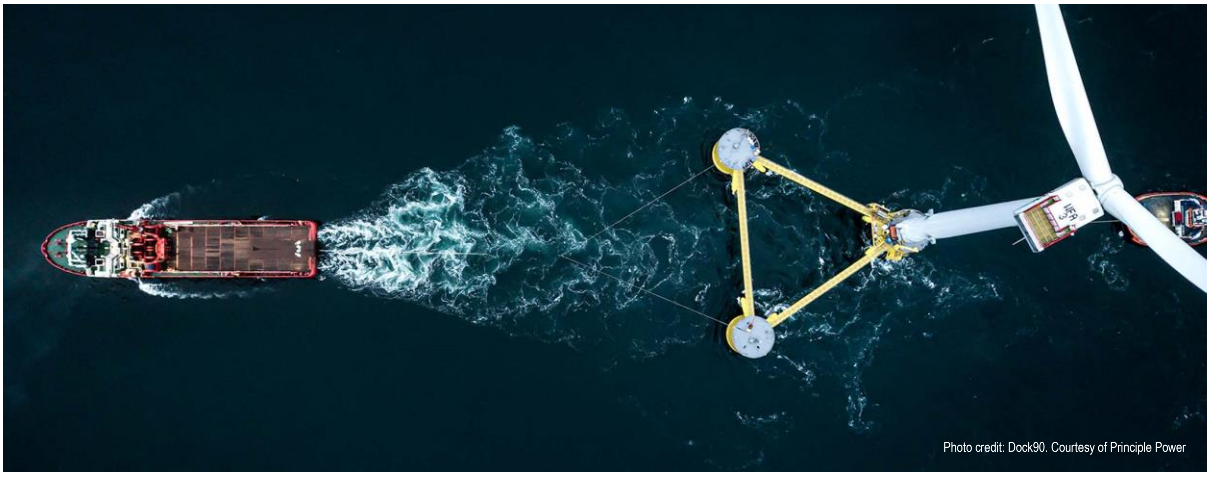


Project Erebus Environmental Statement
Chapter 6: Marine and Coastal Processes

Table of Contents

Acronyms

Term	Definition
ABP R&C	ABP Research & Consultancy Ltd
ABPmer	ABP Marine Environmental Research Ltd
ATR	Astronomical Tide Range
BERR	Department for Business Enterprise and Regulatory Reform
BGS	British Geological Survey
BIOMÔR	Benthic Biodiversity in the Southern Irish Sea
BODC	British Oceanographic Data Centre
BSI	British Standards Institution
CBRA	Cable Burial Risk Assessment
CD	Chart Datum
Cefas	Centre for Environment, Fisheries and Aquaculture Science
COCP	Code of Construction Practices
COWRIE	Collaborative Offshore Wind Research into the Environment
CPA	Coast Protection Act
cSAC	(candidate) Special Area of Conservation
CSIP	Cable Specification and Installation Plan
DECC	Department of Energy and Climate Change
Defra	Department for Environment, Food and Rural Affairs
deg	Degree(s)
DG MARE	Directorate-General for Maritime Affairs and Fisheries
DTI	Department of Trade and Industry
EC	European Commission
ECC	(Offshore) Export Cable Corridor
EIA	Environmental Impact Assessment
EMODnet	European Marine Observation and Data Network
ES	Environmental Statement
FEPA	Food and Environment Protection Act

Term	Definition
HAT	Highest Astronomical Tide MHWS
HDD	Horizontal Directional Drilling
HRA	Habitats Regulations Assessment
HW	High Water
IEMA	Institute of Environmental Management and Assessment
inc.	Including
JNCC	Joint Nature Conservation Committee
km	Kilometres
KP	Kilometre Point
LAT	Lowest Astronomical Tide
LiDAR	Light Detecting and Ranging
LNG	Liquefied Natural Gas
m	Metres
MCZ	Marine Conservation Zone
META	Marine Energy Test Area
MFE	Mass Flow Excavator
MHWN	Mean High Water Neap
MHWS	Mean High Water Springs
MLWN	Mean Low Water Neap
MLWS	Mean Low Water Spring
MMO	Marine Management Organisation
MNR	Mean Neap Range
MSL	Mean Sea Level
MSR	Mean Spring Range
NA	Not Applicable
NAI	No Active Intervention
NFP	Nearshore Floatation Pits
nm	Nautical Miles
NPS	National Policy Statement

