table 6.6**. Where predicted effects are identified, an assessment of the magnitude of change for each effect has been completed based on the methodology provided in **Section 6.8.2**. The magnitude of change, and hence the significance of potential effects has been assessed on the assumption that the embedded environmental measures from **Table 6.8** have been implemented as part of the Project.

Sensitivity or value of receptor

6.11.4.3 The coast at the landfall zones is potentially vulnerable to either direct or indirect disturbance from Project-related activities. However, it is not located within any designated

nature conservation sites and does not therefore contain any protected geodiversity features. It is typically a dynamic environment which is subject to natural change under baseline conditions. Accordingly, it is assessed to have some capacity to recover from disturbance and accommodate change. The overall sensitivity of the coastline at the landfall zones is therefore considered to be **medium**, reflecting the fact that the receptor is of medium value, medium vulnerability and medium recoverability.

Magnitude of impact

6.11.4.4 The removal of structures (especially rock protection) which have been in place for a long time could in theory, lead to much longer-term effects on morphodynamics. This is because the coastal and seabed morphology could have evolved to a new equilibrium state including the influence and presence of that structure. However, it is not expected that the removal of any cable protection from shallow subtidal areas would lead to substantive morphological change. This is because the presence of any cable protection measures is not expected to result in widespread change to the beach in the landfall zones in the first instance.

6.11.4.5 Should cables require removal at the end of its operational life, it will be removed through the same sediments and sub-strata disturbed during installation. This process could result in short term elevations in SSC and localised changes in bed level. Any change would be no greater in magnitude than for the construction stage. If the cables are left in situ at the end of the Project lifespan, impacts will be the same as those described previously for the O&M stage.

6.11.4.6 The embedded environmental measure M-106 from **Table 6.7** means a decommissioning programme will be produced as part of the Project, ensuring decommissioning methods align with good practice, implement agreed embedded environmental measures and are appropriately managed.

6.11.4.7 Overall, the magnitude of the impact that decommissioning activities relating to the Project will have on the coast is considered to be **low**, indicating that the impacts will be of local spatial extent and short-term duration.

Significance of residual effect

6.11.4.8 The embedded environmental measures (as shown in **Table 6.7**) include the production of a decommissioning programme (M-106), to ensure decommissioning methods align with good practice, implement agreed embedded environmental measures and are appropriately managed. Overall, it is predicted that the sensitivity of the receptor is **medium**, and the magnitude is **low**. The effect is of **Minor** (**Not Significant**) in EIA terms.

6.12 Summary of effects

6.12.1.1 A summary of the effects arising from the construction, O&M and decommissioning stages of the Project in relation to marine geology, oceanography and physical processes are summarised in **Table 6.14**.

Table 6.14 Summary of effects during the construction, operation and maintenance and decommissioning stage of the Project on marine geology, oceanography and physical processes

Receptor	Sensitivity / value	Activity and potential effect	Embedded environmental measures	Magnitude of effect	Significance of effects
Construction					
-	**N/A** [Potential pathway of effect for other topics].	Impact C1: Potential changes to SSCs, bed levels and sediment type (**Section 6.9.2**).	-	**N/A** [Potential pathway of effect for other topics].	**N/A**
Designated seabed areas (NCMPAs)	**High**	Impact C1: Potential impacts to seabed morphology (**Section 6.9.2**).	-	**Very low**	**Minor** (**Not Significant**).
The coast	**Medium**	Impact C1: Potential impacts to landfall morphology (**Section 6.9.2**).	M-120 M-121	**Low**	**Minor** (**Not Significant**).
Operation and maintenance					
-	**N/A** [Potential pathway of effect for other topics].	Impact O1: Potential changes to the tidal regime (**Section 6.10.2**).	-	**N/A** [Potential pathway of effect for other topics].	**N/A**
-	**N/A** [Potential pathway of effect for other topics].	Impact O2: Potential changes to the wave regime (**Section 6.10.3**).	-	**N/A** [Potential pathway of effect for other topics].	**N/A**
-	**N/A** [Potential	Impact O3: Potential changes to the sediment transport regime (**Section 6.10.4**).	-	**N/A** [Potential pathway of effect for other topics].	**N/A**

