Morlais Project
Environmental Statement

Chapter 7: Metocean Conditions and Coastal Processes

Volume I

Applicant: Menter Môn Morlais Limited

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Chapter 7: Metocean Conditions and Coastal Processes

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GLOSSARY OF ABBREVIATIONS

ADCP	Acoustic Doppler Current Profiler
AONB	Area of Outstanding Natural Beauty
ATM	Anglesey Turbidity Maximum
CEMP	Construction Environmental Management Plan
CD	Chart Datum
CPA	Coast Protection Act
ES	Environmental Statement
FEPA	Food and Environmental Protection Act
GBS	Gravity Base Structure
HDD	Horizontal Directional Drilling
JLDP	Joint Local Development Plan
MCAA	Marine and Coastal Access Act
MCZ	Marine Conservation Zone
MDZ	Morlais Demonstration Zone
MPS	Marine Policy Statement
NRW	Natural Resources Wales
OfDA	Offshore Development Area
PDE	Project Design Envelope
PDZ	Policy Development Zones
RCP	Representative Concentration Pathway
SAC	Special Area of Conservation
SMP	Shoreline Management Plan
SPA	Special Protection Area
S-P-R	Source-Pathway-Receptor
SSSI	Site of Special Scientific Interest
TAN	Technical Advice Note
TWAO	Transport and Works Act Order
UAV	Unmanned Aerial Vehicle
UK	United Kingdom
UKHO	United Kingdom Hydrographic Office
WNMP	Welsh National Marine Plan

GLOSSARY OF TERMINOLOGY

Astronomical tide	The predicted tide levels and character that would result from the gravitational effects of the earth, sun and moon without any atmospheric influences
Bathymetry	Topography of the sea bed
Beach	A deposit of non-cohesive sediment (e.g. 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 (i.e. waves, tides and currents) and sometimes by winds

Bedforms	Features on the seabed (e.g. sand waves, ripples) resulting from the movement of sediment over it
Bedforms	Features on the seabed (e.g. sand waves, ripples) resulting from the movement of sediment over it
Climate change	A change in global or regional climate patterns. Within this chapter this usually relates to any long-term trend in mean sea level, wave height, wind speed etc, due to climate change
Closure depth	The depth that represents the 'seaward limit of significant depth change', but is not an absolute boundary across which there is no cross-shore sediment transport
Coastal processes	Collective term covering the action of natural forces on the shoreline and nearshore seabed
Crest	Highest point on a bedform or wave
Current	Flow of water generated by a variety of forcing mechanisms (e.g. waves, tides, wind)
Ebb tide	The falling tide, immediately following the period of high water and preceding the period of low water
Erosion	Wearing away of the land or seabed by natural forces (e.g. wind, waves, currents, chemical weathering)
Flood tide	The rising tide, immediately following the period of low water and preceding the period of high water
Glacial diamicton	Poorly sorted or non-sorted sediments of glacial origin
Gravel	Loose, rounded fragments of rock larger than sand but smaller than cobbles. Sediment larger than 2mm (as classified by the Wentworth scale used in sedimentology)
Habitat	The environment of an organism and the place where it is usually found
High water	Maximum level reached by the rising tide
Intertidal	Area on a shore that lies between Lowest Astronomical Tide (LAT) and Highest Astronomical Tide (HAT)
Longshore currents	The movement of currents parallel to the shore
Low water	The minimum height reached by the falling tide
Mean sea level	The average level of the sea surface over a defined period (usually a year or longer), taking account of all tidal effects and surge events
Megaripples	Bedforms with a wavelength of 0.6 to 10.0m and a height of 0.1 to 1.0m. These features are smaller than sand waves but larger than ripples
Metocean	The syllabic abbreviation of meteorology and oceanography
Neap tide	A tide that occurs when the tide-generating forces of the sun and moon are acting at right angles to each other, so the tidal range is lower than average
Nearshore	The zone which extends from the swash zone to the position marking the start of the offshore zone (~20m)

Numerical modelling	Refers to the analysis of coastal processes using computational models
Offshore	Area to seaward of nearshore in which the transport of sediment is not caused by wave activity
Quaternary Period	The last 2 million years of earth history incorporating the Pleistocene ice ages and the post-glacial (Holocene) Period
Sand	Sediment particles, mainly of quartz with a diameter of between 0.063mm and 2mm. Sand is generally classified as fine, medium or coarse
Sand wave	Bedforms with wavelengths of 10 to 100m, with amplitudes of 1 to 10m
Scour protection	Protective materials to avoid sediment being eroded away from the base of the foundations as a result of the flow of water.
Sea level	Generally refers to 'still water level' (excluding wave influences) averaged over a period of time such that periodic changes in level (e.g. due to the tides) are averaged out
Sea-level rise	The general term given to the upward trend in mean sea level resulting from a combination of local or regional geological movements and global climate change
Sediment	Particulate matter derived from rock, minerals or bioclastic matter
Sediment transport	The movement of a mass of sediment by the forces of currents and waves
Shallow water	Commonly, water of such depth that surface waves are noticeably affected by bottom topography. It is customary to consider water of depths less than half the surface wave length as shallow water
Shore platform	A platform of exposed rock or cohesive sediment exposed within the intertidal and subtidal zones
Significant wave height	The average height of the highest of one third of the waves in a given sea state
Spring tide	A tide that occurs when the tide-generating forces of the sun and moon are acting in the same directions, so the tidal range is higher than average
Storm surge	A rise in water level on the open coast due to the action of wind stress as well as atmospheric pressure on the sea surface
Surge	Changes in water level as a result of meteorological forcing (wind, high or low barometric pressure) causing a difference between the recorded water level and the astronomical tide predicted using harmonic analysis
Suspended sediment	The sediment moving in suspension in a fluid kept up by the upward components of the turbulent currents or by the colloidal suspension
Swell waves	Wind-generated waves that have travelled out of their generating area. Swell characteristically exhibits a

	more regular and longer period and has flatter crests than waves within their fetch
Tidal current	The alternating horizontal movement of water associated with the rise and fall of the tide
Tidal range	Difference in height between high and low water levels at a point
Tide	The periodic rise and fall of the water that results from the gravitational attraction of the moon and sun acting upon the rotating earth
Wave climate	Average condition of the waves at a given place over a period of years, as shown by height, period, direction etc.
Wave height	The vertical distance between the crest and the trough
Wavelength	The horizontal distance between consecutive bedform crests

7. METOCEAN CONDITIONS AND COASTAL PROCESSES

7.1. INTRODUCTION

1. This chapter of the Environmental Statement (ES) describes the metocean conditions and coastal processes of the Morlais Project (the Project).

2. The Project is being developed by Menter Môn Morlais Ltd. (Menter Môn) and will have a tidal generating capacity of up to 240 MW within the Morlais Demonstration Zone (MDZ).

3. The development of the Project will provide a consented tidal technology demonstration zone, specifically designed for the installation and commercial demonstration of multiple arrays of tidal energy devices. The Project will include communal infrastructure for tidal technology developers which provides a shared route to the cable landfall point via nine export cables, an onshore landfall substation, and an onshore electrical cable route to the existing electricity network via a grid connection substation (see **Chapter 4, Project Description**).

4. This chapter provides a summary description of key aspects relating to existing metocean conditions and coastal processes followed by an assessment of the magnitude and significance of the effects on the baseline conditions resulting from the construction, operation, repowering and decommissioning of the Project, as well as those effects resulting from cumulative interactions with other existing or planned projects.

5. This chapter of the ES was written by Royal HaskoningDHV metocean and coastal processes specialists and incorporates metocean data collected by Partrac (2014)[1], benthic survey data collected by Ocean Ecology (2018) and geophysical data collected by Partrac (2018), as well as numerical modelling outputs from HR Wallingford (2017, 2019). The assessment process has been informed by the following:

   - Interpretation of survey data specifically collected for the Project including bathymetry, sub-sea bed geology, sea bed sediments and metocean conditions;
   - Consideration of the existing evidence base regarding the effects of Project infrastructure on the physical and sedimentary environments;
   - Discussion and agreement with key stakeholders; and
   - Application of expert-based assessment and judgement by Royal HaskoningDHV.

6. The Project will install multiple technology types within the MDZ, and so the consent application is based on a Project Design Envelope (PDE), determined through knowledge of existing technology and the direction of future developments. Hence, the potential effects on metocean conditions and coastal processes have been assessed conservatively using realistic 'worst-case' scenarios for the Project.

[1] Provided courtesy of OpenHydro

7.2. RELEVANT GUIDANCE AND POLICY

7. This section outlines the relevant national and regional policy and guidance and industry guidance which has be used to support the compilation of this Metocean and Coastal Processes Chapter.

8. An overview of the relevant legislative context for the Project is provided in **Chapter 2, Policy and Legislation**.

7.2.1. Policy Statements

7.2.1.1. National Policy Statements

9. The Project is seeking consent for a Transport and Works Act Order from the Welsh Ministers and a Marine Licence from Natural Resources Wales (NRW). Although this Project is not seeking a Development Consent Order (DCO), its size (240 MW) means it is representative of a Nationally Significant Infrastructure Project (NSIP), therefore guidance relevant to NSIPs is considered appropriate to use for this Project. Guidance that is relevant to assessing impacts for NSIPs is set out within National Policy Statements (NPSs) which are the principal decision-making documents for NSIPs. Those relevant to metocean conditions and coastal processes include:

- Overarching NPS for Energy (EN-1) (Department of Energy and Climate Change (DECC) 2011a); and
- NPS for Renewable Energy Infrastructure (EN-3), July 2011 (DECC, 2011b).

10. Details of specific policies within EN-1 and EN-3 used to inform this assessment are provided in **Table 7-1** below. The specific assessment requirements for metocean conditions and coastal processes are detailed, together with an indication of the paragraph numbers of the chapter where each is addressed.

Table 7-1 NPS EN-1 and EN-3 Assessment Requirements Relevant to Metocean Conditions and Coastal Processes

NPS Requirement	NPS Reference	ES Reference
'Where relevant, applicants should undertake coastal geomorphological and sediment transfer modelling to predict and understand impacts and help identify relevant mitigating or compensatory measures'	NPS EN-1 Section 5.5, paragraph 5.5.6	Modelling has been used to assess the baseline hydrodynamic regime and the impacts from the Project on the baseline hydrodynamic regime. A description of this modelling process is provided in **Appendix 7.1** (**Volume III**). Given the nature of the baseline environment (**Section 7.6**), it was deemed appropriate that the baseline sediment regime (including suspended sediment) has been defined based upon existing literature, previous similar

NPS Requirement	NPS Reference	ES Reference
		projects, geophysical and benthic survey and expert interpretation.
'The ES should include an assessment of the effects on the coast. In particular, applicants should assess: ▪ The impact of the proposed project on coastal processes and geomorphology, including by taking account of potential impacts from climate change. If the development will have an impact on coastal processes the applicant must demonstrate how the impacts will be managed to minimise adverse impacts on other parts of the coast. ▪ The vulnerability of the proposed development to coastal change, taking account of climate change, during the project's operational life and any decommissioning period.'	NPS EN-1 Section 5.5, paragraph 5.5.7	See **Section 7.7.5**, **7.7.6** and **7.7.7**
'The applicant should be particularly careful to identify any effects of physical changes on the integrity and special features of Marine Conservation Zones, candidate marine Special Areas of Conservation (SACs), coastal SACs and candidate coastal SACs, coastal Special Protection Areas (SPAs) and potential SCIs and Sites of Special Scientific Interest (SSSI).'	NPS EN-1 Section 5.5, paragraph 5.5.9	See **Section 7.7** and **7.7.1**
The assessment should include predictions of the physical effect that will result from the construction and operation of the required infrastructure and include effects such as the scouring that may result from the proposed development.	NPS EN-3 Section 2.6, paragraph 2.6.194	See **Section 7.7.5** and **7.7.6**
Mitigation measures which the IPC should expect the applicants to have considered include the burying of cables to a necessary depth and using scour protection techniques around offshore structures to prevent scour effects around them. Applicants should consult the statutory consultees on appropriate mitigation.	NPS EN-3 Section 2.6, paragraph 2.6.197	See **Section 7.7.3** and **94**

7.2.1.2. Marine Policy Statement

11. The Marine Policy Statement (MPS) adopted by all UK administrations in March 2011 provides the policy framework for the preparation of marine plans and establishes how decisions affecting the marine area should be made in order to enable sustainable development. The MPS sets out a vision of having 'clean, healthy, safe, productive and biologically diverse oceans and seas' by supporting the development of Marine Plans. It also sets out the framework for environmental, social and economic considerations that need to be considered in marine planning. Regarding the topics covered by this chapter the key reference is in **Table 7-2**.

7.2.1.3. Welsh National Marine Plan

12. By adopting the MPS, the Welsh Government committed to the requirement to introduce Marine Plans for Wales.

13. The Welsh Government is currently developing the first marine plan for Welsh inshore and offshore waters, the Welsh National Marine Plan (WNMP). The Plan is being developed in accordance with the Marine and Coastal Access Act (MCAA) 2009, the MPS and the Maritime Spatial Planning Directive, a draft version has been issued for consultation (discussed further in **Chapter 2, Policy and Legislation**).

14. Objective 10 of the WNMP, "to maintain and enhance the resilience of marine ecosystems and the benefits they provide in order to meet the needs of present and future generations", is of relevance to this chapter as this covers policies and commitments on the wider ecosystem, as set out in the MPS including those to do with the Marine Strategy Framework Directive and the Water Framework Directive, as well as other environmental, social and economic considerations.

15. The draft WNMP makes reference to the policies shown in **Table 7-2**which are particularly relevant to the Project.

7.2.1.4. Planning Policy Wales

16. Planning policy for Wales is set out in the document Planning Policy Wales (Welsh Government, 2016). The planning policy document outlines the Welsh Government's approach to facilitating the delivery of the aims set out in Energy Wales: A Low Carbon Transition (Welsh Government, 2012b), as well as UK wide and European renewable energy targets, including obligations under the Renewable Energy Directive (2009/28/EC). The relevant points within the policy relating to metocean and coastal processes are outlined in **Table 7-2**.

17. The following Planning Policy Technical Advice Note (TAN) has been reviewed within this chapter of the Morlais ES:

- TAN 14: Coastal Planning.

7.2.2. Regional Plans

7.2.2.1. Anglesey and Gwynedd Joint Local Development Plan

18. Development of the Project will support those objectives of the 2017 Anglesey and Gwynedd JLDP, aimed at promoting the development of renewable or low carbon energy technologies. The Project will prioritise maximising opportunities for local communities directly via employment and indirectly via the establishment of a local supply chain.

19. Of the policies contained in the JLDP, those presented in **Table 7-2** are considered to be of relevance to the proposed development.

7.2.2.2. Shoreline Management Plan

20. A Shoreline Management Plan (SMP) provides a large-scale assessment of the risks associated with coastal evolution and presents a policy framework to address these risks to people and the developed, historic and natural environment in a sustainable manner. In doing so, an SMP is a high-level document that forms an important part of the Department for Environment, Food and Rural Affairs (Defra) strategy for flood and coastal defence (Defra, 2001).

21. The SMP is a non-statutory policy document for coastal defence management planning. It takes account of other existing planning initiatives and legislative requirements and is intended to inform wider strategic planning. The shoreline of Wales is divided into a number of Policy Development Zones (PDZ). The coastal area of the Project lies within PDZ17 – Holy Island and West Anglesey (Twyn y Parc to Twyn Cliperau).

7.2.3. Policy Summary

22. The relevant nation National and Regional policy requirements relevant to the Morlais Metocean and Coastal Processes ES chapter is shown in **Table 7-2**.

Table 7-2 National and Regional Policy Requirements Relevant to Metocean and Coastal Processes

Policy Description	Reference	ES Reference
MPS		
Marine plan authorities should not consider development which may affect areas at high risk and probability of coastal change unless the impacts upon it can be managed. Marine plan authorities should seek to minimise and mitigate any geomorphological changes that an activity or development will have on coastal processes, including sediment movement.	Section 2.6.8.6	The potential impacts on coastal processes associated with the construction, operation and decommissioning of the Project is assessed in **Section 7.7.7**, **7.7.8** and **7.7.9**.
Draft WNMP		
Proposals should demonstrate how they are resilient to coastal change and flooding over their lifetime.	SOC_08: Resilience to coastal change and flooding	Coastal change has been considered when assessing potential impacts and effects, see **Section 7.6.6**.
Proposals are encouraged that: ▪ Demonstrate that they have no significant adverse impact upon coastal processes; ▪ Minimise the risk of coastal change and flooding; and ▪ Align with the relevant Shoreline Management Plan	SOC_09: Effects on coastal change and flooding	The potential impacts on coastal processes associated with the construction, operation and decommissioning of the Project is assessed in **Section 7.7.7**, **7.7.8** and **7.7.9**. The Project will not affect the Shoreline Management Plan and allowance has been made for natural erosion (including allowances for climate change) during the project design. Embedded mitigation to minimise potential impacts at the coast of cable installation and operation are described in **Section 7.7.3**.

Policy Description	Reference	ES Reference
Proposals should demonstrate that they have considered the impacts of climate change and have incorporated appropriate adaption measures, taking into account Climate Change Risk Assessments for Wales.	SOC_11: Resilience to climate change	Climate change impacts have been considered when assessing potential impacts and effects, see **Section 7.6.6**.
Proposals should demonstrate that they have assessed potential cumulative effects and, in order of preference: ▪ a) Avoid adverse effects; and/or ▪ b) Minimise effects where they cannot be avoided; and/or ▪ c) Mitigate effects where they cannot be minimised. If significant adverse effects cannot be adequately addressed, proposals should present a clear and convincing justification for proceeding. Proposals that contribute to positive cumulative effects are encouraged.	GOV_01: Cumulative effects	Cumulative and in-combination impacts of the Project have been considered in **Section 7.7.8** and **Chapter 26, Cumulative and In-Combination Effects**.
Planning Policy Wales		
As part of understanding the characteristics of coastlines it should be recognised that sea level rise, storm surge, wave action and changes in coastal morphology and sediment supply can lead to both direct and indirect effects at the coast. Uncertainty is further exacerbated by the effects of climate change.	Section 6.5.14	Climate change impacts have been considered when assessing potential construction, operation and decommissioning phase impacts and effects, see **Section 7.6.6**.
It is not appropriate for development in one location to unacceptably add to the impacts of physical change to the coast in another location.	Section 6.5.15	Cumulative and in-combination impacts of the Project have been considered in **Section 7.7.8** and **Chapter 26, Cumulative and In-Combination Effects**.
SMPs will influence whether development itself can be justified or how it should be designed.	Section 6.5.17	The Project will not affect the Shoreline Management Plan and allowance has been made for natural erosion (including allowances for climate change) during the project design.
Anglesey and Gwynedd Joint Local Development Plan (JLDP)		
Within the coastal areas that are protected as a Heritage Coast an emphasis will be placed on protecting and promoting the natural beauty of the coast, facilitating access for the public and public appreciation, maintaining the environmental quality of the waterfronts and promoting sustainable types of social and economic development.	AMG 4: Coastal Protection	Holyhead Mountain Heritage Coast has been considered when assessing potential impacts during the construction, operation and decommissioning of the Project.
All impacts on landscape character, heritage assets and natural resources have been adequately mitigated, ensuring that the special qualities of all locally, nationally and internationally important landscape, biodiversity and heritage designations,	ADN 3: Other Renewable Energy and Low Carbon Technologies	Impacts on Holy Island Coast SSSI/SAC, Anglesey AONB and Holyhead Mountain Heritage coast have been assessed in **Section 7.7** and mitigation proposed in **Sections 7.7.3** and **7.7.4**

Policy Description	Reference	ES Reference
including, where appropriate, their settings are conserved or enhanced.		
The Councils will manage development so as to conserve and where appropriate enhance the Plan area's distinctive natural environment, countryside and coastline, and proposals that have a significant adverse effect on them will be refused unless the need for and benefits of the development in that location clearly outweighs the value of the site or area and national policy protection for that site and area in question.	PS 19: Conserving and Where Appropriate Enhancing the Natural Environment	Please see **Chapter 19, Onshore Ecology**; **Chapter 24, Seascape, Landscape and Visual Impact Assessment**, **Chapter 25, Socioeconomics, Tourism and Recreation**
Proposals that are likely to cause direct or indirect significant harm to Local Nature Reserves (LNR), Wildlife Sites (WS) 1 or regionally important geological / geomorphologic sites (RIGS) must have overriding economic and social benefit and not cause unacceptable harm	AMG 6: Protecting Sites of Regional or Local Significance	See **Section 7.7.7, 7.7.8** and **7.7.9** for the impact assessment results.
Wellbeing of Future Generations (Wales) Act 2015		
A nation which maintains and enhances a biodiverse natural environment with healthy functioning ecosystems that support social, economic and ecological resilience and the capacity to adapt to change (for example climate change).	A resilient Wales	See **Section 7.7.7, 7.7.8** and **7.7.9** for the impact assessment results.

7.2.4. Industry Guidance

23. Industry guidance on the generic requirements, including spatial and temporal scales, for metocean and coastal processes studies associated with tidal array developments is provided in several documents (some of which are specifically written for offshore wind farms but are also of relevance here):

- Metocean Procedures Guide for Offshore Renewables (IMarEST, 2018);
- Offshore wind farms: guidance note for Environmental Impact Assessment in respect of Food and Environmental Protection Act (FEPA) and Coast Protection Act (CPA) requirements: Version 2 (Cefas, 2004);
- Coastal Process Modelling for Offshore Wind farm Environmental Impact Assessment (COWRIE, 2009);
- Review of Cabling Techniques and Environmental Effects applicable to the Offshore Wind Farm Industry (BERR, 2008);
- General advice on assessing potential impacts of and mitigation for human activities on Marine Conservation Zone (MCZ) features, using existing regulation and legislation (JNCC and Natural England, 2011); and
- Guidelines for data acquisition to support marine environmental assessments of offshore renewable energy projects (Cefas, 2011).

7.3. CONSULTATION

24. Consultation is an important part of the Transport and Works Act Order (TWAO) application process. To date, consultation regarding metocean conditions and coastal processes has been conducted through the Scoping Opinion for the Scoping Report (Royal HaskoningDHV, 2018). The Scoping responses received are summarised in **Table 7-3**.

Table 7-3 Scoping Opinion Responses

Consultee	Comment	Response/where addressed in the ES
Planning Inspectorate	Reduced energy in tidal currents from energy removed by tidal devices. Paragraph 11.2.2.1 of the Scoping Report requests to scope this matter out on the basis that previous studies for other projects such as Perpetuus Tidal Energy Centre and SeaGen have found little evidence of significant changes to tidal strength downstream of devices and have predicted no significant impacts on coastal processes. Whilst this is noted, the Perpetuus Tidal Energy Centre is a 30MW development and it is not accepted that the findings of such previous studies are directly applicable to the Proposed Works, which is 240MW and is seeking a wide project design envelope. In addition, the request to scope this matter out is contradicted by Table 7-1 of the Scoping Report which states that removal of tidal energy from the environment may result in increased sedimentation downstream of TEC devices and that significance of impact is unknown. It is therefore not agreed that this matter can be scoped out of the ES. The ES should assess potential hydrodynamic impacts from the presence of offshore infrastructure.	The potential impacts on the baseline hydrodynamic conditions from the presence of offshore infrastructure are assessed in **Section 7.7.8**.
Planning Inspectorate	Changes to wave climate from submerged and surface piercing infrastructure. The Applicant states that EIA and monitoring studies from other surface piercing technologies, namely offshore wind, have found no evidence to suggest that surface piercing devices significantly alter wave climate or strength inshore of project areas. No specific studies have been referenced and it is unclear if such studies conducted for different technology types will be applicable to the Proposed Works' tidal technologies, which may include substantially different structures to wind turbines. On the basis of the information provided at this stage, it is not agreed this matter can be scoped out of the ES. The ES should assess potential hydrodynamic impacts from the presence of offshore infrastructure.	The potential impacts on the baseline wave climate from the presence of offshore infrastructure are assessed in **Section 7.7.8**.
Planning Inspectorate	The Scoping Report provides limited detail on how the baseline will be characterised. The Applicant should make efforts to discuss and agree the approach to baseline characterisation with NRW. The proposed coastal process conceptual modelling should inform the need of any further field surveys e.g. bathymetric and/ or geophysical investigations. Sediment samples should also be taken in sediment laden seabed areas to determine sediment type,	The data sources used to inform the conceptual understanding of the baseline environment are listed in **Section 7.5.2**. The baseline environment is described in **Section 7.6**.