Term	Definition
NRW	Natural Resources Wales
NTSLF	National Tide and Sea Level Facility
O&M	Operation & Maintenance
ODN	Ordnance Datum Newlyn
OWF	Offshore Wind Farm
POL	Proudman Oceanographic Laboratory
PU	Policy Unit
RAF	Royal Air Force
RWC	Realistic Worst Case
SAC	Special Area of Conservation
SBP	Sub-Bottom Profiler
SEA	Strategic Environmental Assessment
SMP	Shoreline Management Plan
SMP2	Shoreline Management Plan 2
SPA	Special Protection Area
SPM	Suspended Particulate Matter
SSC	Suspended Sediment Concentration
SSS	Sidescan Sonar
SSSI	Site of Special Scientific Interest
TotalTide	Tidal height and tidal stream predictions Software
TSHD	Trailing Suction Hopper Dredger
TSS	Total Suspended Solids
UK	United Kingdom
UKCP	UK Climate Projections
UKCP09	UK Climate Projections 2009
UKCP18	UK Climate Projections 2018
UKHO	United Kingdom Hydrographic Office
UKMRER	UK Marine Renewable Energy Resources
UNCLOS	United Nations Convention on the Law of the Sea

Term	Definition
WFD	Water Framework Directive
WTG	Wind Turbine Generator

Glossary

Term	Definition
Astronomical tide	The tide levels and character which would result from the gravitational effects of the earth, sun and moon, without any atmospheric influences.
Beach	A deposit of non-cohesive material (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.
Beach profile	A cross-section taken perpendicular to a given beach contour; the profile may include the face of a dune or seawall, extend over the backshore, across the foreshore, and seaward underwater into the nearshore zone.
Bedforms	Features on the seabed (e.g. sandwaves, ripples) resulting from the movement of sediment over it.
Bedload	Sediment particles that travel near or on the bed.
Benthic	A description for animals, plants and habitats associated with the seabed. All plants and animals that live in, on, or near the seabed are benthos.
British Oceanographic Data Centre (BODC)	National facility for looking after and distributing data concerning the marine environment.
Breaking	Reduction in wave energy and height in the surf zone due to limited water depth.
Clay	A fine grained sediment with a typical grain size of less than 0.004 mm. Possesses electromagnetic properties which bind the grains together to give a bulk strength or cohesion.
Climate change	A long term trend in the variation of the climate resulting from changes in the global atmospheric, and ocean, temperatures, and affecting mean sea level, wave height, period and direction, wind speed and storm occurrence.
Coast	A strip of land of indefinite length and width that extends from the seashore inland to the first major change in terrain features.
Coastal processes	Collective term covering the action of natural forces on the coastline and adjoining seabed.
Diurnal	Having a period of a tidal day i.e. 24.84 hours.
European Marine Observation and Data Network (EMODnet)	EMODnet is a Directorate-General for Maritime Affairs and Fisheries (DG MARE) funded network of organisations supported by the European Union's integrated maritime policy. These organisations work together to observe the sea, process the data according to international standards, and make that