Receptor	Sensitivity / value	Activity and potential effect	Embedded environmental measures	Magnitude of effect	Significance of effects
	pathway of effect for other topics].				
Designated seabed areas (NCMPAs)	**High**	Impact O4: Potential changes to seabed morphology (**Section 6.10.5**).	-	**Very low**	**Minor** (**Not Significant**).
The coast	**Medium**	Impact O5: Potential impacts to coastal morphology (**Section 6.10.6**).	M-054	**Low**	**Minor** (**Not Significant**).
-	**N/A** [Potential pathway of effect for other topics].	Impact O6: Scour (**Section 6.10.7**).	M-028	**N/A** [Potential pathway of effect for other topics].	**N/A**
For Designated frontal systems	**Medium**	Impact O7: Potential changes to stratification and frontal systems (**Section 6.10.8**).	-	**Low**	**Minor** (**Not Significant**).
Decommissioning					
-	**N/A** [Potential pathway of effect for other topics].	Impact D1: Potential changes to SSCs, bed levels and sediment type (**Section 6.11.2**).	-	**N/A** [Potential pathway of effect for other topics].	**N/A**
Designated seabed areas (NCMPAs)	**High**	Impact D2: Potential impacts to seabed morphology (**Section 6.11.3**).	M-106	**Very low**	**Minor** (**Not Significant**).
The coast	**Medium**	Impact D3: Potential impacts to landfall morphology (**Section 6.11.4**).	-	**Low**	**Minor** (**Not Significant**).

6.13 Transboundary effects

6.13.1.1 Transboundary effects arise when impacts from a development with one EEA State affects the environment of another EEA State(s). A screening of transboundary effects have been carried out and is presented in Appendix 4B of the Scoping Report (MarramWind Limited, 2023).

6.13.1.2 Based on the established baseline environment, the defined nature and scale of the proposed works, and a robust body of evidence from comparable offshore wind farm developments, such as the Caledonia Offshore Wind Farm, Green Volt Offshore Wind Farm, Muir Mhór Offshore Wind Farm and Salamander Offshore Wind Farm, no transboundary effects are anticipated on marine geology, oceanography and physical processes receptors. This conclusion is supported by the findings of the transboundary screening (MarramWind Limited, 2023), which confirms that the ZOI remains confined to UK waters and does not extend into the jurisdiction of other EEA states.

6.14 Inter-related effects

6.14.1.1 A description and assessment of the likely inter-related effects arising from the Project on marine geology, oceanography and physical processes is provided in **Chapter 32: Inter-Related Effects**.

6.15 Assessment of cumulative effects

6.15.1.1 A description and assessment of the cumulative effects arising from the Project on marine geology, oceanography and physical processes is provided in **Chapter 33: Cumulative Effects Assessment**.

6.16 Summary of residual likely significant effects

6.16.1.1 There are no residual likely significant effects on marine geology, oceanography and physical processes receptors assessed in this Chapter have been identified.

6.17 References

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6.18 Glossary of Terms and Abbreviations

6.18.1 Abbreviations

Acronym	Definition
ABPmer	ABP Marine Environmental Research Ltd
BERR	Department for Business, Enterprise and Regulatory Reform
BGS	British Geological Survey
BODC	British Oceanographic Data Centre
Cefas	Centre for Environment, Fisheries and Aquaculture Science
EC	European Commission
EAA	European Economic Area
EEC	European Economic Community
EIA	Environmental Impact Assessment
FEPA	Food and Environment Protection Act
FLiDAR	Floating Light Detection and Ranging
HDD	Horizontal directional drilling
LAT	Lowest Astronomical Tide
MFE	Mass Flow Excavator
MD-LOT	Marine Directorate - Licensing Operations Team
MHWS	Mean High Water Springs
MSL	Mean Sea Level
MW	Megawatt
NCMPA	Nature Conservation Marine Protected Area
nm	nautical mile
OAA	Option Agreement Area
O&M	Operation and Maintenance
PEA	Potential Energy Anomaly
RCP	Reactive Compensation Platform
s.36	Section 36
SCO	Scottish Coastal Observatory

Acronym	Definition
SDC	Subsea distribution centre
SEA	Strategic Environmental Assessment
SPA	Special Protection Area
SSC	Suspended Sediment Concentrations
SSS	Side scan sonar
SSSI	Site of Special Scientific Interest
TEDA	Thames Estuary Dredging Association
TKE	Turbulent Kinetic Energy
UKCP18	United Kingdom Climate Projections 2018
UKHO	United Kingdom Hydrographic Office
WTG	Wind Turbine Generator

6.18.2 Glossary of terms

Term	Definition
Aberdeenshire Council	One of 32 divisions of Scotland, designated as a Council area for the purposes of local government, covering Aberdeenshire.
Baseline	Existing conditions as represented by the latest available data, whether from literature or survey and used as a benchmark for making comparisons to assess the impact of a development or project.
Bathymetry	Topography of sea/estuary bed measured from a fixed vertical datum.
Beach	A deposit of non-cohesive material (for example, sand, gravel) situated on the interface between dry land and the sea (or other large expanse of water) and actively 'worked' by present-day hydrodynamic processes (for instance, waves, tides and currents) and sometimes by winds.
Bedforms	Features on the seabed (for example, sand waves, ripples) resulting from the movement of sediment over it.
Benthic ecology	The study of the organisms living in and on the sea floor, the interactions between them and their impacts on the surrounding environment.
Climate Change	A long-term trend in the variation of the climate resulting from changes in the global atmospheric and ocean temperatures and affecting mean sea level, wave height, period and direction, wind speed and storm occurrence.
Coastal Cell	Coastline unit within which sediment movement is self-contained.