Consultee	Comment	Response/where addressed in the ES
	composition and sediment volume that could potentially be suspended through the cable trenching activities. Topographical data from the landfall location should be provided to inform any impacts on the beach profile and sediment morphology from cable landfall.	
Planning Inspectorate	The Scoping Report has not detailed how the potential impacts will be assessed. The methodology must be detailed in the ES. It is considered that modelling will be required to predict the anticipated increase in suspended sediment from the Proposed Works. The ES should include details of the parameter inputs to the model and provide an explanation/justification of any worst-case scenario that has been assumed.	The methodology used for the assessment of potential impacts is described in **Section 7.4.1**. Modelling has been used to assess the baseline hydrodynamic regime and the impacts from the Project on the baseline hydrodynamic regime. A description of this modelling process is provided in **Appendix 7.1** (**Volume III**). Given the nature of the baseline environment (**Section 7.6**), it was deemed appropriate that the baseline sediment regime (including suspended sediment) has been defined based upon existing literature, previous similar projects, geophysical and benthic survey and expert interpretation.
Planning Inspectorate	The Scoping Report notes the potential for *Sabellaria alveolata* and *Modiolus modiolus* reef to be present in the offshore scoping area. The Applicant should take into account NRW's response (see Appendix 1 of this Scoping Opinion) stating that several areas of *Sabellaria alveolata* have developed into *Sabellaria* reef. Any likely significant effects on *Sabellaria* reef should be assessed within the ES. The ES should consider potential direct impacts from construction and also the potential impacts from maintenance activities on reef that may colonise the cables during the operational phase.	The potential impacts on Sabellaria reef as a result of the construction, operation and decommissioning phase of the Project are considered in **Chapter 9, Benthic and Intertidal Ecology.**
Planning Inspectorate	It is understood that the type and locations of TEC devices within the offshore area will not be determined by the time of application. As such, the ES should consider a worst-case scenario of habitat loss. When assessing the potential impacts from loss of habitat, the ES should also give consideration to habitat loss resulting from the introduction of any scour and cable protection.	Worst-case scenarios of habitat loss as a result of the construction, operation and decommissioning phase of the Project are considered in **Chapter 9, Benthic and Intertidal Ecology.**
Planning Inspectorate	Potential impacts due to change in sediment regime are included in Table 8-4. However, Table 8-2 identifies potential impacts to benthic ecology interest features of designated marine and coastal sites due to changes in	The likely significant effects on intertidal and subtidal benthic ecology from changes to physical

Consultee	Comment	Response/where addressed in the ES
	coastal processes, sedimentology and hydrodynamic regime in Table 8-2. The ES should assess the likely significant effects on intertidal and subtidal benthic ecology from changes to physical process (e.g. alteration to flow conditions, waves regime and sediment transport pathways).	processes as a result of the construction, operation and decommissioning phase of the Project are considered in **Chapter 9, Benthic and Intertidal Ecology.**
Planning Inspectorate	The ES should assess the likely significant effects from increased turbidity on larvae of fish and shellfish species.	The likely significant effects from increased turbidity on larvae of fish and shellfish species as a result of the construction, operation and decommissioning phase of the Project are considered in **Chapter 10, Fish and Shellfish Ecology.**
Natural Resources Wales	Zone of influence and impact pathway descriptions have not been provided in sufficient detail for scrutiny in the EIA scoping report. We are therefore unable to confirm whether we agree with the impact zone of influence or impact pathways. This presents implications for the advice that can currently be provided with respect to designated sites, cumulative impacts and activities to be scoped out. It is not known at present what devices will be deployed in the demonstration zone area etc therefore it will be important that the zone of influence identifies the maximum environmental impact based on realistic worst-case scenarios. The baseline evidence used to determine the zone of influence will need to be clearly stated in the ES.	The zone of influence approach originally envisaged has subsequently been replaced by hydrodynamic modelling to assess the impacts on the hydrodynamic regime in a quantifiable and rigorous manner.
Natural Resources Wales	Little information is currently provided in the EIA scoping report with regard to cable protection requirements. It is not defined at present where and how much cable protection will be required if the export cables are surface laid on exposed bedrock and protected by rock armour or concrete mattresses. Cable protection could include permanent rock armour protection on the seabed potentially altering current flows near the seabed, inducing sediment scour and potentially altering sediment transport pathways near the coast. Worst-case scenarios for cable protection will need to be assessed in the ES.	The worst-case scenario for cable protection is described in **Section 7.7.6**. The effects of cable protection on baseline conditions are described in **Section 7.7.8**.
Natural Resources Wales	The baseline characterisation work proposed within the EIA scoping report is limited. Clarification is required regarding how the applicant intends to describe the site selection process for the tidal energy devices and grid connection route if detailed hydrodynamic, bathymetric and geophysical investigations are not carried out to provide the necessary baseline evidence. We advise that the applicant should use accurate bathymetry and geophysical survey data of the demonstration zone to inform their decision on the export cable route pathways through the proposed demonstration zone. Sediment samples should also be taken in sediment laden seabed areas to determine sediment type, composition and sediment volume that could potentially be suspended through the cable trenching activities.	The baseline characterisation has been informed by geophysical, subtidal grab sample, intertidal and metocean surveys, as described in **Section 7.5.2**.

Consultee	Comment	Response/where addressed in the ES
Natural Resources Wales	The EIA scoping report suggests that the applicant will not be conducting hydrodynamic investigations of the demonstration zone area. If that is the case, we seek clarification regarding how the applicant intends to assess potential hydrodynamic impacts from the presence of the offshore infrastructure that they are responsible for (i.e. offshore hub, inter array and export cables and associated cable protection) and the tidal energy devices themselves.	In recognition of this comment, hydrodynamic investigations have been undertaken using numerical modelling techniques and geomorphological interpretation of the results to assess the impacts of the Project on the baseline hydrodynamic regime. Description of this numerical modelling process is provided in **Appendix 7.1** (**Volume III**).
Natural Resources Wales	Potential impacts on metocean conditions and coastal processes only includes impacts during the operational phase of the proposed development (see table 7.1). The other phases of the project life (construction and decommissioning) should also be considered within the ES. For example, during the construction phase there could be impacts caused by the cable laying activities, such as alteration to the seabed morphology caused by presence of rock armour protection on the seabed. This could have a significant impact on coastal processes if located across an active sediment transport pathway. There could also be a potential for sediment scour downstream of the structure and alteration of flow near the seabed.	The impact assessment covers not only the construction phase but also the operation and decommissioning phases, as described in **Section 7.7.8** and **7.7.9**.
Natural Resources Wales	Table 7-1 describes the potential impact ‘increased suspended sediment from reduced water energy’. It is unclear how reduced water energy will increase suspended sediment concentrations. Reduced water energy may increase sedimentation of suspended material; is this what is meant?	Noted, further clarification is provided in the assessment of Operational Impacts (**Section 7.7.6**).
Natural Resources Wales	Again, it is unclear how potential impacts relating to metocean conditions and sediment transport, and coastal processes be assessed for impact significance in the EIA without conducting hydrodynamic modelling studies pre and post tidal array/cable installation (see Table 7-1). Without physically measuring or modelling the change in the energy potential downstream of the devices and alteration to the wave directions under different wave conditions, it may not be possible to determine significance and magnitude of impact on the coastal processes.	Modelling has been used to assess the impacts on the hydrodynamic regime and description of this modelling process is provided in **Appendix 7.1** (**Volume III**).
Natural Resources Wales	With reference to Table 7-1 we recommend that consideration should be given in the ES to the alteration of the near bed currents and sediment transport pathways caused by rock armour protection on the seabed, not just the tidal energy devices.	The effects of cable protection have been considered in **Section 7.7.8**.
Natural Resources Wales	Regarding ‘EIA baseline characterisation’ NRW welcome the inclusion of a conceptual model to describe the hydrodynamic and coastal process. A coastal processes conceptual model is a useful way to identify where there are gaps in existing baseline evidence which may then inform the requirement for further metocean data collection through field surveys. At the scoping stage, metocean and	The data sources used to inform the conceptual understanding of the baseline environment are listed in **Section 7.5.2**.

Consultee	Comment	Response/where addressed in the ES
	coastal processes field data collection should not be ruled out (see section 7.1.3).	The baseline environment is described in **Section 7.6**.
Natural Resources Wales	We advise that hydrodynamic modelling to inform the EIA impact assessment should also not be ruled out at the scoping stage until it is confirmed that there is enough baseline evidence to qualify and quantify the EIA impact assessment process for hydrodynamics, sediment transport and coastal processes.	Modelling has been used to assess the impacts on the hydrodynamic regime and description of this modelling process is provided in **Appendix 7.1** (**Volume III**).
Natural Resources Wales	It is recommended that the coastal processes baseline characterisation needs to also include topographical data at the landfall location which may be used to inform any potential impacts on the beach profile and sediment morphology arising from the cable landfall of the export cable from offshore to onshore and the construction of a transition pit.	Morphological and sedimentary characteristics at the landfall have been addressed in **Section 7.6.10**.Geology and Coastal Processes at the Landfall
Natural Resources Wales	Further information is required regarding how the potential impacts to the physical processes caused by the deployment of multiple tidal energy devices will be qualitatively and quantitatively assessed using a non-numerical approach i.e. development of a conceptual model. The physical processes impact assessment is an important assessment as any alteration to the flow conditions, waves regime and sediment transport pathways caused by the presence of the tidal devices and the associated infrastructure will potentially impact on the intertidal and subtidal benthic ecology, water quality and coastal morphodynamics. This in turn could then affect the integrity of the protected sites designated under the Habitats directive and affect the ecological status defined under the Water Framework Directive.	Modelling has been used to assess the impacts on the hydrodynamic regime and description of this modelling process is provided in **Appendix 7.1** (**Volume III**). Hydrodynamic impacts have then been interpreted from the modelling results. Expert assessment has been used elsewhere (e.g. effects on wave regime and sediment transport regime).
Natural Resources Wales	We disagree that the offshore physical processes associated with reduced energy in tidal currents from energy removed by tidal devices should be scoped out from the EIA. It is not clear at this stage what devices will be deployed within the demonstration zone. PTEC are potentially generating 30MW of power whilst the demonstration zone will potentially be generating 240 MW of power. The scale of both projects is very different and ruling out the effects caused by a reduction in energy based on the findings of a much smaller project is not acceptable at this stage.	The potential impacts on the baseline hydrodynamic conditions from the presence of offshore infrastructure are assessed in **Section 7.7.8**. This impacts assessment is informed by numerical modelling which is described in **Appendix 7.1** (**Volume III**).
Natural Resources Wales	There has been no inclusion of tidal current data in the demonstration zone which shows the magnitude and direction of flow over the zone to substantiate the assumption that the suspended sediments would rapidly disperse. We agree that in fast flowing currents, dispersion of suspended sediments could occur rapidly and the potential for smothering would be reduced as a result (see table 7.2). However, there is no baseline evidence presented in the metocean section that supports this assessment of impact. We advise that further evidence is presented to show the magnitude and direction of the tidal currents in the nearshore and intertidal areas which are often much smaller than those experienced offshore, and	The baseline hydrodynamic conditions are assessed in **Section 7.6**. These have been informed by numerical modelling which is described in **Appendix 7.1** (**Volume III**).

Consultee	Comment	Response/where addressed in the ES
	which may not be enough to promote rapid dispersion of suspended sediments and potential contaminants released through trenching activities over this zone.	
Natural Resources Wales	Extreme sea levels can be obtained for this coastline for a range of probability flood events including that of climate change allowances. These extreme sea levels would allow for surge conditions but not wave action. To obtain the levels a request may be made to our data distribution team.	Extreme sea levels are described as part of the baseline environment in **Section 7.6**.
Natural Resources Wales	We welcome the acknowledgement of potential impacts to benthic ecology interest features of designated marine and coastal sites due to changes in coastal processes, sedimentology and hydrodynamic regime in table 8.2. We note, however, that only potential impacts due to change in sediment regime are included in table 8.4 Potential impacts on benthic ecology. We wish to draw the applicant's attention to our comments relating to coastal process aspects of the EIA Scoping Report. Specifically, we would welcome clarity on how the potential impacts to the physical processes caused by the deployment of multiple tidal energy devices and associated infrastructure will be adequately assessed using a nonnumerical (conceptual model) approach, and how this will be applied in the context of potential impacts to intertidal and subtidal benthic ecology, water quality and coastal morphodynamics arising due to physical process impacts (alteration to flow conditions, waves regime and sediment transport pathways).	See **Section 7.7.5** and **Section 7.7.6** for operational impacts. The following chapters have utilised this information to inform the impact assessment sections of those chapters; **Chapter 8, Marine Water and Sediment Quality**, **Chapter 9, Benthic and Intertidal Ecology** as suggested.
Natural Resources Wales	We note that the Offshore Scoping Zone now includes the sea area between the demonstration zone and the shore. Additional multibeam / acoustic survey and benthic ground-truthing will be needed in this area to inform the benthic impact assessment associated with the export cable route from the Lease Area if not already available.	The marine geophysical survey covers all areas of the MDZ, shown in **Figure 7-1** (**Volume II**).

7.4. ASSESSMENT METHODOLOGY

25. To meet the requirements of the guidance documents described in **Section 7.2**, the assessment approach has adopted the following stages:

- Review of existing relevant data and information;
- Acquisition of additional project-specific data to fill any gaps (including additional numerical modelling of effects on the tidal regime);
- Formulation of a conceptual understanding of baseline conditions;
- Consultation and agreement with the regulators regarding proposed assessment approaches;
- Determination of the worst-case scenarios;
- Consideration of embedded mitigation measures; and
- Assessment of effects using data analysis, numerical modelling outputs, and expert-based judgements by Royal HaskoningDHV.

7.4.1. Impact Assessment Methodology

26. As described in **Chapter 5, EIA Methodology**, the assessment of effects on metocean conditions and coastal processes is predicated on a Source-Pathway-Receptor (S-P-R) conceptual model, whereby the source is the initiator event, the pathway is the link between the source and the receptor impacted by the effect, and the receptor is the receiving entity.

27. An example of the S-P-R conceptual model is provided by cable installation which disturbs sediment on the sea bed (source). This sediment is then transported by tidal currents until it settles back to the sea bed (pathway). The deposited sediment could change the composition and elevation of the sea bed (receptor).

28. Consideration of the potential effects of the Project on the metocean conditions and coastal processes is carried out over the following spatial scales:

- Near-field: the area within the immediate vicinity (tens or hundreds of metres) of the Project and along the offshore cable corridor; and
- Far-field: the wider area that might also be affected indirectly by the Project (e.g. due to disruption of waves, tidal currents or sediment pathways).

29. Four main phases of development are considered, in conjunction with the present-day baseline, over the life-cycle of the Project. These are:

- Construction phase;
- Operation and maintenance phase;
- Repowering phase and
- Decommissioning phase.

30. A repowering of a device/array is defined as the end of a berth/array demonstration cycle, at which time the device, device foundations, support structures, electrical hubs, tenant monitoring equipment, and inter-array cabling will be removed, in line with procedures adopted during decommissioning. Once all developer owned assets listed above have been removed, the Project will then have capacity for 'repowering' the berth would then be available for 'repowering' where new devices may be installed to utilise the vacated berth, or be installed at a new berth for further demonstration.

31. For the purposes of this chapter, the effects and impacts of repowering are considered to be the same as assessed for construction and decommissioning.

32. For the effects on metocean conditions and coastal processes, the assessment follows two approaches. The first type of assessment is impacts on metocean conditions and coastal processes whereby several discrete direct receptors are identified. These include certain morphological features with inherent value, such as:

- Offshore sand ridges / sandbanks – these morphological features play an important role in influencing the baseline tidal, wave and sediment transport regimes; and
- Beaches and sea cliffs - these shoreline morphological features play an important natural coastal defence role at the coast and are features which form part of the

designated sites of Holy Island Coast Site of Special Scientific Interest (SSSI)/Special Area of Conservation (SAC), Anglesey Area of Outstanding Natural Beauty (AONB) and Holyhead Mountain Heritage Coast.

33. The impact assessment incorporates a combination of the sensitivity of the receptor, its value (if applicable) and the magnitude of the change to determine a significance of impact. **Chapter 5, EIA Methodology** provides an overview of this approach to the assessment of impacts.

34. In addition to identifiable receptors, the second type of assessment covers changes to metocean conditions and coastal processes which in themselves are not necessarily impacts to which significance can be ascribed. Rather, these changes (such as a change in the wave climate, a change in the tidal regime or a change in suspended sediment concentrations) represent effects which may manifest themselves as impacts upon other receptors, most notably marine sediment and water quality, benthic ecology, and fish and shellfish ecology (e.g. in terms of increased suspended sediment concentrations, or erosion or smothering of habitats on the sea bed).

35. Hence, the two approaches to the assessment of metocean conditions and coastal processes are:

- Situations where potential impacts can be defined as directly affecting receptors which possess their own intrinsic morphological value. In this case, the significance of the impact is based on an assessment of the sensitivity of the receptor and magnitude of effect at the receptor location, taking into the near-field or far-field nature of the effect from the receptor. An impact significance matrix is used as a guide to determine the impact significance; and
- Situations where effects (or changes) in the baseline metocean conditions and coastal processes may occur which could manifest as impacts upon receptors other than metocean conditions and coastal processes. In this case, the magnitude of effect is determined in a similar manner to the first assessment method but the significance of impacts on other receptors is made within the relevant chapters of the ES pertaining to those receptors.

7.4.1.1. Sensitivity, Value and Magnitude

36. The sensitivity of a receptor is dependent upon its:

- *Tolerance* to an effect (the extent to which the receptor is adversely affected by an effect);
- *Adaptability* (the ability of the receptor to avoid adverse impacts that would otherwise arise from an effect); and
- *Recoverability* (a measure of a receptor’s ability to return to a state at, or close to, that which existed before the effect caused a change).

37. In addition, a value component may also be considered when assessing a receptor. This ascribes whether the receptor is rare, protected or threatened.

38. The magnitude of an effect is dependent upon its:

- Scale (i.e. size, extent or intensity);
- Duration;
- Frequency of occurrence; and
- Reversibility (i.e. the capability of the environment to return to a condition equivalent to the baseline after the effect ceases).

39. The sensitivity and value of discrete morphological receptors and the magnitude of effect are assessed using expert judgement and described with a standard semantic scale. Definitions for each term are provided in **Table 7-4**, **Table 7-5** and **Table 7-6**. These expert judgements of receptor sensitivity, value and magnitude of effect are guided by the conceptual understanding of baseline conditions.

Table 7-4 Definitions of Sensitivity Levels for a Morphological Receptor

Sensitivity	Definition
High	Tolerance: Receptor has very limited tolerance of effect. Adaptability: Receptor unable to adapt to effect. Recoverability: Receptor unable to recover resulting in permanent or long-term (greater than ten years) change.
Medium	Tolerance: Receptor has limited tolerance of effect. Adaptability: Receptor has limited ability to adapt to effect. Recoverability: Receptor able to recover to an acceptable status over the medium term (5-10 years).
Low	Tolerance: Receptor has some tolerance of effect. Adaptability: Receptor has some ability to adapt to effect. Recoverability: Receptor able to recover to an acceptable status over the short term (1-5 years).
Negligible	Tolerance: Receptor generally tolerant of effect. Adaptability: Receptor can completely adapt to effect with no detectable changes. Recoverability: Receptor able to recover to an acceptable status near instantaneously (less than one year).

Table 7-5 Definitions of the Different Value Levels for a Morphological Receptor

Value	Definition
High	Value: Receptor is designated and/or of national or international importance for marine geology, oceanography and physical processes. Likely to be rare with minimal potential for substitution. May also be of significant wider-scale, functional or strategic importance.
Medium	Value: Receptor is not designated but is of local to regional importance for marine geology, oceanography and physical processes.
Low	Value: Receptor is not designated but is of local importance for marine geology, oceanography and physical processes.
Negligible	Value: Receptor is not designated and is not deemed of importance for marine geology, oceanography and physical processes.

Table 7-6 Definitions of Magnitude of Effect Levels for Metocean Conditions and Coastal Processes

Magnitude	Definition
High	Scale: A change which would extend beyond the natural variations in background conditions. Duration: Change persists for more than ten years. Frequency: The effect would always occur. Reversibility: The effect is irreversible.
Medium	Scale: A change which would be noticeable from monitoring but remains within the range of natural variations in background conditions. Duration: Change persists for 5-10 years. Frequency: The effect would occur regularly but not all the time. Reversibility: The effect is very slowly reversible (5-10 years).
Low	Scale: A change which would barely be noticeable from monitoring and is small compared to natural variations in background conditions. Duration: Change persists for 1-5 years. Frequency: The effect would occur occasionally but not all the time. Reversibility: The effect is slowly reversible (1-5 years).
Negligible	Scale: A change which would not be noticeable from monitoring and is extremely small compared to natural variations in background conditions. Duration: Change persists for less than one year. Frequency: The effect would occur highly infrequently. Reversibility: The effect is quickly reversible (less than one year).

7.4.1.2. Impact Significance

40. Following the identification of receptor sensitivity and value, and magnitude of effect, it is possible to determine the significance of the impact. A matrix is presented in **Table 7-7** as a framework to guide how a judgement of the significance is determined.

Table 7-7 Impact Significance Matrix

		Negative Magnitude				**Beneficial Magnitude**			
		High	Medium	Low	Negligible	Negligible	Low	Medium	High
Sensitivity	High	Major	Major	Moderate	Minor	Minor	Moderate	Major	Major
	Medium	Major	Moderate	Minor	Minor	Minor	Minor	Moderate	Major
	Low	Moderate	Minor	Minor	Negligible	Negligible	Minor	Minor	Moderate
	Negligible	Minor	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Minor

41. Through use of the matrix shown in **Table 7-7,** an assessment of the significance of an impact can be made in accordance with the definitions in **Table 7-8**.

Table 7-8 Impact Significance Definitions

Impact Significance	Definition
Major	Very large or large change in receptor condition, both adverse or beneficial, which are likely to be important considerations at a regional or district level because they contribute to achieving national, regional or local objectives, or, could result in exceedance of statutory objectives and / or breaches of legislation.

Impact Significance	Definition
Moderate	Intermediate change in receptor condition, which is likely to be an important consideration at a local level.
Minor	Small change in receptor condition, which may be raised as a local issue but is unlikely to be important in the decision-making process.
Negligible	No discernible change in receptor condition.

42. For the purposes of this ES, 'major' and 'moderate' impacts are deemed to be significant (in EIA terms). In addition, whilst 'minor' impacts may not be significant, it is important to distinguish these from other non-significant (negligible) impacts as they may contribute to significant impacts cumulatively.

7.4.1.3. Cumulative Impact Assessment

43. Cumulative impacts are assessed through consideration of the extent of influence of changes to metocean conditions and coastal processes arising from the Project alone and those arising from the Project cumulatively or in combination with other developments including the Deep Green (DG) Holyhead Deep Project Phase 1 (0.5) and DG Holyhead Deep Array Project.

7.5. SCOPE

7.5.1. Study Area

44. The MDZ is in the eastern Irish Sea, encompassing a sea bed area of approximately 35 km^2 and an export cable corridor of 4.75 km^2 (plus an intertidal area of 0.01 km^2), totalling an area of 39.76 km^2 for the Offshore Development Area (OfDA). Its nearest point is located approximately 0.5 km from the west coast of Anglesey. Offshore cables connect Project across an offshore cable corridor to the east of the MDZ and then to the landfall near Penrhos Feilw (**Figure 1-1, Volume II**).