Term	Definition
	information freely available as interoperable data layers and data products.
Erosion	Movement of material by such agents as running water, waves, wind, moving ice and gravitational creep.
Geophysical survey	Activities to obtain data on the distribution and nature of geophysical properties of the seabed (e.g. bathymetry, surficial sediment type and bedforms, sub-surface geology). Geophysical survey outputs typically include multibeam bathymetry, side-scan sonar and sub-bottom profiler data.
Habitat	The place in which a plant or animal lives. It is defined for the marine environment according to geographical location, physiographic features and the physical and chemical environment (including salinity, wave exposure, strength of tidal streams, geology, biological zone, substratum, 'features' (e.g. crevices, overhangs, rockpools) and 'modifiers' (e.g. sand-scour, wave-surge, substratum mobility)).
Hindcast	The retrospective prediction of historical (wind and wave) conditions.
Hydrodynamic	Of, or relating to, the motion of fluids and the forces acting on solid bodies immersed in fluids and in motion relative to them.
Intertidal zone	The zone between the highest and lowest tides. May also be referred to as the littoral zone.
Light Detecting and Ranging (LiDAR)	A surveying method that measures distance to a target by illuminating that target with a laser light.
Littoral drift, littoral transport	The movement of beach material in the littoral zone by waves and currents. Includes movement parallel (longshore transport) and perpendicular (onshore- offshore transport) to the shore.
Longshore drift	Or alongshore or littoral drift. Movement of sand and shingle along the shore. It takes place in two zones, at the upper limit of wave activity and in the breaker zone. Movement of beach (sediments) approximately parallel to the coastline.
Morphological	Of, or relating to, the form, shape and structure of landforms
National Tide and Sea Level Facility (NTSLF)	The NTSLF is the UK centre of excellence for sea level monitoring, coastal flood forecasting and the analysis of sea level extremes
Neap tides	Tides with the smallest range between high and low water, occurring at the first and third quarters of the moon.
Regime	The behavior, statistical properties and trends characterising the variability of hydrodynamic, meteorological, sedimentological and morphological parameters.
Salinity	Measure of all the salts dissolved in water.

Term	Definition
Scour	Local erosion of sediments caused by local flow acceleration around an obstacle and associated turbulence enhancement.
Sediment	Particulate matter derived from rock, minerals or bioclastic debris.
Sediment transport	The movement of a mass of sedimentary material by the forces of currents and waves. The sediment in motion can comprise fine material (silts and clay), sands and gravels. Potential sediment transport is the full amount of sediment that could be expected to move under a given combination of waves and currents, i.e., not supply limited.
Sediment transport pathway	The routes along which net sediment movements occur.
Significant wave height	The average height of the highest of one third of the waves in a given sea state.
Spring tides	Tides with the greatest range which occur at or just after the new and full moon.
Seastate	The state of the sea as described using the Douglas sea scale, based on wave height and swell, ranging from 1 to 10, with accompanying descriptions.
Shoreline Management Plan (SMP)	A Shoreline Management Plan (SMP) is a large-scale assessment of the risks associated with coastal processes. It aims to lessen these risks to people and the developed, historic and natural environments.
Suspended Particulate Matter (SPM)	Close to the bed, suspended matter typically consists of re-suspended mineral matter, but higher up in the water column SPM is typically in the form of flocs – loosely bound aggregates composed of mineral matter (e.g. clay minerals) as well as organic matter.
Surficial sediments	Sediments located at the seabed surface (not necessarily of the same character as underlying sediments).
Surge	In water level as a result of meteorological forcing (wind, high or low barometric pressure) causing a difference between the recorded water level and that predicted using harmonic analysis, may be positive or negative.
Suspended load	The material moving in suspension in a fluid, kept up by the upward components of the turbulent currents or by the colloidal suspension.
Suspended sediment concentration	Mass of sediment in suspension per unit volume of water.
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.

Term	Definition
Tidal excursion	The Lagrangian movement (the physics of fluid motion as an individual fluid parcel moves through space and time) of a water particle during a tidal cycle.
Tidal excursion ellipse	The path followed by a water particle in one complete tidal cycle.
Tide	The periodic rise and fall in the level of the water in oceans and seas; the result of gravitational attraction of the sun and moon.
Till	Collective term for the group of sediments laid down by the direct action of glacial ice without the intervention of water.
Topography	The form of the features of the actual surface of the earth in a particular region considered collectively.
Turbidity	Turbidity is a measure of the degree to which the water loses its transparency due to the presence of suspended particles. Suspended sediment concentration (SSC) refers to the mineral fraction of the suspended solids load whilst SPM includes both the inorganic and organic component.
United Kingdom Climate Projections (UKCP)	UKCP09 is the name given to the latest UK Climate Projections. UKCP09 provides information on plausible changes in 21st century climate for land and marine regions in the United Kingdom.
Wave refraction	When waves approach the shoreline obliquely, the wave crests tend to conform to the bottom (bed) contours; due to the inshore portion of the wave travelling at a lower velocity than the portion in deeper water. The extent of wave refraction depends on the relative magnitudes of water depth to wavelength.