Term	Definition
Cumulative Effects	Additional changes caused by the Project in conjunction with other similar developments or as a combined effect of a set of developments, taken together.
Cumulative Effects Assessment	Assessment of effects as a result of the incremental changes caused by other past, present and reasonably foreseeable human activities and natural processes together with the Project.
Decommissioning	The period during which a development and its associated processes are removed from active operation.
Ebb tide	Period when tide level is falling; often taken to mean the ebb current which occurs during this period.
Environmental Impact Assessment Report	The outcome of the Environmental Impact Assessment (EIA) process is reported within a document called an EIA Report.
Embedded environmental measures	Equate to 'primary environmental measures' as defined by Institute of Environmental Management and Assessment (2016). They are measures to avoid or reduce environmental effects that are directly incorporated into the preferred masterplan for the Project.
Flood tide	The period of time when tide levels are rising.
Front	Area separating two distinct water masses with different densities
Geodiversity	Defines the variety of rocks, minerals, fossils, landforms, sediments and soils, together with the natural processes that form and alter them.
Geomorphology	The physical shape and characteristics of the seabed or coastline.
Geophysical survey	Activities to obtain data on the distribution and nature of geophysical properties of the seabed (for example, bathymetry, surficial sediment type and bedforms, sub-surface geology). Geophysical survey outputs typically include multibeam bathymetry, side-scan sonar and sub-bottom profiler data.
Holocene age	The last 11,700 years covering the period of time since the last glaciation.
Hydrodynamics	The study of liquids in motion, but used here to describe waves and tides, either alone or in combination.
Intertidal	The area of the shoreline which is covered at high tide and uncovered at low tide.
Marine Protected Area	Marine sites at the national level under the Marine (Scotland) Act 2010. In Scotland MPAs are areas of sea defined so as to protect habitats, wildlife, geology, undersea landforms, historic shipwrecks and to demonstrate sustainable management of the sea.
Metocean	Relating to meteorology and oceanography
NatureScot	Formerly known as Scottish Natural Heritage, NatureScot is a public body and government advisor responsible for Scotland's natural heritage, in particular for its natural, genetic and scenic diversity.

Term	Definition
Pleistocene age	The period of time between approximately 2.6 million years ago and 11,700 years ago
Ramsar site	Areas listed by the UK Government under the Convention on Wetlands of International Importance (the Ramsar Convention 1971).
Receptor	This term originates as defined in Regulation 5(2) of The Infrastructure Planning (Environmental Impact Assessment) Regulations 2017 and include population and human health, biodiversity, land, soil, water, air, climate, material assets, cultural heritage and landscape that may be at risk from exposure to pollutants which could potentially arise as a result of the Project. It is equivalent to the term 'factors' defined in 4(3) of the Town and Country Planning (Environmental Impact Assessment) (Scotland) Regulations 2017, where factors may be subject to significant effects of the Project and include population and human health, biodiversity, land, soil, water, air, climate, material assets, cultural heritage and the landscape.
Sandwaves	Large scale asymmetric bedforms with heights of up to 1/3 water depth. Sandwaves may be used to give an indication of the predominant direction of sediment transport. These features are sometimes known to migrate at speeds of several km/year.
Sediment transport	The movement of a mass of sedimentary material by the forces of currents and waves. The sediment in motion can comprise fine material (silts and muds), sands and gravels. Potential sediment transport is the full amount of sediment that could be expected to move under a given combination of waves and currents, for instance, not supply limited.
Site of Special Scientific Interest	Sites designated at the national level under the Nature Conservation (Scotland) Act 2004. They are a series of sites that are designated to protect the best examples of significant natural habitats and populations of species.
Special Protection Area	Sites designated under EU Directive (79/409/EEC) to protect habitats of migratory birds and certain threatened birds under the Birds Directive.
Subtidal	The region of shallow waters which are below the level of low tide.
Tidal excursion ellipse	The path followed by a water particle in one complete tidal cycle.
Turbulent Kinetic Energy	The quantitative measure of the intensity of turbulence for a given flow.

MarramWind