7.5.2. Data Sources

45. Information to support this chapter of the ES has come from several sources (**Table 7-9**).

Table 7-9 Data Sources

Data	Year	Coverage	Confidence	Notes
Geophysical Survey	2018	MDZ, buffer zone and Abraham's Bosom	High	High-resolution sea bed bathymetry, seabed texture and morphological features, and shallow geology using multibeam echosounder, side-scan sonar, and boomer (Partrac, 2018).
Subtidal Grab Sample Survey	2018	MDZ and buffer zone	High	Drop-down camera and five grab samples at selected suitable sites (Ocean Ecology, 2018).
Intertidal Survey	2018	Abraham's Bosom	High	Unmanned Aerial Vehicle (UAV) survey and intertidal walkover (Ocean Ecology, 2018).
Metocean Survey	2014	MDZ	High	Bottom-mounted Acoustic Doppler Current Profilers (ADCP) deployed for a continuous 40-day period in November and December 2014 at two locations.

46. A geophysical survey of the MDZ (plus a 1 km buffer zone to the -10 m Chart Datum (CD) contour around it) was completed between 22nd April 2018 and 19th May 2018 (Partrac, 2018) (**Table 7-9**). Survey lines were completed at 125 m spacing for most of the site with a bearing of 24 ° (tidal flow direction) (**Figure 7-1, Volume II**).

47. In the nearshore zone, the line spacing was decreased to between 30 m and 50 m. Where vessel safety allowed, the survey was extended up to the -5 m CD contour, along the western coast, except for within the bay approaching the landfall known as Abraham's Bosom. The shallow water in this bay was mapped to the 0 m CD contour or as far inshore as possible without compromising vessel safety. Five cross lines were completed at suitable locations to 'tie together' the main lines.

48. Ocean Ecology (2018) also completed an intertidal survey around the proposed cable landfall in Abraham's Bosom (**Table 7-9**) (**Figure 7-2, Volume II**). The area was flown on 30th August 2018 at low spring tide using a UAV to capture high-resolution aerial imagery that was subsequently used to create an ortho-mosaic map of key habitats (**Figure 7-2, Volume II**). The remote sensing was followed by an intertidal walkover survey on 14th September 2018.

Table 7-10 Location of Grab Samples and Drop-Down Camera Stills (Ocean Ecology, 2018) (corresponding to Figure 7-2, Volume II)

Location	Grab Samples	Drop-down Camera
Demonstration Zone	Location 41	Location 33
Buffer Zone	Locations 15 and 20	Location 6
Abraham's Bosom	Location 42	Location 3

49. A metocean survey was undertaken between November and December 2014 by Partrac and provided to Mentor Môn (courtesy of OpenHydro). This involved the deployment of ADCPs at two locations in the MDZ. Site 1 was in approximately 37 m water depth and Site 2 in approximately 35 m water depth. Water level and tidal current velocity were measured over a continuous 40-day period, covering three spring tides and two neap tides.

50. In addition to the new data collection, a range of information sources is available, including:

- Marine Renewable Atlas (BERR, 2008);
- National Tide and Sea Level Facility (British Oceanographic Data Centre);
- Extreme sea levels database (Environment Agency, 2015);
- United Kingdom Hydrographic Office (UKHO) tidal diamonds;
- National Oceanographic Laboratory Class A tide gauges;
- United Kingdom Climate Projections 2018 (UKCP18);
- British Geological Survey 1:250,000 sea bed sediment mapping; and
- Admiralty Charts and United Kingdom Hydrographic Office survey data.

7.6. EXISTING ENVIRONMENT

7.6.1. Bathymetry

51. Water depths across the MDZ and export cable corridor vary between approximately -2 m CD at the landfall and 72 m CD in the northwest part of the MDZ (**Figure 7-1, Volume II**) (Partrac, 2018). The average depth across the MDZ is approximately 40 m.

52. Most of the sea bed comprises large areas of outcropping bedrock with minimal relief above surrounding bed levels (**Figure 7-3, Volume II**). Secondary bathymetric features include a large, generally symmetric, sand ridge north of South Stack which extends to the northwest for approximately 1 km (within the offshore cable corridor) (**Plate 7-1**). The crest of the ridge is about 8 m to 10 m higher than the surrounding sea bed. Several smaller ridges oriented parallel to the main ridge occur to its north-northeast.

53. Within Abraham's Bosom (a bay towards the landfall), the bathymetry is smoother, representing the surface of an area of sediment on top of the bedrock, bounded by rock outcrops to the north and south.

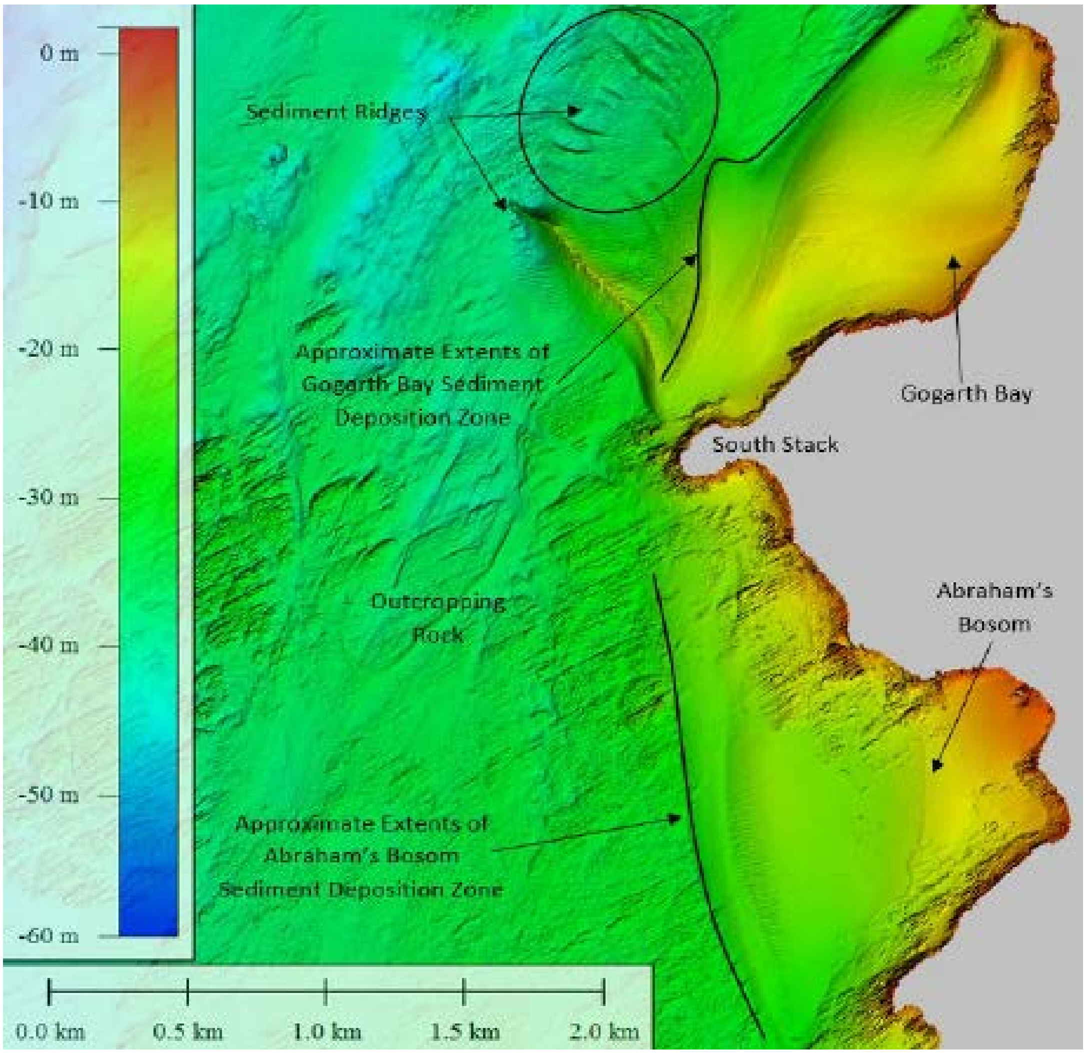

Plate 7-1 Bathymetric Features Close to Shore Within the Offshore Cable Corridor (Partrac, 2018)

54. At a more local scale the sea bed is uneven due to the presence of bedforms of various sizes. Megaripples occur close to Abraham's Bosom within the offshore cable corridor. They are up to 0.6 m high, up to 12.8 m wavelength, with crests oriented approximately west-east, indicative of north-south tidal currents (**Plate 7-2**). Larger fields of megaripples occur in the south and southwest parts of the MDZ, where they are up to 0.6 m high, up to 12.9 m wavelength, with crests oriented approximately west-east.

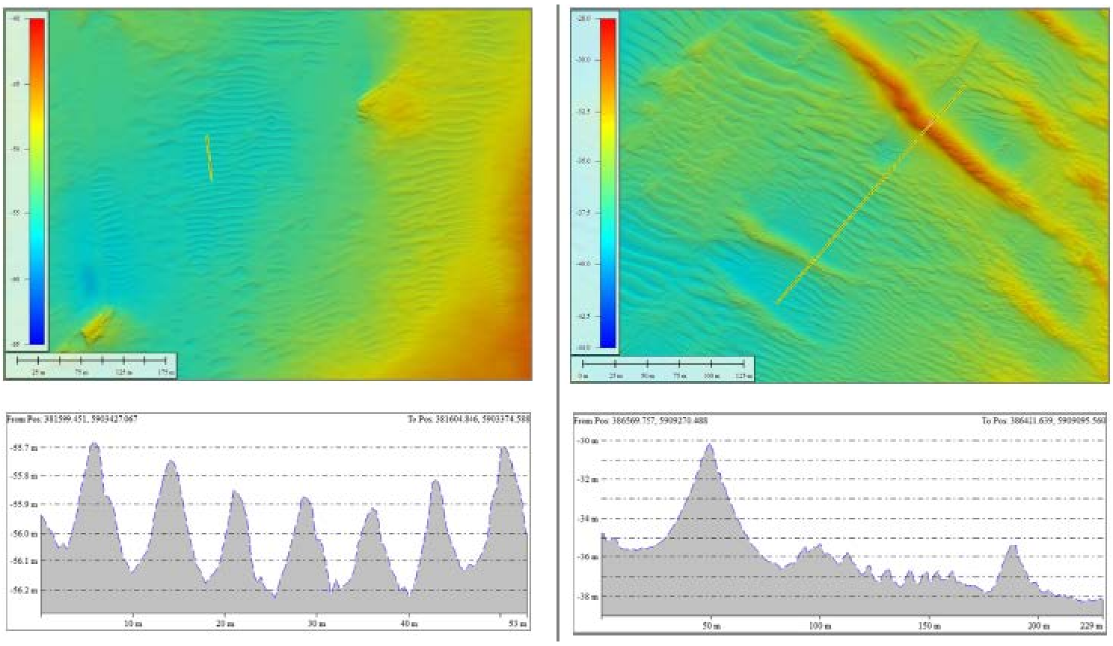

Plate 7-2 Examples of Megaripples in Deeper (left) and Shallower (right) Water

7.6.2. Offshore Geology

55. The geology of the MDZ is dominated by bedrock at, or very close to, the surface, which was not differentiated by Partrac (2018). However, it was postulated that it forms part of the Mona Complex that is exposed across Anglesey, and Holy Island specifically. The bedrock is covered with a sediment veneer composed of gravel and boulders ranging in size from 0.2 m to 1.5 m.

56. Across the west and southwest parts of the MDZ, the bedrock surface dips beneath the sea bed and is covered by undifferentiated 'overburden' (possibly glacial diamicton), up to 29 m thick in the southwest and up to 14 m in the west (**Plate 7-3**). Towards the shoreline and approaching Abraham's Bosom bay, bedrock is overlain by up to 7 m of sediment and then 2 – 4 m of sediment within the bay itself (likely to be mainly sand) (**Plate 7-4**).

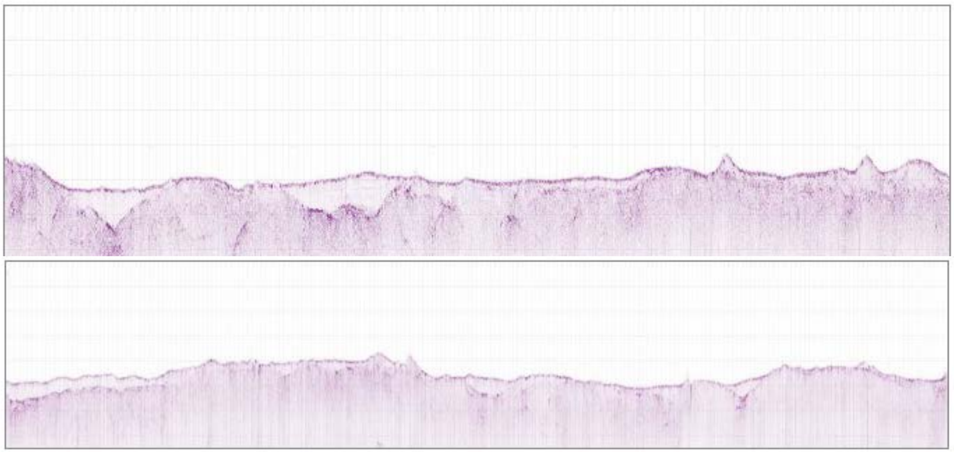

Plate 7-3 Example North-South Aligned Western MDZ and Buffer Zone Sub-Bottom Profiles Showing Overburden on Top of Bedrock (Partrac, 2018)

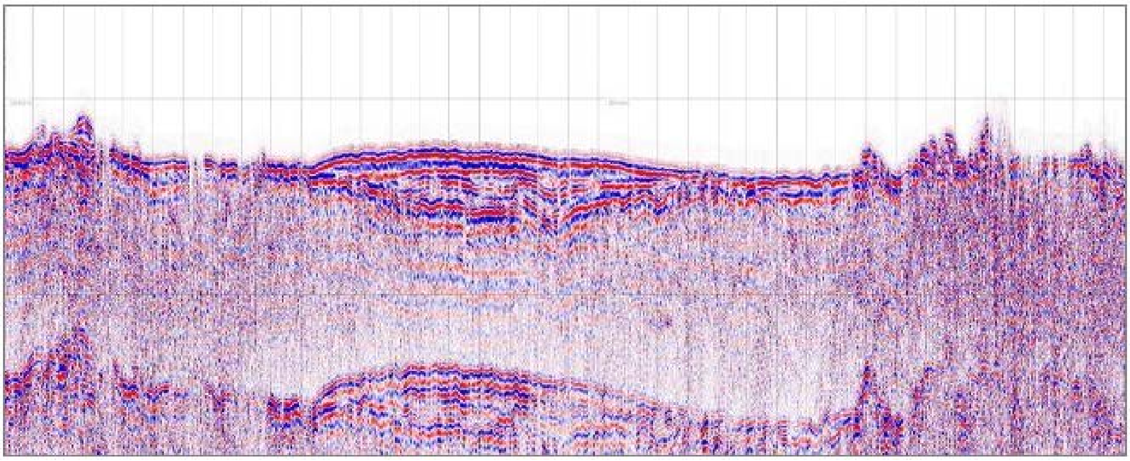

Plate 7-4 Example South (left of the image) to North (right of the image) Sub-Bottom Profile Across the Entrance to Abraham's Bosom Showing Deposition on Top of Bedrock (Partrac, 2018)

7.6.3. Tidal Water Levels

57. Tidal water levels within the MDZ are characterised by the ADCP surveys from Sites 1 and 2 in **Figure 7-4** (**Volume II**) which describe a typical spring tidal range of around 4.5 m and a typical neap tidal range of around 3.0 m (**Plate 7-5**).

58. Tidal water levels at the landfall are best represented by tidal data from the standard port of Holyhead, which are shown in **Table 7-11**. This shows a typical spring tidal range of around 4.9 m and a typical neap tidal range of around 2.4 m.

Table 7-11 Tidal Levels at Holyhead (source: Admiralty Tide Tables 2019)

Parameter	Water Level (m CD)	Water Level (m ODN)
Lowest astronomical tide (LAT)	0.00	-3.05
Mean low water springs (MLWS)	0.70	-2.35
Mean low water neaps (MLWN)	2.00	-1.05
Mean sea level (MSL)	3.30	0.25

Parameter	Water Level (m CD)	Water Level (m ODN)
Mean high water neaps (MHWN)	4.40	1.35
Mean high water springs (MHWS)	5.60	2.55
Highest astronomical tide (HAT)	6.30	3.25

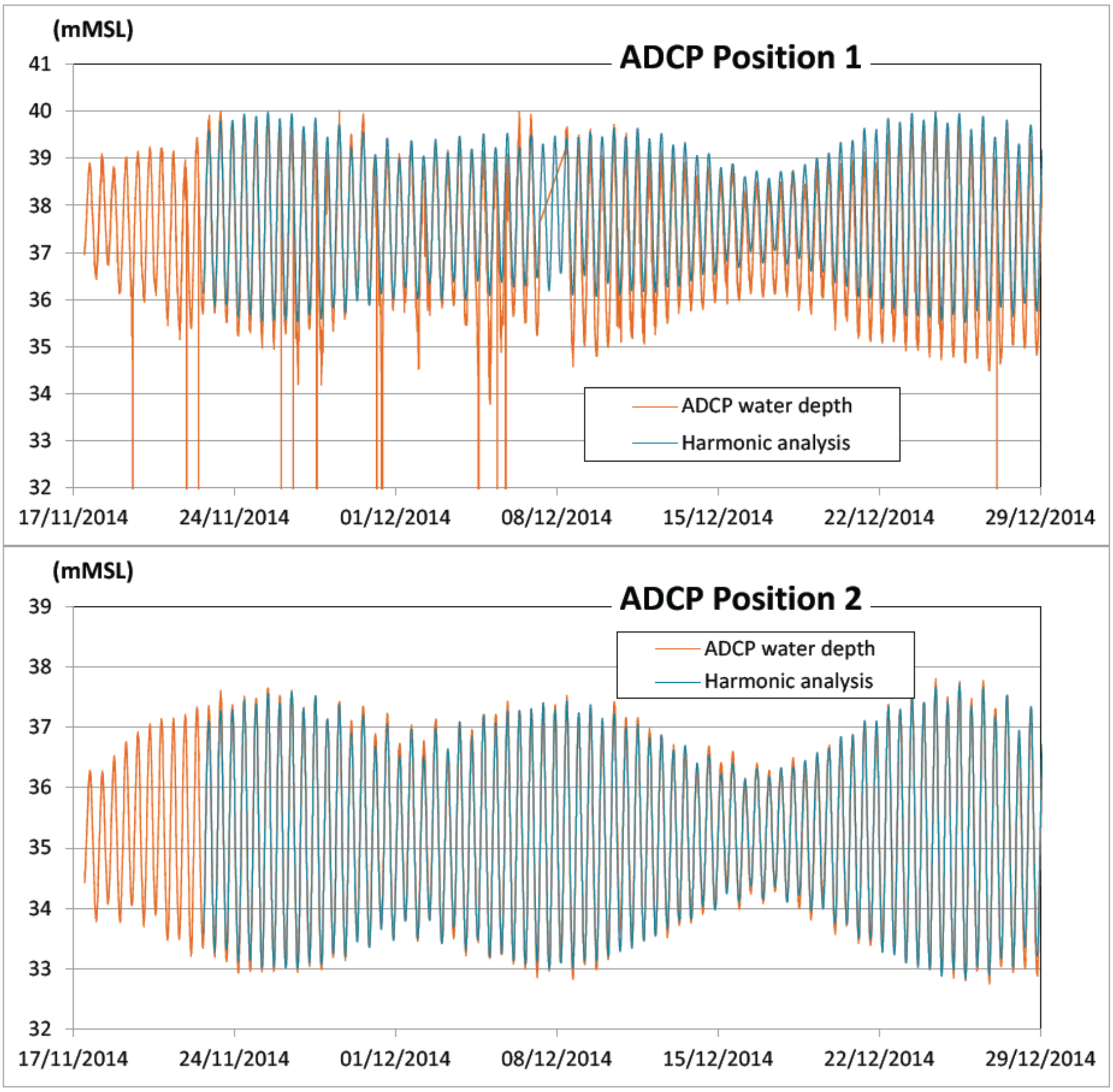

Plate 7-5 Tidal Levels at Sites 1 and 2 within the MDZ (source: HR Wallingford 2017)

7.6.3.1. Storm Surge

59. The tidal water levels described above are astronomically driven and thus are regular and predictable, but these can be elevated or supressed by meteorological events, such as storms and surges. **Table 7-12** presents the extreme sea levels that can be attained at Holyhead for different return period events due to these surge effects. The tidal currents can also become enhanced by positive storm surges, and these effects are implicit within measured tidal current data in the following section.

Table 7-12 Extreme Sea Levels at Holyhead (source: McMillan *et al.*, 2011)

Return Period of Surge Event	Level (m CD)	Level (m ODN)
1 in 1 year	0.31	3.36

Return Period of Surge Event	Level (m CD)	Level (m ODN)
1 in 10 years	0.56	3.61
1 in 50 years	0.72	3.77
1 in 100 years	0.78	3.83
1 in 200 years	0.84	3.89

7.6.4. Tidal Currents

60. Tidal currents within part of the MDZ are characterised by the ADCP surveys from Sites 1 and 2 (**Table 7-13**). These data show that current velocities at the measurement locations are slightly lower towards the sea bed due to bed-friction, but all values recorded exhibit very high baseline current speeds.

Table 7-13 Peak Tidal Currents at Sites 1 and 2 within the MDZ (source: OpenHydro, 2015)

Height above sea bed	Peak Velocities on a Mean Spring Tide Site 1 (m/s)	Peak Velocities on a Mean Spring Tide Site 2 (m/s)
10 m	2.71	2.64
15 m	2.84	2.79
20 m	2.92	2.90

61. The current roses shown in **Figure 7-4** (**Volume II**) **Plate 7-2** indicate that at both Sites 1 and 2, the baseline current velocities are strongly aligned from just east of south to north-northwest. However, further north in the MDZ, the tidal currents flow around Holy Island (to the north on a flooding tide and to the south on an ebbing tide) along a more south-north and then (with progression north) south-southwest-north-northeast axis.

62. Tidal current speeds and directions were predicted by the baseline numerical modelling undertaken by HR Wallingford (2017). **Figure 7-5** (**Volume II**) shows the peak depth-averaged flow velocities for a mean spring tide. Peak speeds are generally faster through the eastern parts of the subzones, reaching around 2.6 – 2.8 m/s in most areas, apart from the northernmost and southernmost subzones. The highest velocities within the MDZ are recorded just off Holy Island (4.0 m/s). For the western parts of the subzones, peak speeds are lower, reaching around 2.2 – 2.6 m/s.

7.6.5. Waves

63. Given the semi-enclosed nature of the Irish Sea, most oceanic swell waves are prevented from reaching the Anglesey coastline through St George's Channel and from the north due to the shelter provided by the Isle of Man. As a result, waves arriving at the Anglesey coastline are predominantly wind generated within the Irish Sea (Royal HaskoningDHV, 2011). The fetch between Ireland and Wales is generally less than 100 km, limiting the height that waves can grow from the west. The largest fetch originates from a southwest direction, where the fetch can reach thousands of kilometres into the Atlantic Ocean.

64. Wave exposure at Holy Island is extremely variable owing to the range of coastline orientations. Most of the Anglesey coast is west facing and dominant offshore waves arrive as swell waves travelling up the Irish Sea from the south-southwest and southwest. Exposure to waves

increases towards Holy Island due to decreasing shelter provided by the Llyn Peninsula. Towards the north of the Anglesey coast, offshore waves arrive predominantly from the west and occasionally from the north to northeast.

65. The wave regime was characterised using data obtained from the Met Office at three locations northwest of the MDZ (**Figure 7-6, Volume II**). Results show the dominant offshore wave direction for all three locations is south-southwest to southwest. The wave rose from the most western point offshore (A) also shows waves from a northerly and southerly direction occurring relatively frequently. Moving eastward (B and C), these waves become less frequent due to the shelter provided by Wales to the south and the Isle of Man to the north.

66. Annual mean significant wave height (SWH) for the area is 1.26 – 1.50 m, ranging from 0.76 – 1.00 m in the summer to 1.51 – 1.75 m in the winter (ABPmer, 2008).

7.6.6. Climate Change

67. Historical data show that the global temperature has risen significantly due to anthropogenic influences since the beginning of the 20th century, and predictions are for an accelerated rise, the magnitude of which is dependent on the magnitude of future emissions of greenhouse gases and aerosols.

68. As a result of future global warming, sea-level is predicted to rise at accelerated rates. The latest available science of projected sea-level rise is available from the UK Climate Projections 2018 (UKCP18). **Table 7-14** presents projections of sea level rise to 2050 (relative to 2018) under three Representative Concentration Pathways (RCPs) (Met Office, 2018).

Table 7-14 Sea level Rise Projections to 2050 with 5th, 50th and 95th Percentile Confidence Intervals (Met Office, 2018)

Representative Concentration Pathway (RCP)	Year	UKCP18 projected increase in sea level (m relative to 2018 values)		
		5th percentile	50th percentile	95th percentile
RCP 2.6	2050	0.071	0.117	0.180
RCP 4.5	2050	0.084	0.132	0.201
RCP 8.5	2050	0.108	0.168	0.246

69. As the indicative design life of the Project is 37 years, and both onshore and offshore infrastructure is set far enough from the coast, the projected increases in sea level to 2050 will not change significantly through the design life of the Project.

70. Climate change will also affect extreme sea levels. **Table 7-15** presents projections of sea level rise to 2050 (relative to 2018) under three RCPs (Met Office, 2018).

71. Different methods were used for analysis of present-day extreme water levels and future projections under UKCP18, and the former is currently being updated by the Environment Agency with a scheduled release for the update in 2019. It is notable that the three projections of future extreme sea levels do not show marked increases relative to each other and the effects over the life of the development are modest and can be adequately accounted for in design.

Table 7-15 Extreme Sea Levels at Holyhead (source: McMillan *et al.*, 2011)

	Extreme Sea Level (mODN)			
Return Period of Surge Event	**Present Day (2018(**	**2050 (RCP2.6) (50 percentile)**	**2050 (RCP4.5) (50 percentile)**	**2050 (RCP8.5) (50 percentile)**
1 in 1 year	3.36	3.48	3.50	3.53
1 in 10 years	3.61	3.74	3.75	3.79
1 in 50 years	3.77	3.91	3.92	3.96
1 in 100 years	3.83	3.99	4.00	4.03
1 in 200 years	3.89	4.06	4.07	4.11

73. With respect to waves, climate projections from UKCP18 indicate that at Holyhead mean significant wave heights will decrease under all but one modelled scenario by between 0 – 20 % by 2100 (although under one scenario they could increase by up to 30 %). Annual maximum wave heights at Holyhead could increase or decrease by up to 20 % by 2100 depending on modelled scenario (Palmer *et al*., 2018). These results demonstrate the uncertainty inherent in projecting changes in future wave climate associated with climate change.

7.6.7. Sea Bed Sediment Distribution

7.6.7.1. MDZ

74. Partrac (2018) used side-scan sonar to provide a general overview of the sea bed sediment distribution across the MDZ. Throughout most of the northern, central and eastern parts of the MDZ the sea bed is dominated by outcropping bedrock with thin patches of sandy gravel, whereas the deeper western part comprises relatively uniform gravel or gravelly sand.

75. Only one sea bed sediment sample (location 41) was recovered from the MDZ, on its eastern boundary, northwest of South Stack (Ocean Ecology, 2018). Two samples were collected in the buffer zone, one north of South Stack (location 15) and one to the south of the MDZ (location 20). The particle size characteristics of these three samples are presented in **Plate 7-6** and **Table 7-16**. The dominant sediment type in sample 41 is gravel (73 %) with 27 % sand, with a median particle size of about 3.8 mm. In samples 15 and 20, the dominant component is sand (89-93 %) with a median particle size of 0.63 mm and 0.75 mm (both coarse sand).

Table 7-16 Particle Size Characteristics of Sea Bed Sediment Samples in the MDZ and Buffer Zone. Data from Ocean Ecology (2018)

Station	Gravel (%)	Sand (%)	Mud (%)	d_{50} (mm)
41	73	27	0	3.8
15	9	89	2	0.63
20	7	93	0	0.75

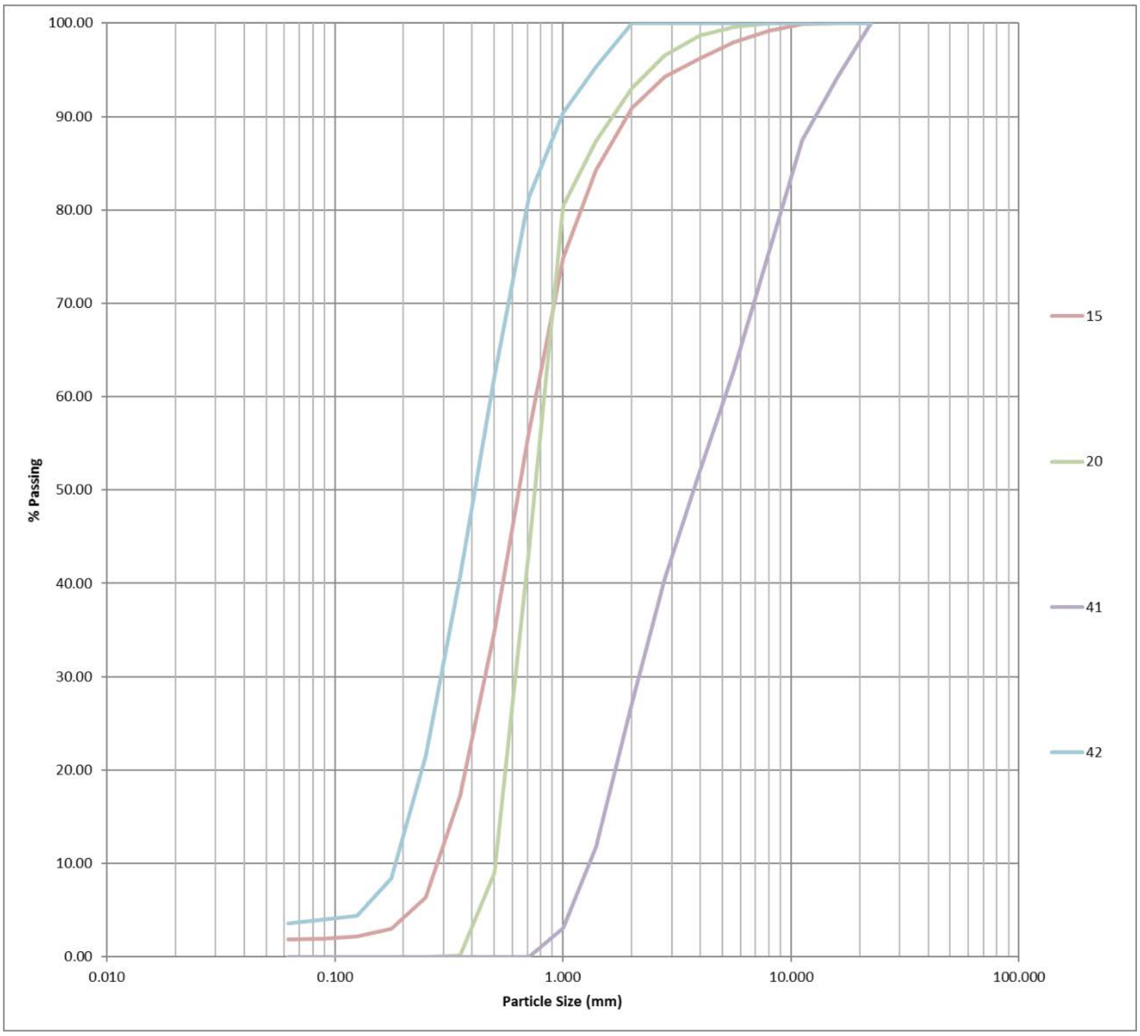

Plate 7-6 Cumulative Particle Size Distribution Curves for the Four Seabed Sediment Samples. Data from Ocean Ecology (2018)

7.6.7.2. Export Cable Corridor

76. One sample (42) was collected along the landward part of the offshore cable corridor in Abraham's Bosom (Ocean Ecology, 2018). The particle size characteristics of this sample is presented in **Plate 7-6** and **Table 7-17**. The dominant sediment size is sand (96 %) with a median particle size of about 0.41 mm (medium sand). This sample falls within the Abraham's Bosom sediment deposition zone identified by Partrac (2018) (**Plate 7-1**).

Table 7-17 Particle Size Characteristics of the Sea Bed Sediment Sample in the Offshore Cable Corridor. Data from Ocean Ecology (2018)

Station	Gravel (%)	Sand (%)	Mud (%)	d_{50} (mm)
42	0	96	4	0.41

7.6.8. Bedload Sediment Transport

77. Sediment transport pathways within the MDZ and across the offshore cable corridor have been analysed using the orientation and asymmetry of bedforms. The orientation of sand ridges and megaripples indicate that gross sediment transport is to the north and south to the south of South Stack and then bends to the northeast and southwest to the north of South Stack. The

size and shape of the bedforms makes it difficult to determine a long-term net transport direction as they are generally symmetric and change their geometry on different states of the tide (Partrac, 2018).

78. Previous studies show that regional sediment transport is north to northeast (BGS, 2005). Littoral drift is very weak because of shoaling within bays and diffraction around headlands along the Anglesey coastline and so sediment is contained within pockets between headlands (Royal HaskoningDHV, 2011). If longshore currents exist, they usually decrease as they transport sediment towards one side of the bay, as the beach rotates to face incoming waves (Royal HaskoningDHV, 2011).

7.6.9. Suspended Sediment Transport

79. Measurements of suspended sediment concentration were carried out generally across the Irish Sea during June and November 1997, and April and September 1998 at a total of 85 stations. Overall, suspended sediment concentrations were between 2.55 and 23 mg/l over the period (**Table 7-18**), although concentrations varied seasonally (Bowers *et al*., 2002).

Table 7-18 Concentration of Total Suspended Solids (mg/l) in the Irish Sea 1997 - 1998

	Min	**Max**	**Mean**
June 1997, 16 stations	3.73	14.18	6.57
November 1997, 17 stations	2.55	20.38	9.82
April 1998, 26 stations	3.30	23.00	10.27
September 1998, 26 stations	2.76	17.18	5.70

80. More specific to the sea bed off Anglesey, several authors have described an Anglesey Turbidity Maximum (ATM) based on observations from space (Simpson and Brown, 1987; Weeks and Simpson, 1991; Bowers *et al*., 1998) and ships (Mitchelson, 1984; Weeks, 1989, Bowers *et al*., 2002). This is an isolated area of enhanced turbidity that is geographically fixed and present all year, although more strongly marked in winter.

81. The position of the maximum coincides with the area of high tidal currents off the northwest coast of Anglesey and its continued presence has been described as “a puzzle” (Bowers *et al*., 2005). Indeed, the phenomenon is not easy reproduced by models and there is no obvious source of sediment, since the local (and surrounding) sea bed is largely comprised of bare rock with occasional boulders. Despite being defined by authors as a “turbidity maximum”, it is only defined in this context because suspended sediment concentrations are of the order of 2 – 3 times those of the surrounding sea bed (i.e. it is a maximum *relative* to surrounding areas). In *absolute* terms, suspended sediment concentrations remain very low, reaching about 5 mg/l in summer and 10 – 15 mg/l in winter. Beyond the ATM, background suspended sediment concentrations are about 3 – 4 mg/l (Ellis *et al*., 2008).

7.6.10. Geology and Coastal Processes at the Landfall

82. The geology of the landfall comprises steep cliffs and shore platforms composed of bedded turbiditic sandstones and mudstones of the Cambrian-Ordovician South Stack Formation (of the Holy Island Group) overlain by a thin layer Quaternary diamicton (**Plate 7-7**). The bay is studded

with very small pocket beaches in enclosed sub-bays composed of shingle and occasional areas of sand (Ocean Ecology, 2018) (**Plate 7-8**).

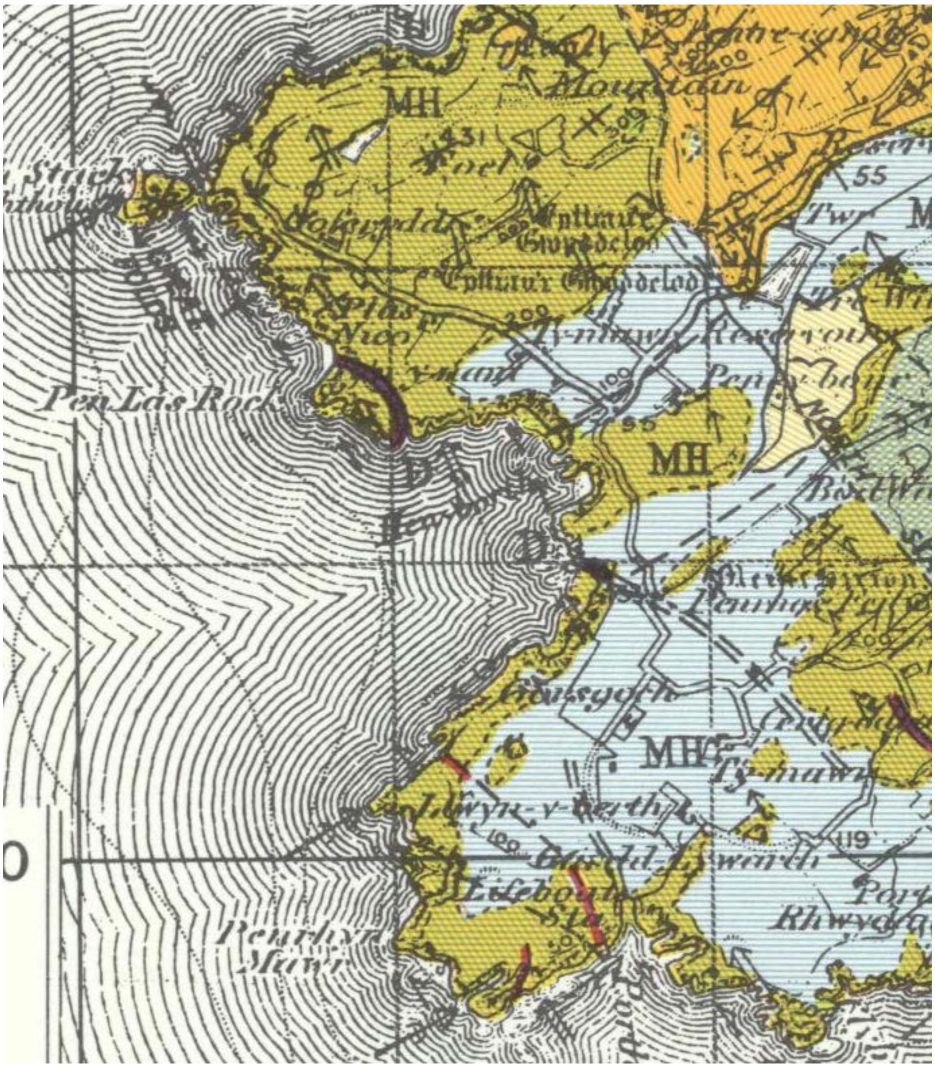

Plate 7-7 Bedrock and Quaternary Geology of the Landfall (British Geological Survey, 1974)

Plate 7-8 Photos of the cable landfall point at Abraham's Bosom (Partrac, 2018)

83. Although the west coast of Holy Island is exposed to significant wave action from the southwest, the strength of the cliffs (Cambrian-Ordovician rocks) at the landfall means that they are subject to only minor erosion.

7.7. POTENTIAL IMPACTS AND EFFECTS

7.7.1. Impact Receptors

84. The principal receptors with respect to metocean conditions and coastal processes are those features with an inherent geological or geomorphological value or function which may potentially be affected by the Project. Protected sites that could be potentially impacted by the Project include national SSSIs which underpin international SACs and Special Protection Areas (SPAs) along the coast of Holy Island. The Holy Island coast is also a Heritage Coast and part of the larger Anglesey AONB. No marine designations are within the boundaries of the Project or within a metocean or coastal processes impact pathway.

85. The potential impacts on metocean conditions and coastal processes are considered for three receptors. The specific features defined within these receptors as requiring assessment are listed in **Table 7-19** and shown in **Figure 7-7** (**Volume II**).

Table 7-19 Metocean and Coastal Processes Receptors Relevant to the Project

Receptor (Plate 7-1)	Extent of coverage	Description of features	Distance from the Project
Holy Island Coast SSSI / SAC	Holyhead West Breakwater to Cymyran Bay	Vegetated sea cliffs	Designation covers cable landfall point
Anglesey AONB	Holyhead Mountain to Cymyran Bay	Cliffs, coves and gravel beaches	Designation covers cable landfall point
Holyhead Mountain Heritage Coast	Holyhead Mountain to Cymyran Bay	Cliffs, coves and gravel beaches	Designation covers cable landfall point

86. This section assesses the significance of potential impacts on the wave and/or current and/or sediment transport regimes on the receptor groups.

7.7.1.1. Holy Island Coast SSSI / SAC

87. The west coast of Holy Island including the landfall is composed of rock cliffs which support important examples of coastal cliff heathland vegetation. In addition to maritime heath, there are extensive maritime cliff-crevice and grassland communities.

7.7.1.2. Anglesey AONB

88. The main features of the Anglesey AONB are undeveloped cliffs (including North and South Stack) alternating with coves and gravel beaches (many within Abraham’s Bosom bay and the landfall).

7.7.1.3. Holyhead Mountain Heritage Coast

89. The AONB designation is supported by the non-statutory designation of the Holyhead Mountain Heritage Coast.

7.7.2. Effects

90. In addition to the receptor groups listed in **Table 7-19** there are other potential changes (effects) to metocean conditions and coastal processes associated with the Project which may manifest themselves as impacts upon a wider grouping of receptors. These include marine sediment and water quality, benthic and intertidal ecology, fish and shellfish ecology, offshore archaeology and commercial fisheries.

91. In respect of these effects, the assessment only defines the magnitude of change in metocean conditions or coastal processes. The assessments of the significance of impacts arising from these effects or changes on other receptors are made within the relevant chapters of this ES pertaining directly to those receptor types (**Chapter 8, Marine Water and Sediment Quality**, **Chapter 9, Benthic and Intertidal Ecology**, **Chapter 10, Fish and Shellfish Ecology**, **Chapter 13, Offshore Archaeology** and **Chapter 14, Commercial Fisheries**).

7.7.3. Mitigation Measures

7.7.3.1. Embedded Mitigation

92. Menter Môn has committed to several techniques and engineering designs/modifications inherent as part of the Project, during the pre-application phase, in order to avoid a number of impacts or reduce impacts as far as possible. Embedding mitigation into the project design is a type of primary mitigation and is an inherent aspect of the EIA process.

93. A range of different information sources has been considered as part of embedding mitigation into the design of the Project including engineering preference, ongoing discussions with stakeholders and regulators, commercial considerations and environmental best practice.

94. The embedded mitigation relevant to metocean conditions and coastal processes includes;

- Devices within the MDZ will be spaced appropriately to minimise the energy loss between adjacent rows. This also has the added advantage of causing least potential impact on the baseline tidal current regime.
- So far as other constraints (for example, Chapter 24, Chapter Seascape, Landscape and Visual Impact Assessment) allow, devices within the MDZ are most likely to be placed towards the eastern part of the MDZ, where the baseline tidal currents are higher. This means that any suspended sediment effects will be more rapidly and more widely dispersed than if devices were to be placed towards the west of the MDZ.

7.7.3.2. Additional Mitigation Measures

95. An outline Construction Environmental Management Plan (CEMP) (**Document MOR/RHDHV/DOC/0073**) and outline Pollution Prevention and Management Plan (PPMP) (**MOR/RHDHV/DOC/0077**) will be submitted with the TWAO application and Marine Licence application. The development of the detailed design will refine the worst-case impacts assessed in this EIA. It is recognised that construction mitigation is an important element in the management and verification of the actual Project impacts. The outline CEMP and PPMP would be agreed with NRW prior to construction works commencing.

7.7.4. Worst-Case Scenarios

96. The offshore project area consists of the offshore cable corridor with landfall at Penrhos Feilw and the Project within the MDZ. Their detailed designs (including numbers of devices, layout configuration, requirement for scour protection etc.) will not be determined until after the TWAO has been determined. Therefore, realistic worst-case scenarios in terms of potential impacts/effects on metocean conditions and coastal processes are adopted to undertake a precautionary and robust impact assessment. The realistic worst-case scenarios used are described in the sections below.

97. To achieve the maximum 240 MW export capacity, there would be up to 620 devices, supporting up to 1,648 Tidal Energy Convertors (TECS) and up to 740 inter-array cables within the MDZ. This represents the worst case scenario as outlined in **Chapter 4, Project Description**. In addition, numerous electrical hubs that aggregate the power to transmit along the offshore cable are considered as part of the worst-case scenario, as well as navigation marker buoys, environmental monitoring platforms and ADCPs, all of which will also interact with the seabed. The hubs could include a combination of fully submerged sea bed mounted (up to 120), floating (up to 93) and sea bed mounted and surface emergent (up to eight).

98. For the purpose of defining impact assessment parameters for the repowering phase, an assumption has been made that 50% of the tenants will undertake repowering, i.e. for 50% of the tenants, their infrastructure will be removed and replaced (potentially with different infrastructure by a different tenant). For the other 50% of tenants, their infrastructure will remain over the lifetime of the project.

99. In terms of impact assessment parameters, the repowering process has been defined as per below:

- Initial temporary seabed disturbance via deployment of barge anchors to remove foundations, TEC’s, hubs, inter-array cables and monitoring equipment for 50% of the Tenants (berths); and
- Further temporary seabed disturbance via re-installation (repowering) of foundations, TEC’s, hubs, inter-array cables and monitoring equipment for the same 50% of Tenants (berths).

100. The export cables and export cable tails would not be removed as part of the repowering phase

101. As the repowering phase will involve both the removal and installation of infrastructure, the types of effects on metocean conditions and coastal processes would be analogous to those identified for the construction and decommissioning phase and therefore is considered within **Section 7.7.5** and **Section 7.7.7**, where relevant. However, note that repowering will occur during the 37-year operation of the Project.

7.7.4.1. Foundations

102. Within the Project, several different types of foundation types for the devices and hubs are being considered, as described in **Chapter 4, Project Description**, these include:

- Monopiles or jacket (on pin piles): the piling method would be dependent on the nature of the sea bed. Although piles can be hammered into soft sea bed types using percussive piling, such an approach is not appropriate in areas of predominantly hard sea bed such as the MDZ. In such locations rock sockets may be pre-drilled and grouted pin piles, or screw piles may be used to anchor the foundation;
- Gravity base structures (GBS): if piling and drilling into hard sea bed types would be technically challenging, there is also the potential for gravity base structures to be used. These would consist of bases (concrete, steel or iron) attached to a jacket foundation, acting as feet on the jacket structure);
- Catenary floating devices: catenary moorings may require up to four gravity anchors. These anchors tend to weigh in the region of 300 tonnes. Mooring lines are attached to the anchors to hold the device support structure in place. Gravity foundations for larger floating platforms may be up to 2000 tonnes in weight, with a footprint of up to 312 m^2; and
- Tension floating devices: a tensile mooring system may be used to reduce movement. These are typically deployed using four anchor points and kept under tension, as opposed to the catenary mooring system which is not held under tension.

103. Due to the high energy dynamic environment of the MDZ, with associated limited superficial sediment cover on the sea bed, it is assumed that the need for scour protection will be minimal.

104. The layout of the tidal devices would be defined post consent but would be based on deployed capacity of up to 240 MW plus hubs. The total number of devices within the MDZ will be dependent on the individual generating capacity of the devices being installed. The site may be divided into eight subzones, with the zones allowing the demarcation of different technology types.

7.7.4.2. Cable Installation

7.7.4.2.1. Inter-Array and Offshore Cables

105. Inter-array cables would link individual devices within an array to a singular point (hubs), where output from all the devices is collected prior to exporting via the offshore cable. Up to 204.5 km of inter-array cables may be installed on the sea bed. Individual inter-array cables would be up to 2.5 km long with a total sea bed footprint of up to 30, 040 m^2 (including rock bag cable protection).

106. Up 40.5 km of offshore cables will be installed, one from each of the tidal arrays in each sub-zone (not including inter-array cables). The location of the offshore cable corridor is shown on **Figure 1-1** (**Volume II)**. Individual offshore cables would be between 1.2 km and 6 km long with a total sea bed footprint of about 11,745 m^2 (including split-pipe cable protection).

7.7.4.2.2. Cable Protection

107. Cables would be free laid with protection at locations along their lengths. For most of their length, no trenching will be required, although it is possible that some post-installation jetting may be needed to bury the cable across the sand wave feature in the northern half of the cable corridor.

108. The following cable protection options may be used and this would be determined during the final design of the Project:

- Rock (bags) placement - the laying of rocks on top of the cable; and
- Concrete mattresses - prefabricated flexible concrete coverings that are laid on top of the cable. The placement of mattresses is slow and as such is only used for short sections of cable.

109. It is assumed on a worst-case scenario that up to 270 individual rock bags or concrete mattresses (18 m^2 each) could be used on the export cables. This is additional to the split-pipe protection referenced in **Section 7.7.4.2.1** above.

7.7.4.2.3. Cable Burial

110. There is a significant sand wave feature located in the northern half of the offshore cable corridor. It is likely that cables will be installed over this after which an as-laid survey would be completed to identify any areas where the cable is in suspension to target any necessary remedial work at that time. The sand wave can be reduced using a mass flow excavator or dredger. The spatial extent of the sandwave covers an estimated 27,258 m^2.

7.7.4.2.4. Boulder Clearance

111. Pre-construction surveys will identify any requirement for boulder clearance within the offshore project area. Boulder clearance would involve localised relocation of boulders which would have no overall impact on metocean and coastal processes and is therefore not considered further.

7.7.4.2.5. Pre-lay Grapnel Run

112. A pre-lay grapnel run would be undertaken to clear any identified debris in advance of each phase of installation. The maximum width of sea bed disturbance along the pre-grapnel run would be 20 m. This is encompassed by the maximum footprint of cable installation works associated with ploughing (30 m disturbance width).

7.7.4.3. Landfall

113. The offshore cable landfall would be at Penrhos Feilw using either Horizontal Directional Drilling (HDD) (preferred) or use of ducts or J-tubes pinned to the cliff and/or laid in a shallow trench or slot.

114. A HDD landfall would comprise the following components:

- Up to nine cable tails each up to 620 m long at the landfall;
- Up to nine separate drills, each up to 550 m long;
- Separation of 20 m between HDD exit points; and
- Total drill cuttings volume of up to 900 m^3 for HDD alone (total amount for all nine drills).

115. A trenched landfall would comprise the following components:

- Up to nine cable tails each up to 620 m long at the landfall;

- Up to nine separate shallow trenches (with slots within the cliff face) from the intertidal zone to the transition pits, each up to 740 m long;
- Individual trench width would be up to 600 mm with approximately 0.5 m separation distances or a single trench approximately 10 m wide and 0.5 m to 1.2 m deep, with all nine cables laid within it;
- Total material removed would be approximately 8,880 m^3. The majority would be replaced to backfill the trench after the ducts / cables have been installed; and
- Duct or split pipe over 370 m to 550 m of each cable, up to 350 mm external diameter.

7.7.4.4. Construction Programme

116. The construction of offshore works (for installation of tidal devices and associated cabling and infrastructure) would be phased over a period of several years, taking up to 15 days per device or hub and up to 1.5 days for each inter-array cable, up to 20 days for each offshore cable, and up to 12 days for each phase of cable protection. Up to nine separate cable laying and protection campaigns are possible. **Table 7-20** provides an indicative construction programme for the Project.

Table 7-20 Worst-Case Project Construction Programme Based on 240 MW Deployment

Indicative Programme	Approximate Duration (per event)	Approximate Duration (full 240 MW capacity)
Foundations and devices (including drilling of up to 3 days per device – maximum of 596 devices[2])	15 days	4,306 days
Hub installation vessel days (per hub – 120 hubs)	15 days	1,800 days
Inter-array cable vessel days (per cable – 740 cables)	1.5 days	1,110 days
Export cables vessel days (per cable – 9 cables)	20 days	180 days
Export cable Protection (per cable – 9 cables)	12 days	108 days

7.7.4.5. Operations and Maintenance

7.7.4.5.1. Devices

117. Regular maintenance of the devices will be required during operation. These works will have minimal impact on metocean conditions and coastal processes. However, the placement of anchors or jack-up vessels during maintenance activity has been considered to provide a comprehensive assessment. A maximum average of two turbine locations per day, visited by a jack-up vessel has been assessed, to cover 15 inspections of each device annually (for both planned and unplanned maintenance activities).

7.7.4.5.2. Cable Repairs

118. It is expected that once installed, the ongoing offshore operations for the offshore cables would be limited to inspection (through survey) and maintenance of the cables and ancillaries. It is

[2] Based on a worst-case installation scenario of a full 240 MW deployment of pin-piled anchors

anticipated that up to ten major cable repairs (five days each) may be required throughout the Project life. It is assumed that up to 750 m of cable would be subject to repair works per event (7,500 m in total). These will involve the same type of sea bed disturbance as experienced during the main cable installation phase. However, any such disturbance would be more temporally and spatially limited. Annual inspections will be carried out for the first three years, reducing to two years thereafter.

119. In most cases a cable failure would lead to the following operation:

- Vessel anchor placement;
- Cutting the cable;
- Lifting the cable ends to the repair vessel;
- Jointing a new segment of cable to the old cable; and
- Lowering the cable (and joints) back to the sea bed.

7.7.4.6. Summary

120. **Table 7-21** describes the relevant worst-case scenarios for metocean conditions and coastal processes.

Table 7-21 Summary of Worst-Case Scenarios for the Project

Impact	Parameter	Worst-case	Rationale
Construction and Repowering			
Changes in suspended sediment concentrations due to foundation installation in the Project	Sediment plume created by foundation installation	Monopiles / jackets with pin piles	Greatest volume of disturbed/released sediment
Changes in sea bed level (morphology) due to deposition during foundation installation in the Project	Sediment deposited from the plume created by foundation installation	Monopiles / jackets with pin piles	Greatest morphological change would be associated with greatest volume of disturbed/released sediment
Changes in suspended sediment concentrations during offshore export cable installation (including nearshore) (construction only)	Sediment plume created by offshore export cable installation	Placement of up to 40.5 km of cable and cable protection at locations along the length, plus post-installation jetting to bury offshore cable across the sand ridge feature in the northern half of the cable corridor	Greatest volume of disturbed/released sediment
Changes in sea bed level due to offshore export cable installation (construction only)	Changes in sea bed level due to deposition from the suspended sediment plume created during offshore export cable installation	Placement of up to 40.5 km of cable and cable protection at locations along the length plus levelling of sand ridge in northern half of the cable corridor	Greatest morphological change

Impact	Parameter	Worst-case	Rationale
Changes in suspended sediment concentrations during inter-array cable installation	Sediment plume created by inter-array cable installation	Placement of up to 204.5 km cable and cable protection at locations along the length	Greatest volume of disturbed/released sediment
Changes in sea bed level due to inter-array cable installation	Sediment deposited from plume created by inter-array cable installation	Placement of up to 204.5 km cable and cable protection at locations along the length	Greatest morphological change would be associated with greatest volume of disturbed/released sediment
Changes in sea bed level (morphology) due to indentations during installation in the Project	Indentations on the sea bed due to the physical presence of installation vessels	Jack-up and anchor footprints	Greatest morphological change would be associated with vessels working around turbines for foundation installation
Operation and Maintenance			
Changes to the tidal regime due to the presence of structures in the Project	Changes to tidal currents created by the presence of devices and hubs	Envelope covering 240 no. 1 MW devices to 620 no. smaller (0.3-0.5 MW) devices	Maximum 240 MW capacity
Changes to the wave regime due to the presence of structures in the Project	Changes to waves created by the presence of devices and hubs	GBS foundations	Of all foundation types being considered, GBS would have the greatest physical blockage effect on the baseline wave regime
Changes to the sediment transport regime due to the presence of structures in the Project	Sediment plume and changes to bedload sediment transport created by the presence of devices and hubs	GBS foundations supporting an envelope covering 240 no. 1 MW devices to 620 no. smaller (0.3-0.5 MW) devices	The greatest changes to the sediment transport regime would be caused by the greatest changes to the tidal regime and/or the greatest changes to the wave regime
Loss of sea bed morphology due to the footprint of structures in the Project	Sea bed morphology	Total footprint of 129,932 m^2	This includes the worst-case scenario of GBS foundations, drill arisings, export cable footprint (cables and protection systems), array cable footprint, additional cable protection material, cable tails, footprint of navigation marker buoys and footprint of ADCP moorings
Morphological and sediment transport effects due to cable protection measures for offshore export cables (including nearshore and at the coastal landfall)	Sea bed morphology and sediment transport along offshore cables	Total footprint of 11,745 m^2 Placement of free laid cable and rock bags and/or concrete mattresses	Greatest footprint from offshore export cables and cable protection

Impact	Parameter	Worst-case	Rationale
Morphological and sediment transport effects due to cable protection measures for inter-array cables	Sea bed morphology and sediment transport along inter-array cables	Total footprint of 30,040 m^2 Placement of free laid cable and rock bags and/or concrete mattresses	Greatest footprint from inter-array cables and cable protection
Changes in sea bed level (morphology) due to maintenance during maintenance in the Project	Cable repairs and maintenance vessel footprints	Turbine maintenance – jack-up and anchor footprints from a maximum two turbine locations visited per day Cable repairs – a maximum of ten cable repairs (five days each)	Greatest morphological change would be associated with vessels working around turbines for foundation maintenance and for repairs of cables
Decommissioning and Repowering			
Changes in suspended sediment concentrations due to device and hub removal	Suspended sediment concentrations	GBS removal	Greatest volume of disturbed/released sediment would be with removal of GBS since monopiles/pin piles would be cut-off at sea bed level
Changes in sea bed level due to device and hub removal	Sea bed morphology	GBS removal	Greatest morphological change would be associated with greatest volume of disturbed/released sediment
Changes in suspended sediment concentrations during offshore export cable removal (including nearshore and at the coastal landfall) (decommissioning only)	Suspended sediment concentrations	Removal of up to 204.5 km of cable and cable protection at locations along the length	Greatest volume of disturbed/released sediment (compared to leaving *in situ*)
Changes in sea bed levels due to removal of the offshore export cables (decommissioning only)	Sea bed morphology	Removal of up to 204.5 km of cable and cable protection at locations along the length	Greatest morphological change would be associated with greatest volume of disturbed/released sediment (compared to leaving *in situ*)
Changes in suspended sediment concentrations during removal of parts of the inter-array cables	Suspended sediment concentrations	Removal of up to 40.5 km of cable and cable protection at locations along the length	Greatest volume of disturbed/released sediment (compared to leaving *in situ*)
Changes in sea bed levels due to removal of parts of the inter-array cables	Sea bed morphology	Removal of up to 40.5 km of cable and cable protection at locations along the length	Greatest morphological change would be associated with greatest volume of disturbed/released sediment (compared to leaving *in situ*)

Impact	Parameter	Worst-case	Rationale
Changes in sea bed level (morphology) due to indentations during decommissioning in the Project	Indentations on the sea bed due to the physical presence of decommissioning vessels	Jack-up and anchor footprints	Greatest morphological change would be associated with vessels working around turbines for foundation removal

7.7.5. Potential Impacts During Construction and Repowering

7.7.5.1. Impact 1: Changes in Suspended Sediment Concentrations During Foundation Installation in the Project

121. During the construction phase there is potential for foundation installation activities within the Project to disturb sediments, either from the sea bed surface or from below the sea bed (depending on foundation type) and release them into the water column as a plume. This will enhance the baseline suspended sediment concentrations in the water column, making it more turbid, until the plume becomes dispersed by tidal current action and the sediments settle once again on the sea bed.

122. The principal causes of disturbance during foundation installation would be:

- Preparatory works for foundation installation, including boulder clearance;
- Placement of bed-mounted GBS foundations on the sea bed;
- Installation of anchor points for floating systems; and
- Pre-drilling of rock sockets for piled foundations (e.g. monopiles or pin piles).

123. Throughout the MDZ, there is a paucity of surface sediment, with tide-swept bedrock prevailing. Where sediment does exist in these areas, it is sparse, and predominantly gravel, cobbles and rock boulders, which are not particle sizes that can be suspended in the water column and therefore will not form part of a sediment plume even if disturbed during construction.

124. Due to the above, any release of sediments from pre-drilling below the sea bed is of greater potential significance. This would be associated with the installation of monopile or pin pile (for jacket) foundations that may be required for the Project. This has been considered as the worst-case scenario for this impact.

125. In practice, the pre-drilling work required for foundations will progress sequentially over time (rather than being instantaneous). Therefore, the realistic worst-case scenario is sediment release from one foundation location at a time. Under this scenario, any plume that is generated would disperse well before the potential exists for its coalescence with plumes from adjacent (or any other) pre-drill locations.

126. The total volume of sediment released from pre-drilling for monopile or pin pile installation would be extremely small (1,020 m^3 per foundation). From experience of other schemes, this is likely to result in peak increases in suspended sediment concentration at the points of release within the Project being only a few mg/l (typically less than 10 mg/l) and peak values at only a short distance from each release point reducing rapidly to less than 1 mg/l. This low (barely measurable) effect is partly due to the low volume of sediment released from drilling at the

location of each release point, and partly because any fine material released would be rapidly dispersed by the strong tidal currents along the axis of tidal flow.

127. The maximum envisaged effect associated with sediment plumes arising from the foundation installation activities will cause only very minor enhancements in suspended sediment concentration (typically less than 1 mg/l a short distance from the release point) over only a small geographical area (a few hundred metres). The effects will be temporary, with a return to very low background concentrations occurring rapidly upon cessation of installation activities (i.e. the effect is temporary only). Other than at the immediate release point, such a change would be immeasurable. Based on this qualitative assessment the likely magnitudes of effect are shown in **Table 7-21**.

Table 7-22 Magnitude of Effects on Suspended Sediment Concentrations During Foundation Installation

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field	Low	Negligible	Negligible	Negligible	Negligible
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

128. Changes in the suspended sediment concentrations arising from foundation installation do not directly impact on the identified geomorphological receptors *per se* but are important to consider because they inform subsequent assessment of impacts arising from any sediment deposition associated with the plume (see Impact 2, **Section 7.7.5.2**). There is no physical pathway that links the source of the impact to the beaches and sea cliffs before the plume is diminished. Hence, there is **no change** to these identified shoreline geomorphological receptors. There is a direct physical pathway that links the source of the impact to the offshore sand ridge in the north of the MDZ, but plume effects are **negligible** near this sea bed geomorphological receptor.

129. These changes in suspended sediment concentrations arising from foundation installation are also important to consider in the assessment of impacts on marine water quality (see **Chapter 8, Marine Water and Sediment Quality**), benthic and intertidal ecology (see **Chapter 9, Benthic and Intertidal Ecology**), and fish and shellfish (see **Chapter 10, Fish and Shellfish Ecology**).

7.7.5.1.1. Mitigation

130. There is no suggested mitigation.

7.7.5.1.2. Residual Impact

131. The residual impact on the identified shoreline geomorphological receptors remains **no change** and on the identified sea bed geomorphological receptor remains **negligible**.

7.7.5.2. Impact 2: Changes in Sea Bed Level (Morphology) Due to Deposition During Foundation Installation in the Project

132. Any sediment that becomes entrained within the plume generated by foundation installation will have the potential to deposit on the sea bed at some distance from its point of release, as it settles through the water column. Similar to Impact 1 (**Section 7.7.5.1**), the greatest potential

effect would arise from the release of sediment into the water column from pre-drilling for monopile installation.

133. Based upon a realistic worst-case of sediment release from a single monopile at a time, the sediment deposition on the sea bed will be extremely small in thickness. From experience of similar schemes, it is envisaged that in the immediate vicinity of the release point, deposition depths of no more than 0.1 m will be observed. These sediments are then highly likely to become re-entrained by currents during the peak velocities of the following tide and transported further away in small concentrations.

134. Further away from the release point, the deposition of sediments would extend over a similar zone of influence to that of the sediment plume (i.e. within a few hundred metres of each release point, following the axis of the tidal current flow), but the thickness of deposits would be extremely small, typically millimetres. In such a highly dynamic tidal area, this would be an immeasurable change.

135. As sediment plumes and sediment deposition will be governed by the axis of the tidal flows, there is limited potential for the sediment deposited from different turbine locations to coalesce and remain on the sea bed in any measurable magnitude within this area of strong tidal currents. Rather, deposited sediments would be very quickly re-suspended and redistributed across a wide area in low (immeasurable) quantities. Based on this qualitative assessment the likely magnitudes of effect are shown in **Table 7-22**.

Table 7-23 Magnitude of Effects On Sea Bed Levels Due to Sediment Deposition Associated with Foundation Installation

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field	Low	Negligible	Negligible	Negligible	Negligible
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

136. There is no physical pathway that links the source of the impact arising from foundation installation to the beaches and sea cliffs and therefore there is **no change** to these identified shoreline geomorphological receptors. However, there is a direct physical pathway that links the source of the impact arising from foundation installation to the offshore sand ridge in the north of the MDZ, but deposition effects are **negligible** near this sea bed geomorphological receptor.

137. Changes in sea bed level due to sediment deposition arising from foundation installation are also important to consider in the assessment of impacts on benthic and intertidal ecology (see **Chapter 9, Benthic and Intertidal Ecology**), and fish and shellfish (see **Chapter 10, Fish and Shellfish Ecology**).

7.7.5.2.1. Mitigation

138. There is no suggested mitigation.

7.7.5.2.2. Residual Impact

139. The residual impact on the identified shoreline geomorphological receptors (beaches and sea cliffs) remains **no change** and on the identified sea bed geomorphological receptor (offshore sand ridge) remains **negligible**.

7.7.5.3. Impact 3: Changes in Suspended Sediment Concentrations During Offshore Export Cable Installation (including Nearshore and Landfall)

140. During the construction phase only, there is potential for offshore export cable installation activities within the cable corridor (including the nearshore and landfall) to disturb sediments and release them into the water column as a plume. This will enhance the baseline suspended sediment concentrations in the water column, making it more turbid, until the plume becomes dispersed by tidal current action and the sediments settle once again on the sea bed.

141. The principal causes of sediment disturbance during offshore cable installation would be:

- Free-laying of up to 40.5 km of offshore export cable on the sea bed;
- Placement of cable protection (rock bags of concrete mattresses) at specific locations along the cable length; and
- Post-installation jetting to bury offshore cable across the sand ridge feature in the northern half of the cable corridor.

142. The offshore parts of the cable corridor are mostly governed by large areas of outcropping bedrock, with minimal relief and only sparse sediment cover, predominantly gravel, cobbles and rock boulders. However, the northern part of the cable corridor is covered by a sand ridge north of South Stack headland and extending northwest for around 1 km. This is where post-lay jetting may be required to bury the offshore cable, which would cause some sea bed sediment disturbance.

143. Nearer to the landfall, Abraham's Bosom is a bay bounded by rock headlands to the north and south, with a cover of sediment overlying bedrock. The grab sample from this location recovered medium-grained sand. Just offshore of the bay is a patch of megaripples (up to 0.6 m high).

144. The free-laying of cables and the placement of cable protection would not cause plumes along the offshore sections of the cable corridor because the sea bed is characterised by bedrock or, where sparse sediment cover does exist, by sediments with a particle size that cannot be suspended in the water column. In the nearshore, the bedrock is overlain by sand which has the potential to be disturbed by the free-laying of cables and the placement of cable protection. However, any plume arising from these activities would only arise from the force of the cable or protection measures on the sea bed.

145. At the landfall, the worst-case scenario would be open trenching rather than the preferred option of HDD. Under open trenching, up to 7,440 m^3 of sand would be excavated and the majority replaced to backfill the trench, with only a small net loss to the inshore system. Due to these factors, the likely increase in suspended sediment concentration in areas with sand cover nearer to shore (including at the landfall) will remain within the bounds of natural behaviour that are governed by storm waves and surge effects. Furthermore, these effects will be one-off and temporary in duration and are unlikely to be measurable.

146. The principal effect would arise from the post-installation jetting to bury the offshore cable across the sand ridge feature in the northern half of the cable corridor. Under this activity, it is likely that the maximum envisaged effect associated with sediment plumes arising from the jetting will cause only modest (but measurable) increases in suspended sediment concentration locally (typically a few tens of mg/l above background levels). This increase would reduce rapidly with distance from the point of disturbance to a few mg/l over a small geographical area (within a few hundred metres, along the axis of tidal currents). Furthermore, these effects will be one-off and temporary in duration, with a return to the very low background concentrations occurring rapidly upon cessation of installation. Based on this qualitative assessment the likely magnitudes of effect are shown in **Table 7-24**.

147. Changes in the suspended sediment concentration do not directly impact on the identified geomorphological receptors *per se* but are important to consider because they inform subsequent assessment of impacts arising from any sediment deposition associated with the plume (see Construction Impact 4). There is a direct physical pathway that potentially links the source of the impact (arising at the landfall) to the beaches and sea cliffs before the plume is diminished, but plume effects are **negligible** near these geomorphological receptors. There is also a direct physical pathway that potentially links the source of the impact (arising in the offshore part of the cable corridor) to the offshore sand ridge, but plume effects are **low** near this geomorphological receptor.

Table 7-24 Magnitude of Effects on Suspended Sediment Concentrations During Offshore Cable and Cable Protection Installation

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field	Low (sand ridge) to Negligible (elsewhere)	Negligible	Negligible	Negligible	Low (sand ridge) to Negligible (elsewhere)
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

148. These changes in suspended sediment concentration arising from offshore cable installation are also important to consider in the assessment of impacts on marine water quality (see **Chapter 8, Marine Water and Sediment Quality**), benthic and intertidal ecology (see **Chapter 9, Benthic and Intertidal Ecology**), and fish and shellfish (see **Chapter 10, Fish and Shellfish Ecology**).

7.7.5.3.1. Mitigation

149. There is no suggested mitigation.

7.7.5.3.2. Residual Impact

150. The residual impact on the identified shoreline geomorphological receptors remains **no change** and on the identified sea bed geomorphological receptor remains **negligible**.

7.7.5.4. Impact 4: Changes in Sea Bed Level Due to Offshore Cable Installation (including Nearshore and Landfall)

151. Any sediment that becomes entrained within the plume generated by offshore cable installation (Impact 3, **Section 7.7.5.3**) during the construction phase only will have the potential to become deposited on the sea bed at some distance from its point of release as it settles through the water column. Similar to the plume effects, the greatest potential depositional effects would be associated with the post-installation jetting to bury the offshore cable across the sand ridge feature in the northern part of the cable corridor. Other depositional effects (e.g. sediment disturbed from the free-laying of cables or the placement of cable protection on the sea bed) will remain within the bounds of natural behaviour that are governed by storm waves and surge effects, with construction phase effects being one-off and temporary in duration, and unlikely to be measurable.

152. From experience of similar schemes, it is envisaged that in the immediate vicinity of the post-lay jetting through the sand ridge, deposition depths of no more than 0.1 m will be observed. These are highly likely to become re-entrained by currents during the peak velocities of the following tide and transported further away in small concentrations.

153. Further away from the immediate vicinity of the post-lay jetting, the deposition of sediments would extend over a similar zone of influence to that of the sediment plume (i.e. within a few hundred metres of each release point, following the axis of the tidal current flow). Within a short distance from the release points the thickness of deposits will be extremely small, typically millimetres. In this highly dynamic tidal area, this is effectively an immeasurable change. Based on this qualitative assessment the likely magnitudes of effect are shown in **Table 7-25**.

Table 7-25 Magnitude of Effects on Sea Bed Levels Due to Sediment Deposition Associated with Offshore Cable and Cable Protection Installation

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field	Low (sand ridge) to Negligible (elsewhere)	Negligible	Negligible	Negligible	Negligible
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

154. There is a direct physical pathway that potentially links the source of the impact (arising at the landfall) to the beaches and sea cliffs, but effects on sea bed and beach levels are **negligible** for these geomorphological receptors. There is also a direct physical pathway that potentially links the source of the impact (arising in the offshore part of the cable corridor) to the offshore sand ridge, but effects on sea bed levels are **negligible** for this geomorphological receptor.

155. Changes in sea bed level due to sediment deposition arising from foundation installation are also important to consider in the assessment of impacts on benthic and intertidal ecology (see **Chapter 9, Benthic and Intertidal Ecology**), and fish and shellfish (see **Chapter 10, Fish and Shellfish Ecology**).

7.7.5.4.1. Mitigation

156. There is no suggested mitigation.

7.7.5.4.2. Residual Impact

157. The residual impact on the identified shoreline geomorphological receptors remains **no change** and on the identified sea bed geomorphological receptor remains **negligible**.

7.7.5.5. Impact 5: Changes in Suspended Sediment Concentrations During Inter-Array Cable Installation

158. During the construction phase there is potential for inter-array cable installation activities within the Project to disturb sediments and release them into the water column as a plume. This would enhance the baseline suspended sediment concentrations in the water column, making it more turbid, until the plume becomes dispersed by tidal current action and the sediments settle once again on the sea bed.

159. The principal causes of sediment disturbance during inter-array cable installation would be:

- Free-laying of up to 204.5 km of inter-array cable on the sea bed; and
- Placement of cable protection (rock bags of concrete mattresses) at specific locations along the cable length.

160. The substrate across the Project is mostly large areas of outcropping bedrock, with minimal relief and only sparse sediment cover, predominantly gravel, cobbles and rock boulders. Only in the south and southwest of the Project does the sea bed have any sediment that could potentially be affected by inter-array cable or cable protection installation, where megaripples are present with heights up to 0.6 m.

161. The free-laying of inter-array cables and the placement of cable protection would not cause plumes to be created in most areas of the Project because these areas are characterised by bedrock or, where sparse sediment cover does exist, by sediments which have particle sizes that cannot be suspended in the water column. In the areas with megaripples, plumes may locally and temporarily arise from these activities, but only due to the impact force of the cable or protection measures on the sea bed. Hence, the likely increases in suspended sediment concentration in areas with megaripples would remain within the bounds of natural behaviour that are governed by storm waves and surge effects. Furthermore, these construction-related effects will be one-off and temporary in duration and are unlikely to be measurable. Based on this qualitative assessment the likely magnitudes of effect are shown in **Table 7-26**.

Table 7-26 Magnitude of Effects on Suspended Sediment Concentrations During Inter-Array Cable and Cable Protection Installation

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field	Negligible	Negligible	Negligible	Negligible	Negligible
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

162. Changes in the suspended sediment concentrations do not directly impact on the identified geomorphological receptors *per se* but are important to consider because they inform subsequent assessment of impacts arising from any sediment deposition associated with the plume (Impact 6, **Section 7.7.5.6**). There is no direct physical pathway that potentially links the source of the impact to the beaches and sea cliffs before the plume is diminished, and so there

is **no change** in these shoreline geomorphological receptors. There is a direct physical pathway that potentially links the source of the impact (arising in parts of the Project) to the offshore sand ridge, but plume effects are **negligible** near this geomorphological receptor.

163. These changes in suspended sediment concentration arising from inter-array cable installation are also important to consider in the assessment of impacts on marine water quality (see **Chapter 8, Marine Water and Sediment Quality**), benthic and intertidal ecology (see **Chapter 9, Benthic and Intertidal Ecology**), and fish and shellfish (see **Chapter 10, Fish and Shellfish Ecology**).

7.7.5.5.1. Mitigation

164. There is no suggested mitigation.

7.7.5.5.2. Residual Impact

165. The residual impact on the identified shoreline geomorphological receptors remains **no change** and on the identified sea bed geomorphological receptor remains **negligible**.

7.7.5.6. Impact 6: Changes in Sea Bed Level Due to Inter-Array Cable Installation

166. Any sediment that becomes entrained within a plume generated by inter-array cable installation or placement of cable protection (Impact 5, **Section 7.7.5.5**) will have the potential to become deposited on the sea bed at some distance from its point of release as it settles through the water column. However, these depositional effects will remain within the bounds of natural behaviour, with construction phase effects being one-off and temporary in duration and unlikely to be measurable.

167. The deposition of sediments arising from plumes associated with inter-array cable installation or cable protection would likely be immeasurable. Based on this qualitative assessment the likely magnitudes of effect are shown in **Table 7-27**.

Table 7-27 Magnitude of Effects on Sea Bed Levels Due to Sediment Deposition Associated with Inter-Array Cable and Cable Protection Installation

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field	Negligible	Negligible	Negligible	Negligible	Negligible
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

168. There is no physical pathway that links the source of the impact arising from inter-array cable installation to the beaches and sea cliffs and therefore there is **no change** to these identified shoreline geomorphological receptors. However, there is a direct physical pathway that potentially links the source of the impact (arising in the offshore part of the cable corridor) to the offshore sand ridge, but effects on sea bed levels are **negligible** for this geomorphological receptor.

169. Changes in sea bed level due to sediment deposition arising from inter-array installation are also important to consider in the assessment of impacts on benthic and intertidal ecology (see

Chapter 9, Benthic and Intertidal Ecology), and fish and shellfish (see **Chapter 10, Fish and Shellfish Ecology**).

7.7.5.6.1. Mitigation

170. There is no suggested mitigation.

7.7.5.6.2. Residual Impact

171. The residual impact on the identified shoreline geomorphological receptors remains **no change** and on the identified sea bed geomorphological receptor remains **negligible**.

7.7.5.7. Construction Impact 7: Changes in Sea Bed Level Due to Indentations During Installation in the Project

172. During the construction phase, specialist vessels will be used for installation activities. While these are present at the site, their jack-up legs or anchors will exert influences in the form of scars or indentations on the sea bed morphology.

173. Due to the predominance of exposed bedrock on the sea bed, with occasional gravel cobbles and boulders, the legs / anchors of the vessels will not cause significant effects. In areas where a sand ridge is present (in the north of the Project) or where megaripples are present (in the south and southwest of the Project), there will be local effects on the sand surface. However, due to the high tidal energy environment across these areas, any depressions are likely to become rapidly re-worked after the legs / anchors are removed. Furthermore, at each location these effects will be highly localised, one-off and temporary in duration. Based on this qualitative assessment the likely magnitudes of effect are shown in **Table 7-28**.

Table 7-28 Magnitude of Effects on Sea Bed Levels Due to Indentations During Installation

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field	Negligible	Negligible	Negligible	Negligible	Negligible
Far-field	No effect	Negligible	Negligible	Negligible	Negligible

174. There are no areas where the legs / anchors of vessels are likely to affect the beaches and cliffs and therefore there is **no change** in the shoreline geomorphological receptors. Changes in sea bed level due to indentations during installation activities are **negligible** for the sea bed geomorphological receptor.

175. Changes in sea bed level due to indentations during installation are also important to consider in the assessment of impacts on benthic and intertidal ecology (see **Chapter 9, Benthic and Intertidal Ecology**), and fish and shellfish (see **Chapter 10, Fish and Shellfish Ecology**).

7.7.5.7.1. Mitigation

176. There is no suggested mitigation.

7.7.5.7.2. Residual Impact

177. The residual impact on the identified shoreline geomorphological receptors remains **no change** and on the identified sea bed geomorphological receptor remains **negligible**.

7.7.6. Potential Impacts During Operation

7.7.6.1. Impact 1: Changes to the Tidal Regime Due to Presence of Structures in the Project

178. Once installed within the MDZ, tidal devices have the intention of affecting the baseline tidal regime due to the extraction of energy from the tidal currents. This will result in the formation of wakes within the hydrodynamic current flow arising from each tidal device within the Project. The overall effect will be to (mainly) pacify the existing tidal regime downstream of the tidal devices, when compared to the pre-existing (baseline) situation, recognising that the location of this wake will change along the axis of tidal flow depending on the stage of the tide. Wake effects have been visually observed at the water surface on previous tidal device deployments (e.g. SeaGen deployment in Strangford Lough, Northern Ireland). There could also be some (less significant) local increases in current speed between the wakes of adjacent tidal devices and/or around some of the foundations or support structures within the site.

179. The changes caused by the tidal devices and their foundations or support structures could lead to a modification of the tidal regime downstream of an individual tidal device (device scale), downstream of a sub-zone occupied by a small array of tidal devices (near-field scale) or across the whole demonstration site and beyond (far-field scale).

180. To investigate this issue, numerical modelling has been used to determine the changes in the baseline tidal regime arising from the worst-case scenario. The modelling was undertaken principally to assess the effects of tidal energy resource extraction on the levels of resource available to adjacent projects within the MDZ. The results are also of direct relevance to this chapter of the ES in terms of the effects on the baseline tidal regime within the demonstration site, across surrounding sea bed areas and at the adjacent shoreline.

181. A very high resolution 2D finite element model was set-up, calibrated and run to simulate the effects on the baseline tidal regime. The modelling considered ‘generic turbine rotor characteristics’ as follows:

- 20 rotor diameter turbines
- 4.5D spacings (along e-w alignment)
- Mid-depth in water column
- Each device rated 595kW electrical power

182. This rating of device yielded four scenarios, using the indicative subzones shown in **Figure 4-4** (**Volume II**):

- Scenario 1 – 60 MW total capacity, with a total of 102 turbines within the MDZ (17 no. turbines installed in each of subzones 2 – 6 and 8);
- Scenario 2 – 120 MW total capacity, with a total of 204 turbines within the MDZ (34 no. turbines installed in each of subzones 2 – 6 and 8);

- Scenario 3 – 180 MW total capacity, with a total of 306 turbines within the MDZ (51 no. turbines installed in each of subzones 2 – 6 and 8); and
- Scenario 4 – 240 MW total capacity, with a total of 408 turbines[3] within the MDZ (17 no. turbines installed in each of subzones 1 – 8) (**Plate 7-9**).

183. As this is a demonstration site with a wide Project Design Envelope, there will potentially be a vast number of different (presently unknown) layouts, types and ratings of device in reality selected from within the Project Description. It is not possible or proportionate to model each and every permutation, so instead the modelling approach was to assess the effects from an indicative array, to provide insight into potential scale of effects from various scales of deployment. It used a generic exemplar that was considered to be representative of extent and magnitude effects on physical processes.

184. If in reality a larger number of devices (up to 620) was used than has been modelled, then those devices will be of smaller rating and therefore of smaller physical size. Thus, they would each have a smaller individual effect than has been modelled, so the array-scale effects from the modelled scenario would likely be conservative.

185. For deployment of arrays, the MDZ may be spilt into a series of subzones, with the zones allowing the demarcation of different technology types. Eight indicative subzones within the MDZ are shown in **Plate 7-9**, however, these indicative zones may be modified to meet the requirements of tenants and regulators.

186. Since the precise configuration, type and characteristics of the tidal devices to be deployed within each sub-zone of the MDZ will not be known until a later date, generic turbine characteristics, dimensions, power curves and thrust curves were used in the assessments, together with a specific configuration of the multiple arrays of tidal stream devices within the MDZ focused on optimising deployments within locations of greatest baseline tidal current flows. This involved simulation of effects from devices with 20 m rotor diameters, placed at 4.5D spacings (east to west within each row) and located at mid-depth in the water column. Successive rows were spaced 333 m apart with turbines staggered by 2.25D in an east-west direction between rows. The model was run for a 44-day simulation period covering a complete lunar cycle. Further details of the numerical modelling set-up, calibration and runs are provided in **Appendix 7.1** (**Volume III**).

187. Results from the modelling of all four scenarios show that the greatest changes in baseline tidal currents occur at the peak of the flood flow or the peak of the ebb flow, with changes being greater on a mean spring tide than on a mean neap tide.

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[3] *Even though worst-case no. of TECs stated in earlier sections was 620, the max. total of 408 TEC's used in Scenario 4 were worst-case for this specific assessment. The modelling used an indicative array, to provide insight into potential scale of effects from various scales of deployment. It used a generic exemplar that was considered to be potentially most impactful representative of effects on physical processes. Development of the project description continued after the modelling.*

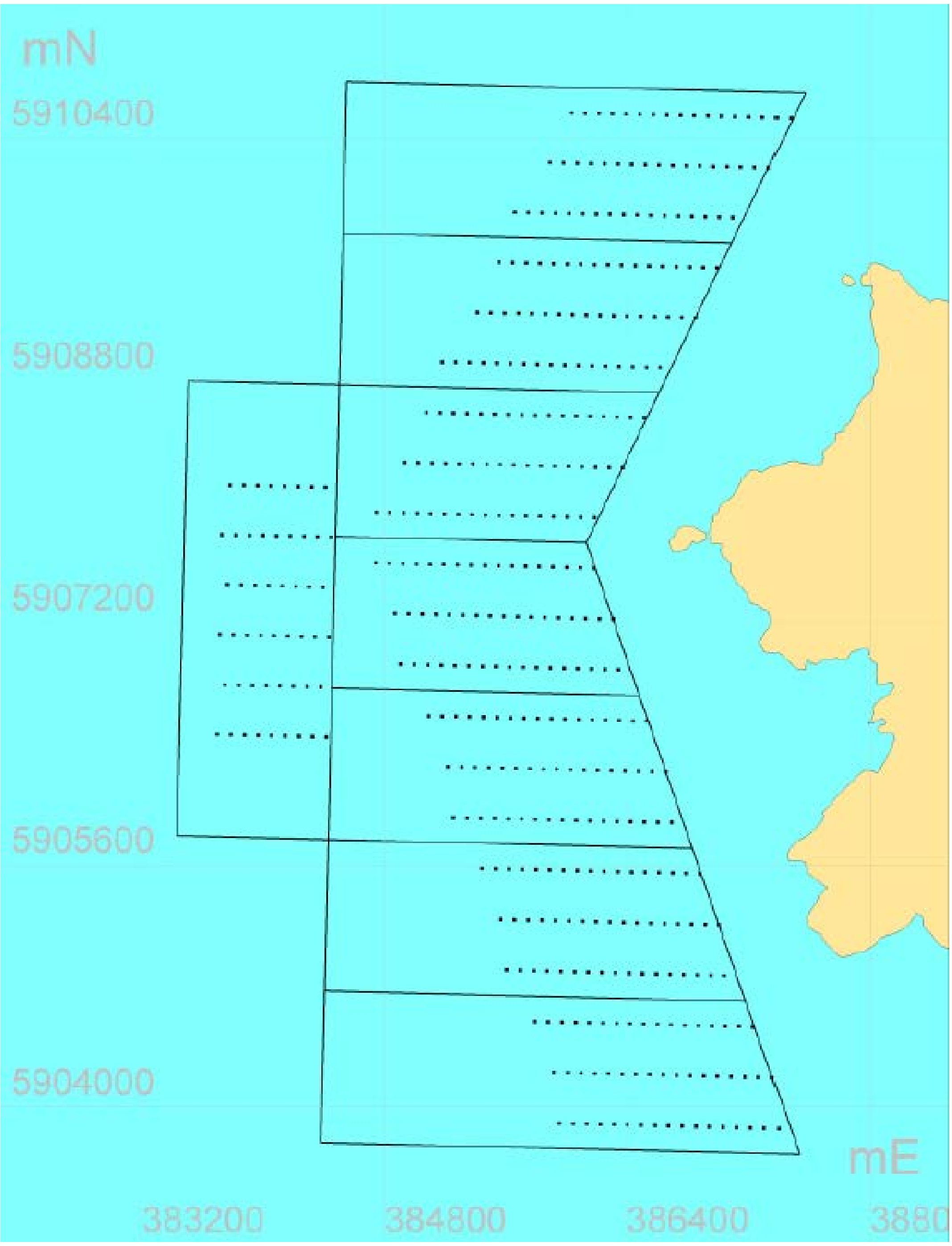

Plate 7-9 Arrays of Tidal Devices Across All Eight Subzones of the MDZ for the 240MW Worst Case Model Run

7.7.6.1.1. Scenario 1 (60 MW Capacity, 102 Turbines) - Peak Flood Flow on a Mean Spring Tide

188. **Figure 7-8 (Volume II**) shows that reductions of up to 0.3 – 0.4 m/s in baseline current speeds are predicted locally across small areas in the easternmost parts of subzones 1, 2 and 3 within the MDZ under peak flood flow on a mean spring tide. However, typically the reductions are in the range 0.1 – 0.3 m/s within around two-thirds of subzones 1 and 2 (entire central and eastern parts) and a smaller area within sub-zone 3 (typically in part of the eastern side). The changes in baseline tidal regime extend beyond the northern limits of the MDZ, following the axis of the baseline tidal currents as they flow northeast around Holy Island.

189. The remainder of subzones 1 and 2 (i.e. western parts) show no change in baseline conditions. Elsewhere, the wakes (with reductions in flow typically of 0.1 – 0.2 m/s) are locally focused around individual turbines within subzones 3 (western and central parts), 4, 5, 6 and 8, with no change in sub-zone 7 (which has no turbines present under this scenario).

7.7.6.1.2. Scenario 1 (60 MW Capacity, 102 Turbines) - Peak Ebb Flow on a Mean Spring Tide

190. **Figure 7-9** (**Volume II**) shows predicted reductions of up to 0.2 – 0.3 m/s in baseline current speeds across the central parts of subzones 6 and 7 under peak ebb flow on a mean spring tide. However, typically the reductions are in the range 0.1 – 0.2 m/s across large portions of subzones 4, 5, 6, 7 and 8, with changes in baseline tidal regime of this magnitude also extending beyond the southern limit of the MDZ, following the axis of the baseline tidal currents as they flow towards the south-southeast.

191. More confined wakes (with reductions in flow of 0.1 – 0.2 m/s) are predicted in subzones 2 and 3 with no change in sub-zone 1 (which has no turbines present under this scenario).

7.7.6.1.3. Scenario 2 (120 MW Capacity, 204 Turbines) - Peak Flood Flow on a Mean Spring Tide

192. **Figure 7-10 (Volume II**) shows that reductions of up to 0.6 – 0.7 m/s in baseline current speeds are predicted locally within subzones 1 and 2. However, more typically the peak changes in the eastern half of these subzones, and extending a small distance into sub-zone 3, are in the range 0.4 – 0.6 m/s. Reductions of up to 0.5 m/s also extend beyond the northern limits of the MDZ, following the axis of the baseline tidal currents towards the northeast.

193. Over the central parts of subzones 1 and 2 and the eastern part of sub-zone 3, the reductions are typically in the range 0.1 – 0.4 m/s with this zone of effect also extending beyond the northern limits of the MDZ, towards the northeast around Holy Island and approaching closer to shore off the north coast of Holy Island.

194. The central parts of subzones 3, 4 and 5 and the central northern segment of sub-zone 8 have reductions in flow of 0.1 – 0.2 m/s. In sub-zone 6, the wakes are confined to individual devices (with local reductions up to 0.1 – 0.2 m/s) whilst there is no change in sub-zone 7 (which has no turbines present under this scenario).

7.7.6.1.4. Scenario 2 (120 MW Capacity, 204 Turbines) - Peak Ebb Flow on a Mean Spring Tide

195. **Figure 7-11 (Volume II**) shows that reductions of up to 0.5 – 0.6 m/s in baseline current speeds are predicted locally across the central part of sub-zone 6. However, typically the peak reductions across the central parts of subzones 5, 6 and 7, extending slightly south of the southern limit of the MDZ, are in the range 0.4 – 0.5 m/s. Changes in tidal currents of around 0.1 – 0.3 m/s are also experienced offshore from Abraham's Bosom.

196. Large parts of subzones 2, 3 and 8, as well as most of subzones 4, 5, 6 and 7 show reductions in baseline flow of 0.1 – 0.4 m/s. A zone of effect of this magnitude also extends south of the southern boundary of the MDZ by up to 5 km.

197. Sub-zone 1 (which has no turbines present under this scenario) is predicted to show no change in baseline conditions.

7.7.6.1.5. Scenario 3 (180 MW Capacity, 306 Turbines) - Peak Flood Flow on a Mean Spring Tide

198. **Figure 7-12** (**Volume II**) shows that reductions in baseline tidal currents of up to 0.8 m/s are predicted to occur across the eastern side of sub-zone 1 (and a small part of sub-zone 2), with reductions up to 0.6 m/s common throughout the central and eastern parts of subzones 1 and 2 and the eastern part of sub-zone 3. Effects of this magnitude also extend around 1 km to the northeast of the northern boundary of the MDZ, before diminishing to reductions of around between 0.1 – 0.4 m/s for a further 3.5 km to the northeast along the axis of baseline flood flows. Changes in tidal currents of around 0.1 – 0.3 m/s are also experienced closer to shore off the north coast of Holy Island.

199. Elsewhere within the MDZ, the reductions are typically in the range 0.1 – 0.4 m/s throughout significant areas of indicative subzones 3, 4, 5, 6 and the northern parts of 8.

200. Sub-zone 7 (which has no turbines present under this scenario) is predicted to show no change in baseline conditions.

7.7.6.1.6. Scenario 3 (180 MW Capacity, 306 Turbines) - Peak Ebb Flow on a Mean Spring Tide

201. **Figure 7-13** (**Volume II**) shows that peak reductions in baseline tidal currents of up to 0.8 m/s occur only locally, within sub-zone 6, but reductions between 0.4 – 0.7 m/s are predicted more commonly throughout the central and eastern parts of subzones 4 (part), 5, 6 and 7. Effects of this magnitude also extend around 750 m to the southeast of the southern boundary of the MDZ, before diminishing to reductions of around between 0.1 – 0.4 m/s for a further approximately 3.5 km to the southeast along the axis of baseline flood flows. Changes in tidal currents of around 0.1 – 0.4 m/s are also predicted offshore from Abraham's Bosom.

202. Elsewhere within the MDZ, the reductions in current velocity are typically in the range 0.1 – 0.4 m/s throughout significant areas of subzones 2 and 3, and the western parts of subzones 4, 5, 6 and 7, as well as the southern and central parts of sub-zone 8.

203. Sub-zone 1 (which has no turbines present under this scenario) shows no change in baseline conditions.

7.7.6.1.7. Scenario 4 (240 MW Capacity, 408 Turbines) - Peak Flood Flow on a Mean Spring Tide

204. **Figure 7-14** (**Volume II**) shows that reductions in baseline tidal currents of up to 0.8 m/s are predicted to occur across the entire eastern side of sub-zone 1 (and a small part of the sub-zone 2), extending around 1 km to the northeast of the northern boundary of the MDZ.

205. Elsewhere, predicted peak reductions in current velocity are 0.6 – 0.7 m/s across much of sub-zone 2, reducing to 0.5 – 0.6 m/s across much of sub-zone 3 and part of sub-zone 4, and reducing further to 0.4 – 0.5 m/s across central parts of sub-zone 5. The zone of effect of this magnitude beyond the northern limit if the MDZ extends for a distance of about 3 km northeast of the northern boundary. Changes in tidal currents of around 0.1 – 0.4 m/s are also predicted approaching closer to shore off the north coast of Holy Island.

206. The wake effects are also observed across central and eastern parts of subzones 6 and 7, the northern central part of sub-zone 8, and extending 2.5 km to the northeast of the MDZ, but at a lower magnitude of change, typically 0.1 – 0.4 m/s.

7.7.6.1.8. Scenario 4 (240 MW Capacity, 408 Turbines) - Peak Ebb Flow on a Mean Spring Tide

207. **Figure 7-15** (**Volume II**) shows that predicted peak reductions in baseline tidal currents of up to 0.8 m/s occur only locally, within subzones 6 and 7, but reductions between 0.4 – 0.7 m/s are predicted more commonly throughout the central and eastern parts of subzones 4, 5, 6 and 7. Effects of this predicted magnitude also extend around 1 km to the southeast of the southern boundary of the MDZ, before diminishing to reductions of around 0.1 – 0.2 m/s for a further 4 km to the south-southeast along the axis of baseline flood flows. Changes in tidal currents of around 0.1 – 0.3 m/s are also predicted offshore from Abraham's Bosom.

208. Elsewhere within the MDZ, the predicted reductions are typically 0.1 – 0.4 m/s throughout significant areas of subzones 2 and 3, and westernmost parts of subzones 4, 5, 6 and 7, as well as the southern and central parts of sub-zone 8.

209. Sub-zone 1 (which does have turbines present under this scenario) shows predicted reductions of up to 0.1 – 0.3 m/s, over only a small area.

7.7.6.1.9. Summary

210. Overall, the modelling results show that there is a predicted increase in the effect on baseline tidal conditions with increasing capacity of the arrays within the subzones of the MDZ. The effects occur: (i) local to individual devices; (ii) from one array to another array within the MDZ; and (iii) from the MDZ to surrounding areas of sea bed.

211. The zone of influence of effect tends to follow the axes of baseline tidal flows, extending northeast beyond the MDZ on a flood tide and south-southeast beyond the MDZ on an ebb tide.

212. However, in even the worst-cases, the magnitude of reduction in tidal current flow (up to 0.8 m/s) results in a residual current flow of high speeds, because the baseline flow conditions in these most affected areas are typically greater than 2 m/s.

213. Based on the qualitative and quantitative modelling assessments the likely magnitudes of effect are shown in **Table 7-29**.

Table 7-29 Magnitude of Effects on Tidal Regime Due to the Presence of Structures in the Project

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Device	Medium	High	Medium	Negligible	Medium
Near-field	Low - Medium	High	Medium	Negligible	Low - Medium
Far-field	Negligible	High	Medium	Negligible	Negligible

214. Changes in the tidal regime do not directly impact on the identified geomorphological receptors *per se* but are important to consider because they inform subsequent assessment of effects arising from any changes to sediment erosion or deposition associated with the changes in tidal regime (see Operational Impact 3).

215. As there is no physical pathway that links the source of the impact to the beaches and sea cliffs before the wake effect on the tidal velocities is back to baseline, there is **no change** to these identified shoreline geomorphological receptors. There is a direct physical pathway that links the source of the impact to the offshore sand ridge in the north of the MDZ, and the magnitude of changes in the tidal regime are **low - medium** near this sea bed geomorphological receptor.

7.7.6.1.10. Mitigation

216. There is no recommended further mitigation.

7.7.6.1.11. Residual Impact

217. The magnitude of change in tidal regime at the shoreline receptor remains **no change** and at the sea bed receptor remains at **low – medium** change.

7.7.6.2. Impact 2: Changes to the Wave Regime Due to Presence of Structures in the Project

218. Once installed within the MDZ, tidal devices and their associated foundations or support structures will have the potential to affect the baseline wave regime. This would be most notable for devices with foundations/support structures that occupy the greatest height within the water column and present the greatest cross-sectional area as a solid mass, causing the greatest potential for blockage.

219. The changes caused by the tidal devices and their foundations or support structures could lead to a modification of the wave regime downstream of an individual tidal device and its foundation or support structure (device scale), downstream of a sub-zone occupied by a small array of tidal devices (near-field scale) or across the whole demonstration site and beyond (far-field scale). To further investigate this issue, experience from the offshore wind farm industry is drawn upon.

220. For monopiles, wave theory exists which relates the pile diameter (D) to the wavelength (L) of the incident waves. Diffraction effects become important when $D/L \geq 0.2$. Using wavelengths typical of the demonstration site, which is often characterised by long period Atlantic swell, wave diffraction is not envisaged to be induced at the MDZ by a monopile foundation. This confirms that effects on the wave regime from a monopile would be confined to local scale reflections and blockage, and that the wave trains will regroup and return to baseline values within a short distance from each foundation.

221. For GBS, which are likely to represent the worst-case foundation type due to their occupation of a greater cross sectional area within the water column, there is a strong evidence base which demonstrates that the changes in the wave regime due to the presence of foundation structures (even under a worst-case scenario of the largest diameter GBS considered by the offshore wind farm industry to date), are relatively small in magnitude (typically less than 10 % of baseline wave heights in close proximity to each wind turbine, reducing with greater distance from each turbine). Effects are localised in spatial extent, extending as a shadow zone typically up to several tens of kilometres from the site along the axis of wave approach, but with low magnitudes (only a few percent change across this wider area). This is confirmed by a review of modelling studies from over 30 offshore wind farms in the UK and European waters (Seagreen 2012), existing guidance documents (ETSU 2000; ETSU 2002; Lambkin *et al*. 2009), published research (Ohl *et al*. 2001) and post-installation monitoring (Cefas 2005).

222. Based on the above assessment the likely magnitudes of effect are shown in **Table 7-30**.

Table 7-30 Magnitude of Effects on Wave Regime Due to the Presence of Structures in the Project

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Device	Medium	High	Medium	Negligible	Medium
Near-field	Low	High	Medium	Negligible	Low
Far-field	Negligible	High	Medium	Negligible	Negligible

223. Changes in the wave regime do not directly impact on the identified geomorphological receptors *per se* but are important to consider because they inform subsequent assessment of effects arising from any changes to sediment erosion or deposition associated with the changes in wave regime (see Impact 3, **Section 7.7.6.3**).

224. As there is no physical pathway that links the source of the impact to the beaches and sea cliffs before the shadow effect on the wave regime is diminished, there is **no change** to these identified shoreline geomorphological receptors. There is a direct physical pathway that links the source of the impact to the offshore sand ridge in the north of the MDZ, and the magnitude of changes in the wave regime are **low** near this sea bed geomorphological receptor.

7.7.6.2.1. Mitigation

225. There is no recommended further mitigation.

7.7.6.2.2. Residual Impact

226. The magnitude of change in wave regime at the shoreline receptor remains **no change** and at the sea bed receptor remains at **low – medium** change.

7.7.6.3. Impact 3: Changes to the Sediment Transport Regime Due to Presence of Structures in the Project

227. Changes in the sediment transport regime will arise as either: (i) an indirect effect, consequent upon changes in the tidal and/or wave regimes caused by tidal devices and their foundations; or (ii) a direct effect due to blockage of (bedload) sediment transport by the foundations of tidal devices or electrical hubs on the sea bed within the Project.

228. As the magnitude of impacts on the tidal regime (Impact 1, **Section 7.7.6.1**) and wave regime (Impact 2, **Section 7.7.6.2**) are negligible across the far-field, then the associated knock-on effects on sediment transport will also be negligible across the far-field.

229. At a device scale, the worst-case for potential blockage of (bedload) sediment transport by foundations is associated with the use of GBS for all devices deployed in a 240 MW array. Under the worst case seabed footprint deployment scenario detailed in **Chapter 4, Project Description**, there could, potentially, be up to 590 devices plus 120 hubs, all deploying GBS, with a seabed footprint of up to 74,790 m^2 within the MDZ.

230. However, at the demonstration site there is little mobile sediment available for bedload transport. This is because the sea bed has been swept to bedrock (with or without a gravel, cobble, boulder

lag) by strong tidal currents. Given this dominant process, the potential for interruption or disturbance of sediment transport by the foundations and electrical hubs is limited. The greatest potential effect will arise in the immediate vicinity of the sand ridge in the north of the MDZ and the area of megaripples in the south and southwest of the MDZ. However, it is unlikely that any project infrastructure will present such an obstacle to sediment transport locally that far-reaching effects will become manifest.

231. Based on the above assessment the likely magnitude of effects are shown in **Table 7-31**.

Table 7-31 Magnitude of Effects on Sediment Transport Regime Due to Presence of Structures in the Project

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Device	Low	High	Medium	Negligible	Low
Near-field	Negligible	High	Medium	Negligible	Negligible
Far-field	Negligible	High	Medium	Negligible	Negligible

232. There is no physical pathway that links the source of the impact (indirectly caused by changes to the tidal and/or wave regimes) to the beaches and sea cliffs and therefore there is **no change** to these identified shoreline geomorphological receptors. However, there is a physical pathway that links the source of the impact arising from local (device location) changes to the tidal and/or wave regimes and direct placement of foundations in the vicinity of the offshore sand ridge in the north of the MDZ. Reductions in tidal velocities of the order expected are relatively small in relation to the very high baseline tidal flows (within a defined zone of influence) and would not result in changes to the existing erosion or deposition patterns of sediment since the critical thresholds for deposition of sediments of different grain particle sizes will still not be crossed. Consequently, these effects on the sediment transport regime are **low** at the location of the device, and **negligible** further afield.

7.7.6.3.1. Mitigation

233. There is no recommended further mitigation.

7.7.6.3.2. Residual Impact

234. The magnitude of effect on the sediment transport regime at the shoreline receptor remains **no change** and at the sea bed receptor remains at **low** (at the location of a foundation) and **negligible** elsewhere.

7.7.6.4. Impact 4: Increases in Suspended Sediment Concentrations Due to Sea Bed Scour Induced by the Project

235. The greatest potential sea bed scour effect will be associated with changes in the flow regimes around the foundations of devices as the flow bifurcates around the obstruction provided by each foundation. Where the sea bed is comprised of bare bedrock or where this is covered with boulders, cobbles or gravels there is unlikely to be any change in suspended sediment concentrations. If devices are placed in areas of the MDZ characterised by sands (e.g. southwest section and in the vicinity of the sand ridge in the north) there is potential for locally accelerated flows around foundations to increase suspended sediment concentrations, but since flows in these areas are very high in the baseline conditions, this will not be a major

exacerbation of the issue. Given the nature of the sea bed morphology, comprised mostly of exposed bedrock, the potential for adverse effects of this nature is extremely limited.

236. Based on the above assessment the likely magnitude of effects is shown in **Table 7-32**.

Table 7-32 Magnitude of Effects on Suspended Sediment Concentrations Due to Sea Bed Scour Induced by the Project

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field (direct footprint)	Low	High	Medium	Negligible	Low
Far-field	No change	No change	No change	No change	No change

237. There is no physical pathway that links the source of the impact to the beaches and sea cliffs and therefore there is **no change** to these identified shoreline geomorphological receptors.

238. However, there is a physical pathway that links the source of the impact to the offshore sand ridge in the north of the MDZ, but effects are **low** at the location of each device placed across this feature.

7.7.6.4.1. Mitigation

239. There is no recommended further mitigation.

7.7.6.4.2. Residual Impact

240. The magnitude of effect on suspended sediment concentrations at the shoreline receptor remains **no change** and at the sea bed receptor remains **low** (at the location of a foundation placed on the sand ridge or sand covered bedrock), with **no change** elsewhere (areas dominated by coarser material).

7.7.6.5. Impact 5: Loss of Sea Bed Morphology Due to Footprint of Structures in the Project

241. The physical presence of foundations, support structures, mooring anchors and chains, surface-laid cables and cable protection works on the sea bed will affect the existing morphology.

242. In the case of the static infrastructure, there will be a footprint imposed on the sea bed that will directly cover the morphology. In the case of the moorings, an area of the sea bed morphology will be ‘swept’ by the drag of the catenary chain.

243. Given the nature of the sea bed morphology, comprised mostly of exposed bedrock, the potential for adverse effects is limited.

244. Based on the above assessment the likely magnitude of effects are shown in **Table 7-33**.

Table 7-33 Magnitude of Effects on Sea Bed Morphology Due to Footprint of Structures in the Project

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field (direct footprint)	Low	High	Medium	Negligible	Low
Far-field	No change	No change	No change	No change	No change

245. There is no physical pathway that links the source of the impact to the beaches and sea cliffs and therefore there is **no change** to these identified shoreline geomorphological receptors.

246. However, there is a physical pathway that links the source of the impact to the offshore sand ridge in the north of the MDZ, but effects are **low** at the location of each device placed across this feature, and **there is no change** beyond the direct footprint.

7.7.6.5.1. Mitigation

247. There is no recommended further mitigation.

7.7.6.5.2. Residual Impact

248. The magnitude of effect on the sediment transport regime at the shoreline receptor remains **no change** and at the sea bed receptor remains **low** (at the location of a foundation placed on the sand ridge), with **no change** elsewhere.

7.7.6.6. Impact 6: Changes to the Morphology and Sediment Transport Regime Due to Offshore Cable and Cable Protection (including Nearshore and Landfall)

249. Changes in the morphology and sediment regime will potentially arise as a direct result of blockage of (bedload) sediment transport by the surface-laid offshore cables and cable protection works on the sea bed.

250. Surface-laid offshore cables, together with any cable protection works, will present an obstacle to bedload sediment transport up to a short height off the sea bed. If bedload transport processes are active, then it would be expected that a ‘ramp’ of sediment would rapidly form against the obstruction and transport process would then occur across the ramp. Such processes are observed across pipelines on the sea bed in areas of active sediment transport. If sediment transport processes are not active, then the presence of the offshore cable and cable protection present no concern in respect of this impact.

251. Across much of the offshore cable corridor, there is little mobile sediment available for bedload transport. This is because the sea bed has generally been swept to bedrock by strong tidal currents. There are exceptions to this in the northern part of the cable corridor, where a sand ridge is present, and closer to shore in Abraham’s Bosom, where sand overlies bedrock. However, the Project infrastructure at the shoreline or within the shallow nearshore that is inshore of the ‘closure depth’ of the active beach profile, will not present an obstruction to bedload sediment transport because the cable will be buried here (by HDD or trenching).

252. Based on the above qualitative assessment the likely magnitude of effects are shown in **Table 7-34**.

Table 7-34 Magnitude of Effects on Morphology and Sediment Transport Regime Due to Offshore Cable and Cable Protection

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field	Negligible	High	Medium	Negligible	Negligible
Far-field	Negligible	High	Medium	Negligible	Negligible

253. There is no physical pathway that links the source of the impact (either indirectly caused by changes to the tidal and/or wave regimes, or directly due to cables or cable protection) to the beaches and sea cliffs and therefore there is **no change** to these identified shoreline geomorphological receptors.

254. However, there is a physical pathway that links the source of the impact arising from near-field changes to the tidal and/or wave regimes and direct placement of offshore cables and cable protection near the offshore sand ridge in the north of the MDZ, but effects are **negligible**.

7.7.6.6.1. Mitigation

255. There is no recommended further mitigation.

7.7.6.6.2. Residual Impact

256. The magnitude of effect on the sediment transport regime at the shoreline receptor remains **no change** and at the sea bed receptor remains **negligible**.

7.7.6.7. Impact 7: Changes to the Morphology and Sediment Transport Regime Due to Inter-Array Cable and Cable Protection

257. Changes in the morphology and sediment regime will potentially arise as a direct result of blockage of (bedload) sediment transport by the surface-laid inter-array cables and cable protection works on the sea bed.

258. Surface-laid inter-array cables, together with any cable protection works, will present an obstacle to bedload sediment transport up to a short height off the sea bed. If bedload transport processes are active, then it would be expected that a ‘ramp’ of sediment would rapidly form against the obstruction and transport process would then occur across the ramp. Such processes are observed across pipelines on the sea bed in areas of active sediment transport. If sediment transport processes are not active, then the presence of the offshore cable and cable protection presents no concern in respect of this impact.

259. Across much of the MDZ (where the inter-array cables will be installed), there is little mobile sediment available for bedload transport. This is because the sea bed has generally been swept to bedrock by the strong tidal currents. There are exceptions to this in the northern part of the MDZ where a large sand ridge is present, and in the south and southwest of the MDZ where megaripples occur. It is unlikely that any Project infrastructure will present a significant obstruction to bedload sediment transport in these areas since it will occupy only a short height above the sea bed.

260. Based on the above qualitative assessment the likely magnitude of effects are shown in **Table 7-35**.

Table 7-35 Magnitude of Effects on Morphology and Sediment Transport Regime Due to Inter-Array Cable and Cable Protection

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field	Negligible	High	Medium	Negligible	Negligible
Far-field	Negligible	High	Medium	Negligible	Negligible

261. There is no physical pathway that links the source of the impact (either indirectly caused by changes to the tidal and/or wave regimes, or directly due to cables or cable protection) to the beaches and sea cliffs and therefore there is **no change** to these identified shoreline geomorphological receptors.

262. However, there is a physical pathway that links the source of the impact arising from near-field changes to the tidal and/or wave regimes and direct placement of inter-array cables and cable protection near the offshore sand ridge in the north of the MDZ, but effects are **negligible**.

7.7.6.7.1. Mitigation

263. There is no recommended further mitigation.

7.7.6.7.2. Residual Impact

264. The magnitude of effect on the sediment transport regime at the shoreline receptor remains **no change** and at the sea bed receptor remains **negligible**.

7.7.6.8. Impact 8: Changes in Sea Bed Level Due to Indentations During Maintenance in the Project

265. During the operational phase, specialist vessels will be used for maintenance activities. While these are present at the site, their jack-up legs or anchors will form scars or indentations on the sea bed.

266. Due to the predominance of exposed bedrock, with occasional gravel, cobbles and boulders, the legs / anchors of the vessels will not cause significant effects. In areas where either a sand ridge is present (in the north of the Project) or where megaripples are present (in the south and southwest of the Project), there will be local effects on the sand surface. However, due to the high tidal energy environment across these areas, any depressions are likely to be re-worked soon after the legs / anchors are removed. Based on this qualitative assessment the likely magnitude of effects are shown in **Table 7-36**.

Table 7-36 Magnitude of Effects on Sea Bed Levels Due to Indentations During Installation

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field	Negligible	Negligible	Negligible	Negligible	Negligible
Far-field	No effect	Negligible	Negligible	Negligible	Negligible

267. There are no areas where the legs / anchors of vessels are likely to affect the beaches and cliffs and therefore there is **no change** in the shoreline geomorphological receptors. Changes in sea bed level due to indentations during maintenance activities are **negligible** for the sea bed geomorphological receptor.

268. Changes in sea bed level due to indentations during maintenance are also important to consider in the assessment of impacts on benthic and intertidal ecology (see **Chapter 9, Benthic and Intertidal Ecology**), and fish and shellfish (see **Chapter 10, Fish and Shellfish Ecology**).

7.7.6.8.1. Mitigation

269. There is no suggested mitigation.

7.7.6.8.2. Residual Impact

270. The residual impact on the identified shoreline geomorphological receptors remains **no change** and on the identified sea bed geomorphological receptor remains **negligible**.

7.7.7. Potential Impacts During Decommissioning and Repowering

7.7.7.1. Impact 1: Changes in Suspended Sediment Concentrations During Device and Hub Removal in the Project

271. During the decommissioning phase the potential for device and hub removal activities within the Project to disturb sediments on the sea bed and release them into the water column as a plume is lower than the effects arising from installation of foundations.

272. This is primarily because the removal activities will cause less direct interference (i.e. no pre-drilling) and the Project substrate is largely characterised by bedrock with little surface sediment other than occasional gravel, cobbles and boulders, which would not form a plume. The only areas with sand are in the north where a sand ridge is identified and in the south and southwest where megaripples are identified in parts of the Project. Based on this qualitative assessment the likely magnitude of effects are shown in **Table 7-37**.

Table 7-37 Magnitude of Effects on Suspended Sediment Concentrations Due to Device and Hub Removal

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field	Negligible	Negligible	Negligible	Negligible	Negligible
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

273. Changes in suspended sediment concentration arising from device and hub removal do not directly impact on the identified geomorphological receptors *per se* but are important to consider because they inform subsequent assessment of impacts arising from any sediment deposition associated with the plume (Impact 2, **Section 7.7.7.2**). There is no physical pathway that links the source of the impact to the beaches and sea cliffs before the plume has diminished. Hence, there is **no change** to these identified shoreline geomorphological receptors. There is a direct physical pathway that links the source of the impact to the offshore sand ridge in the north of the MDZ, but plume effects are **negligible** near this sea bed geomorphological receptor.

274. These changes in suspended sediment concentration arising from device and hub removal are also important to consider in the assessment of impacts on marine water quality (see **Chapter 8, Marine Water and Sediment Quality**), benthic and intertidal ecology (see **Chapter 9, Benthic and Intertidal Ecology**), and fish and shellfish (see **Chapter 10, Fish and Shellfish Ecology**).

7.7.7.1.1. Mitigation

275. There is no suggested mitigation.

7.7.7.1.2. Residual Impact

276. The residual impact on the identified shoreline geomorphological receptors remains **no change** and on the identified sea bed geomorphological receptor remains **negligible**.

7.7.7.2. Impact 2: Changes in Sea Bed Level (Morphology) due to Device and Hub Removal

277. Any sediment that becomes entrained within the plume generated by device and hub removal will have the potential to be deposited on the sea bed at some distance from its point of release as it settles through the water column. However, such plumes arising from decommissioning activities will be of negligible significance and the tidal currents are strong, encouraging rapid dispersion. Based on this qualitative assessment the likely magnitude of effects are shown in **Table 7-38**.

278. There is no physical pathway that links the source of the impact arising from device and hub removal to the beaches and sea cliffs and therefore there is **no change** to these identified shoreline geomorphological receptors. However, there is a direct physical pathway that links the source of the impact arising from device and hub removal to the offshore sand ridge in the north of the MDZ, but deposition effects are **negligible** in the vicinity of this sea bed geomorphological receptor.

Table 7-38 Magnitude of Effects on Sea Bed Levels Due to Sediment Deposition Arising from Device and Hub Removal

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field	Negligible	Negligible	Negligible	Negligible	Negligible
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

279. Changes in sea bed level due to sediment deposition arising from device and hub removal are also important to consider in the assessment of impacts on benthic and intertidal ecology (see **Chapter 9, Benthic and Intertidal Ecology**), and fish and shellfish (see **Chapter 10, Fish and Shellfish Ecology**).

7.7.7.2.1. Mitigation

280. There is no suggested mitigation.

7.7.7.2.2. Residual Impact

281. The residual impact on the identified shoreline geomorphological receptors (beaches and sea cliffs) remains **no change** and on the identified sea bed geomorphological receptor (offshore sand ridge) remains **negligible**.

7.7.7.3. Impact 3: Changes in Suspended Sediment Concentrations Due to Removal of Offshore Cable (including Nearshore and Landfall)

282. During the decommissioning phase there is potential for offshore cable removal activities within the cable corridor (including the nearshore and landfall), during the decommissioning phase only, to disturb sediments and release them into the water column as a plume. This will enhance the baseline suspended sediment concentrations in the water column, making it more turbid, until the plume becomes dispersed by tidal current action and the sediments settle to the sea bed.

283. The offshore sea bed along the cable corridor are mostly governed by large areas of outcropping bedrock, with minimal relief and only sparse sediment cover, predominantly gravel, cobbles and rock boulders. Here, cable removal will create minimal sediment plumes.

284. In the northern part of the cable corridor where the cable has been buried within a sand ridge and nearer to the landfall where there is sand over bedrock, including the presence of some megaripples, removal of the offshore cable will cause effects like those experienced during installation.

285. These effects will be one-off and temporary in duration, with a return to the very low background concentrations occurring rapidly upon cessation of removal. Based on this qualitative assessment the likely magnitude of effects are shown in **Table 7-39**.

Table 7-39 Magnitude of Effects on Suspended Sediment Concentrations Due to Removal of the Offshore Cable (including Nearshore and Landfall)

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field	Low (sand ridge) to Negligible (elsewhere)	Negligible	Negligible	Negligible	Low (sand ridge) to Negligible (elsewhere)
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

286. Changes in the suspended sediment concentration do not directly impact on the identified geomorphological receptors *per se* but are important to consider because they inform subsequent assessment of impacts arising from any sediment deposition associated with the plume (Impact 4, **Section 7.7.7.4**). There is a direct physical pathway that potentially links the source of the impact (arising at the landfall) to the beaches and sea cliffs before the plume is diminished, but plume effects are **negligible** near these geomorphological receptors. There is also a direct physical pathway that potentially links the source of the impact (arising in the offshore part of the cable corridor) to the offshore sand ridge, but plume effects are **low** near this geomorphological receptor.

287. These changes in suspended sediment concentration arising from offshore cable removal are also important to consider in the assessment of impacts on marine water quality (see **Chapter 8, Marine Water and Sediment Quality**), benthic and intertidal ecology (see **Chapter 9, Benthic and Intertidal Ecology**), and fish and shellfish (see **Chapter 10, Fish and Shellfish Ecology**).

7.7.7.3.1. Mitigation

288. There is no suggested mitigation.

7.7.7.3.2. Residual Impact

289. The residual impact on the identified shoreline geomorphological receptors remains **no change** and on the identified sea bed geomorphological receptor remains **negligible**.

7.7.7.4. Impact 4: Changes in Sea Bed Level Due to Removal of Offshore Cable (including Nearshore and Landfall)

290. Any sediment that becomes entrained within the plume generated by offshore cable removal (Impact 3, **Section 7.7.7.3**), during the decommissioning phase only, has the potential to be deposited on the sea bed at some distance from its point of release as it settles through the water column. Depositional effects will remain within the bounds of natural behaviour that are governed by storm waves and surge effects, with decommissioning phase effects being one-off and temporary in duration, and unlikely to be measurable. Based on this qualitative assessment the likely magnitude of effects are shown in **Table 7-40**.

291. There is a direct physical pathway that potentially links the source of the impact (arising at the landfall) to the beaches and sea cliffs, but effects on sea bed and beach levels are **negligible** for these geomorphological receptors. There is also a direct physical pathway that potentially links the source of the impact (arising in the offshore part of the cable corridor) to the offshore sand ridge, but effects on sea bed levels are **negligible** for this geomorphological receptor.

Table 7-40 Magnitude of Effects on Sea Bed Levels Due to Sediment Deposition Arising from Removal of the Offshore Cable

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field	Low (sand ridge) to Negligible (elsewhere)	Negligible	Negligible	Negligible	Negligible
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

292. Changes in sea bed level due to sediment deposition arising from offshore cable removal are also important to consider in the assessment of impacts on benthic and intertidal ecology (see **Chapter 9, Benthic and Intertidal Ecology**), and fish and shellfish (see **Chapter 10, Fish and Shellfish Ecology**).

7.7.7.4.1. Mitigation

293. There is no suggested mitigation.

7.7.7.4.2. Residual Impact

294. The residual impact on the identified shoreline geomorphological receptors remains **no change** and on the identified sea bed geomorphological receptor remains **negligible**.

7.7.7.5. Impact 5: Changes in Suspended Sediment Concentrations Due to Removal of Inter-Array Cable

295. During the decommissioning phase there is potential for inter-array cable removal activities within the Project to disturb sediments and release them into the water column as a plume. This will enhance the baseline suspended sediment concentrations in the water column, making it more turbid, until the plume becomes dispersed by tidal current action and the sediments eventually settle on the sea bed.

296. The sea bed of the Project is mostly composed of large areas of outcropping bedrock, with minimal relief and only sparse sediment cover, predominantly gravel, cobbles and rock boulders. Only in the south and southwest does the sea bed have superficial sediment that could potentially be affected by inter-array cable removal, where megaripples are present with heights up to 0.6 m.

297. Removal of the offshore cable will cause effects like those experienced during installation. These effects will be one-off and temporary in duration, with a return to the very low background suspended sediment concentrations occurring rapidly upon cessation of removal. Based on this qualitative assessment the likely magnitude of effects are shown in **Table 7-41**.

298. Changes in the suspended sediment concentrations do not directly impact on the identified geomorphological receptors *per se* but are important to consider because they inform subsequent assessment of impacts arising from any sediment deposition associated with the plume arising from inter-array cable removal (Impact 6, **Section 7.7.7.6**). There is no direct physical pathway that potentially links the source of the impact to the beaches and sea cliffs before the plume has diminished, and so there is **no change** to these shoreline geomorphological receptors. There is a direct physical pathway that potentially links the source of the impact (arising in parts of the Project) to the offshore sand ridge, but plume effects are **negligible** near this geomorphological receptor.

Table 7-41 Magnitude of Effects on Suspended Sediment Concentrations During Removal of the Inter-Array Cables

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field	Negligible	Negligible	Negligible	Negligible	Negligible
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

299. These changes in suspended sediment concentrations arising from inter-array cable removal are also important to consider in the assessment of impacts on marine water quality (see **Chapter 8, Marine Water and Sediment Quality**), benthic and intertidal ecology (see **Chapter 9, Benthic and Intertidal Ecology**), and fish and shellfish (see **Chapter 10, Fish and Shellfish Ecology**).

7.7.7.5.1. Mitigation

300. There is no suggested mitigation.

7.7.7.5.2. Residual Impact

301. The residual impact on the identified shoreline geomorphological receptors remains **no change** and on the identified sea bed geomorphological receptor remains **negligible**.

7.7.7.6. Impact 6: Changes in Sea Bed Level Due to Removal of Inter-Array Cable

302. Any sediment that becomes entrained within the plume generated by inter-array cable removal (Impact 5, **Section 7.7.7.5**) will have the potential to be deposited on the sea bed at some distance from its point of release as it settles through the water column. However, these depositional effects will remain within the bounds of natural behaviour, with decommissioning phase effects being one-off and temporary in duration and unlikely to be measurable.

303. The deposition of sediments arising from plumes associated with inter-array cable removal will likely be immeasurable. Based on this qualitative assessment the likely magnitude of effects are shown in **Table 7-42**.

Table 7-42 Magnitude of Effects on Sea Bed Levels Due to Sediment Deposition Associated with Removal of the Inter-Array Cables

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field	Negligible	Negligible	Negligible	Negligible	Negligible
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

304. There is no physical pathway that links the source of the impact arising from inter-array cable removal to the beaches and sea cliffs and therefore there is **no change** to these identified shoreline geomorphological receptors. However, there is a direct physical pathway that potentially links the source of the impact (arising in the offshore part of the cable corridor) to the offshore sand ridge, but deposition effects on sea bed levels are **negligible** for this geomorphological receptor.

305. Changes in sea bed levels due to sediment deposition arising from inter-array cable removal are also important to consider in the assessment of impacts on benthic and intertidal ecology (see **Chapter 9, Benthic and Intertidal Ecology**), and fish and shellfish (see **Chapter 10, Fish and Shellfish Ecology**).

7.7.7.6.1. Mitigation

306. There is no suggested mitigation.

7.7.7.6.2. Residual Impact

307. The residual impact on the identified shoreline geomorphological receptors remains **no change** and on the identified sea bed geomorphological receptor remains **negligible**.

7.7.7.7. Impact 7: Changes in Sea Bed Level Due to Indentations in the Seabed

308. During the decommissioning phase, specialist vessels will be used for removal activities. While these are present at the site, their jack-up legs or anchors will form scars or indentations on the sea bed morphology.

309. Due to the predominance of exposed bedrock on the sea bed, with occasional gravel, cobbles and boulders, the legs / anchors of the vessels will not cause significant effects. In areas where either a sand ridge is present (in the north of the Project) or where megaripples are present (in the south and southwest of the Project), there will be localised effects on the sand surface, but due to the high tidal energy environment across these areas, any depressions are likely to become re-worked soon after the legs / anchors are removed. Furthermore, at each location these effects will be local, one-off and temporary in duration. Based on this qualitative assessment the likely magnitude of effects are shown in **Table 7-43**.

Table 7-43 Magnitude of Effects on Sea Bed Levels due to Indentations in the Seabed

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field	Negligible	Negligible	Negligible	Negligible	Negligible
Far-field	No effect	Negligible	Negligible	Negligible	Negligible

310. There are no areas where the legs / anchors of vessels are likely to affect the beaches and cliffs and therefore there is **no change** in the shoreline geomorphological receptors. Changes in sea bed level due to indentations during decommissioning activities are **negligible** for the sea bed geomorphological receptor.

311. Changes in sea bed level due to indentations during installation are also important to consider in the assessment of impacts on benthic and intertidal ecology (see **Chapter 9, Benthic and Intertidal Ecology**), and fish and shellfish (see **Chapter 10, Fish and Shellfish Ecology**).

7.7.7.7.1. Mitigation

312. There is no suggested mitigation.

7.7.7.7.2. Residual Impact

313. The residual impact on the identified shoreline geomorphological receptors remains **no change** and on the identified sea bed geomorphological receptor remains **negligible**.

7.7.8. Cumulative and In-Combination Impacts

314. Of the projects listed in **Chapter 26, Cumulative and In-combination Effects**, the only one which could potentially have a cumulative or in-combination effect with the MDZ Project in respect of coastal processes is Minesto's Holyhead Deep. All other projects are either too remote from the Project or on land and thus do not affect coastal processes.

Minesto's Holyhead Deep project will be a 80 MW installation of tidal energy devices, delivered in a phased manner, and located a short distance due west of the MDZ Project. Based upon the geographical configuration of the Minesto Project Development Area (PDA) with respect to the MDZ Project, there is no possibility of changes in tidal flow interacting between projects, due to the alignment of flood and ebb flows off the coast of Anglesey (i.e. the two projects are not upstream/downstream of each other).

315. Similarly, any (minor) sediment plumes arising from construction from either project will not coalesce because of: (i) the alignment of principal tidal flows; and (ii) likely different construction programmes (note that phase 1 of the Holyhead Deep project is already installed).

316. The predicted impacts of Minesto's Holyhead Deep project on coastal processes have been assessed as being not significant in their own right (Minesto, 2016), and this conclusion is considered equally valid when both projects are considered in combination.

7.7.9. Inter-relationships

317. The range of effects on marine physical processes of the Project have the potential to directly affect the identified marine physical processes receptors but may also manifest as impacts upon receptors other than those considered within the context of marine physical processes. The assessments of significance of these impacts on other receptors are provided in the chapters listed in **Table 7-44**.

Table 7-44 Inter-topic relationships

Topic and description	Related Chapter	Where addressed in this Chapter	Rationale
Marine Water and Sediment Quality	Chapter 8	**Sections 7.7.5.1, 7.7.5.3, 7.7.5.5, 7.7.7.1, 7.7.7.3, 7.7.7.5**	Changes in certain metocean conditions, morphological features or coastal processes have been identified in this Chapter, with their significance on marine water and sediment quality assessed in **Chapter 8, Marine Water and Sediment Quality**
Benthic and Intertidal Ecology	Chapter 9	**Sections 7.7.5.1, 7.7.5.2, 7.7.5.3, 7.7.5.4, 7.7.5.5, 7.7.5.6, 7.7.5.7, 7.7.6.8, 7.7.7.1, 7.7.7.2, 7.7.7.3, 7.7.7.4, 7.7.7.5, 7.7.7.6, 7.7.7.7.**	Changes in certain metocean conditions, morphological features or coastal processes have been identified in this Chapter, with their significance on benthic and inter-tidal ecology assessed in **Chapter 9, Benthic and Intertidal Ecology**
Fish and Shellfish Ecology	Chapter 10	**Sections 7.7.5.1, 7.7.5.2, 7.7.5.3, 7.7.5.4, 7.7.5.5, 7.7.5.6, 7.7.5.7, 7.7.6.8, 7.7.7.1, 7.7.7.2, 7.7.7.3, 7.7.7.4, 7.7.7.5, 7.7.7.6, 7.7.7.7.**	Changes in certain metocean conditions, morphological features or coastal processes have been identified in this Chapter, with their significance on fish and shellfish ecology assessed in **Chapter 10, Fish and Shellfish Ecology**

7.7.10. Interactions

318. The impacts identified and assessed in this chapter have the potential to interact with each other, which could give rise to synergistic impacts as a result of that interaction. The worst case impacts assessed within the chapter take these interactions into account and for the impact assessments are considered conservative and robust. For clarity the areas of interaction between impacts are presented in **Table 7-45** for construction/decommissioning and **Table 7-46** for operational impacts, along with an indication as to whether the interaction may give rise to synergistic impacts.

Table 7-45 Potential Interaction Between Metocean and Coastal Processes Impacts During Construction / Decommissioning

Potential interaction between impacts							
Construction / Repowering / Decommissioning	1: Changes in Suspended Sediment Concentrations During Foundation Installation / Device and Hub Removal in the Project	2: Changes in Sea Bed Level (Morphology) Due to Deposition During Foundation Installation / Device and Hub Removal in the Project	3: Changes in Suspended Sediment Concentrations During Offshore Export Cable Installation / Removal (including Nearshore and Landfall)	4: Changes in Sea Bed Level Due to Offshore Cable Installation / Removal (including Nearshore and Landfall)	5: Changes in Suspended Sediment Concentrations During Inter-Array Cable Installation / Removal	6: Changes in Sea Bed Level Due to Inter-Array Cable Installation / Removal	7: Changes in Sea Bed Level Due to Indentations in the Seabed
1: Changes in Suspended Sediment Concentrations During Foundation Installation / Device and Hub Removal in the Project	-	Yes	Yes	Yes	Yes	Yes	Yes
2: Changes in Sea Bed Level (Morphology) Due to Deposition During Foundation Installation / Device and Hub Removal in the Project	Yes	-	Yes	Yes	Yes	Yes	Yes
3: Changes in Suspended Sediment Concentrations During Offshore Export Cable Installation / Removal (including Nearshore and Landfall)	Yes	Yes	-	Yes	Yes	Yes	Yes
4: Changes in Sea Bed Level Due to Offshore Cable Installation / Removal (including Nearshore and Landfall)	Yes	Yes	Yes	-	Yes	Yes	Yes
5: Changes in Suspended Sediment Concentrations During Inter-Array Cable Installation / Removal	Yes	Yes	Yes	Yes	-	Yes	Yes

Potential interaction between impacts							
Construction / Repowering / Decommissioning	1: Changes in Suspended Sediment Concentrations During Foundation Installation / Device and Hub Removal in the Project	2: Changes in Sea Bed Level (Morphology) Due to Deposition During Foundation Installation / Device and Hub Removal in the Project	3: Changes in Suspended Sediment Concentrations During Offshore Export Cable Installation / Removal (including Nearshore and Landfall)	4: Changes in Sea Bed Level Due to Offshore Cable Installation / Removal (including Nearshore and Landfall)	5: Changes in Suspended Sediment Concentrations During Inter-Array Cable Installation / Removal	6: Changes in Sea Bed Level Due to Inter-Array Cable Installation / Removal	7: Changes in Sea Bed Level Due to Indentations in the Seabed
6: Changes in Sea Bed Level Due to Inter-Array Cable Installation / Removal	Yes	Yes	Yes	Yes	Yes	-	Yes
7: Changes in Sea Bed Level Due to Indentations in the Seabed	Yes	Yes	Yes	Yes	Yes	Yes	-

Table 7-46 Potential Interaction Between Metocean and Coastal Processes Impacts During Operation

Potential interaction between impacts								
Operation	1: Changes to the Tidal Regime Due to Presence of Structures in the Project	2: Changes to the Wave Regime Due to Presence of Structures in the Project	3: Changes to the Sediment Transport Regime Due to Presence of Structures in the Project	4: Increases in Suspended Sediment Concentrations Due to Sea Bed Scour Induced by the Project	5: Loss of Sea Bed Morphology Due to Footprint of Structures in the Project	6: Changes to the Morphology and Sediment Transport Regime Due to Offshore Cable and Cable Protection (including Nearshore and Landfall)	7: Changes to the Morphology and Sediment Transport Regime Due to Inter-Array Cable and Cable Protection	8: Changes in Sea Bed Level Due to Indentations During Maintenance in the Project
1: Changes to the Tidal Regime Due to Presence of Structures in the Project	-	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Potential interaction between impacts								
Operation	1: Changes to the Tidal Regime Due to Presence of Structures in the Project	2: Changes to the Wave Regime Due to Presence of Structures in the Project	3: Changes to the Sediment Transport Regime Due to Presence of Structures in the Project	4: Increases in Suspended Sediment Concentrations Due to Sea Bed Scour Induced by the Project	5: Loss of Sea Bed Morphology Due to Footprint of Structures in the Project	6: Changes to the Morphology and Sediment Transport Regime Due to Offshore Cable and Cable Protection (including Nearshore and Landfall)	7: Changes to the Morphology and Sediment Transport Regime Due to Inter-Array Cable and Cable Protection	8: Changes in Sea Bed Level Due to Indentations During Maintenance in the Project
2: Changes to the Wave Regime Due to Presence of Structures in the Project	Yes	-	Yes	Yes	Yes	Yes	Yes	Yes
3: Changes to the Sediment Transport Regime Due to Presence of Structures in the Project	Yes	Yes	-	Yes	Yes	Yes	Yes	Yes
4: Increases in Suspended Sediment Concentrations Due to Sea Bed Scour Induced by the Project	Yes	Yes	Yes	-	Yes	Yes	Yes	Yes
5: Loss of Sea Bed Morphology Due to Footprint of Structures in the Project	Yes	Yes	Yes	Yes	-	Yes	Yes	Yes
6: Changes to the Morphology and Sediment Transport Regime Due to Offshore Cable and Cable Protection (including Nearshore and Landfall)	Yes	Yes	Yes	Yes	Yes	-	Yes	Yes
7: Changes to the Morphology and Sediment Transport Regime Due to Inter-Array Cable and Cable Protection	Yes	Yes	Yes	Yes	Yes	Yes	-	Yes
8: Changes in Sea Bed Level Due to Indentations During Maintenance in the Project	Yes	Yes	Yes	Yes	Yes	Yes	Yes	-

7.8. SUMMARY

319. As sediment plumes and sediment deposition will be governed by the axis of the tidal flows, there is limited potential for the sediment deposited from different turbine locations to coalesce and remain on the sea bed in any measurable magnitude within this area of strong tidal currents. Rather, deposited sediments would be very quickly re-suspended and redistributed across a wide area in low (immeasurable) quantities.

320. Due to the predominance of exposed bedrock on the sea bed, with occasional gravel cobbles and boulders, the Project will not cause significant changes in bed levels. In areas where a sand ridge is present (in the north of the Project) or where megaripples are present (in the south and southwest of the Project), there will be local effects on the sand surface. However, due to the high tidal energy environment across these areas, any depressions are likely to become rapidly re-worked following removal. Furthermore, these effects will be highly localised, one-off and temporary in duration.

321. Consideration of the potential effects of the Project is carried out over the following spatial scales:

- Near-field: the area within the immediate vicinity (tens or hundreds of metres) of the Project and along the offshore ECC; and
- Far-field: the wider area that might also be affected indirectly by the Project (e.g. due to disruption of waves, tidal currents or sediment pathways).

322. The magnitude of effect associated with these works have been assessed as being **negligible** to **medium** for near-field effects and **negligible** for far-field effects (**Table 7-47**).

323. **Chapter 7, Metocean Conditions and Coastal Processes** also identifies potential effects/changes on marine physical processes for which the receptor is considered in other Chapters (e.g. **Chapter 8, Marine Water and Sediment Quality** and **Chapter 9, Benthic and Intertidal Ecology**).

Table 7-47 Summary of potential impacts identified for metocean and coastal processes

Potential Effect	Scale	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Construction / Repowering Phase						
Effect 1: Changes in suspended sediment concentrations due to foundation installation in the Project	Near-field	Low	Negligible	Negligible	Negligible	Negligible
	Far-field	Negligible	Negligible	Negligible	Negligible	Negligible
Effect 2: Changes in sea bed level (morphology) due to deposition during foundation installation in the Project	Near-field	Low	Negligible	Negligible	Negligible	Negligible
	Far-field	Negligible	Negligible	Negligible	Negligible	Negligible
Effect 3: Changes in suspended sediment concentrations during offshore export cable installation (including nearshore) (construction only)	Near-field	Low (sand ridge) to Negligible (elsewhere)	Negligible	Negligible	Negligible	Low (sand ridge) to Negligible (elsewhere)
	Far-field	Negligible	Negligible	Negligible	Negligible	Negligible
Effect 4: Changes in sea bed level due to offshore export cable installation (construction only)	Near-field	Low (sand ridge) to Negligible (elsewhere)	Negligible	Negligible	Negligible	Negligible
	Far-field	Negligible	Negligible	Negligible	Negligible	Negligible
Effect 5: Changes in suspended sediment concentrations during inter-array cable installation	Near-field	Negligible	Negligible	Negligible	Negligible	Negligible
	Far-field	Negligible	Negligible	Negligible	Negligible	Negligible
Effect 6: Changes in sea bed level due to inter-array cable installation	Near-field	Negligible	Negligible	Negligible	Negligible	Negligible
	Far-field	Negligible	Negligible	Negligible	Negligible	Negligible
Effect 7: Changes in sea bed level (morphology) due to indentations during installation in the Project	Near-field	Negligible	Negligible	Negligible	Negligible	Negligible
	Far-field	No effect	Negligible	Negligible	Negligible	Negligible
Operational Phase						
Effect 1: Changes to the tidal regime due to the presence of structures in the Project	Device	Medium	High	Medium	Negligible	Medium
	Near-field	Low - Medium	High	Medium	Negligible	Low - Medium
	Far-field	Negligible	High	Medium	Negligible	Negligible

Potential Effect	Scale	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Effect 2: Changes to the wave regime due to the presence of structures in the Project	Device	Medium	High	Medium	Negligible	Medium
	Near-field	Low	High	Medium	Negligible	Low
	Far-field	Negligible	High	Medium	Negligible	Negligible
Effect 3: Changes to the sediment transport regime due to the presence of structures in the Project	Device	Low	High	Medium	Negligible	Low
	Near-field	Negligible	High	Medium	Negligible	Negligible
	Far-field	Negligible	High	Medium	Negligible	Negligible
Effect 4: Loss of sea bed morphology due to the footprint of structures in the Project	Near-field (direct footprint)	Low	High	Medium	Negligible	Low
	Far-field	No change	No change	No change	No change	No change
Effect 5: Morphological and sediment transport effects due to cable protection measures for offshore export cables (including nearshore and at the coastal landfall)	Near-field	Negligible	High	Medium	Negligible	Negligible
	Far-field	Negligible	High	Medium	Negligible	Negligible
Effect 6: Morphological and sediment transport effects due to cable protection measures for inter-array cables	Near-field	Negligible	High	Medium	Negligible	Negligible
	Far-field	Negligible	High	Medium	Negligible	Negligible
Effect 7: Changes in sea bed level (morphology) due to maintenance during maintenance in the Project	Near-field	Negligible	Negligible	Negligible	Negligible	Negligible
	Far-field	No effect	Negligible	Negligible	Negligible	Negligible
Repowering / Decommissioning Phase						
Effect 1: Changes in suspended sediment concentrations due to device and hub removal	Near-field	Negligible	Negligible	Negligible	Negligible	Negligible
	Far-field	Negligible	Negligible	Negligible	Negligible	Negligible
Effect 2: Changes in sea bed level due to device and hub removal	Near-field	Negligible	Negligible	Negligible	Negligible	Negligible
	Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

Potential Effect	Scale	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Effect 3: Changes in suspended sediment concentrations during offshore export cable removal (including nearshore and at the coastal landfall) (decommissioning only)	Near-field	Low (sand ridge) to Negligible (elsewhere)	Negligible	Negligible	Negligible	Low (sand ridge) to Negligible (elsewhere)
	Far-field	Negligible	Negligible	Negligible	Negligible	Negligible
Effect 4: Changes in sea bed levels due to removal of the offshore export cables (decommissioning only)	Near-field	Low (sand ridge) to Negligible (elsewhere)	Negligible	Negligible	Negligible	Negligible
	Far-field	Negligible	Negligible	Negligible	Negligible	Negligible
Effect 5: Changes in suspended sediment concentrations during removal of parts of the inter-array cables	Near-field	Negligible	Negligible	Negligible	Negligible	Negligible
	Far-field	Negligible	Negligible	Negligible	Negligible	Negligible
Effect 6: Changes in sea bed levels due to removal of parts of the inter-array cables	Near-field	Negligible	Negligible	Negligible	Negligible	Negligible
	Far-field	Negligible	Negligible	Negligible	Negligible	Negligible
Effect 7: Changes in sea bed level (morphology) due to indentations during decommissioning in the Project	Near-field	Negligible	Negligible	Negligible	Negligible	Negligible
	Far-field	No effect	Negligible	Negligible	Negligible	Negligible

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