Chapter 6 Marine and Coastal Processes

6.1 Introduction

6.1.1.1 The proposed Project Erebus (the Project) is a demonstration scale Floating Offshore Wind (FLOW) development in the Celtic Sea region. The Applicant, Blue Gem Wind, is a joint venture between Simply Blue Energy (SBE) and TotalEnergies, set up to create a new low carbon offshore energy sector in the region; that contributes to climate change targets, supply chain diversification and energy security.

6.1.1.2 This assessment has been undertaken by ABPmer. This Chapter of the Environmental Statement (ES) has been authored by: Anthony Brooks (PhD, MIMarEST, CSci, CMarSci, CEnv), who has more than 15 years' experience in the field of marine and costal processes; and David Lambkin (PhD), who has more than 20 years' experience in the field of marine and costal processes.

6.1.1.3 The array area is located approximately 35 km southwest of the Pembrokeshire coastline, covering an area of 43.5 km^2 in water depths of between 65-85 m. The array area is located outside of the 12 nm limit, but all elements of the Project, array area, offshore export cable corridor and landfall, fall within Welsh territorial waters or the Welsh Zone.

6.1.1.4 The Project comprises six to ten Wind Turbine Generators (WTG) with a total generating capacity up to 100 MW. Each WTG is housed on a semi-submersible floating platform with a mooring system comprising a maximum of five catenary mooring lines, up to 870 m in length, and a range of foundation options including drag embedment anchors, driven piles, drilled piles and/or suction piles. Up to 10 dynamic array cables are proposed, with a lazy wave configuration from the semi-submersible floating platform to the seabed. The offshore export cable, up to 49 km in length, links the array area to landfall at West Angle Bay, Pembrokeshire.

6.1.1.5 The Study Area for this assessment is defined in Section 6.4 (also see Volume 2, Figure 6.1).

6.1.1.6 This chapter of the Environmental Statement (ES) presents the results of the Environmental Impact Assessment (EIA) for the potential effects of the Proposed Development on marine and coastal processes. Specifically, this chapter considers the potential effect of the Project seaward of Mean High Water Springs (MHWS) during its construction, operation & maintenance (O&M), and decommissioning phases.

6.1.1.7 The potential effects on marine and coastal processes have been assessed conservatively using realistic worst-case scenarios for the Project, summarised in section 6.6. The Project Design Envelope (PDE) is provided in full in Chapter 4: Proposed Development Description.

6.1.1.8 Marine and coastal processes are a collective term for the following:

- Water levels;
- Currents;
- Waves (and winds);
- Sediments and geology: (including seabed sediment distribution and sediment transport);
- Seabed geomorphology; and
- Coastal geomorphology.

6.1.1.9 The assessment results presented in this chapter and in the accompanying technical report (Volume 3, Technical Appendix 6.1: Marine and Coastal Processes Assessment Technical Report) have been used to inform the Appropriate Assessment (Habitats Regulations Assessment) (see Volume 3, Technical Appendix 8.3: Report to Inform Appropriate Assessment) and impact assessments for other environmental receptors, considered within the following chapters:

- Chapter 7: Marine Seabed and Water Quality;
- Chapter 8: Offshore Designated Sites;
- Chapter 9: Marine and Coastal Ecology;
- Chapter 10: Fish & Shellfish Ecology;
- Chapter 11: Offshore Ornithology; and
- Chapter 12: Marine Mammals.

6.1.1.10 The full list of environmental receptors considered either in this chapter, or the chapters above were identified in collaboration with Natural Resources Wales (NRW) and others and are shown in Volume 2, Figure 6.1. Along with designated nature conservation sites, they include:

- Annex I bedrock and stony reef – within and around Export Cable Corridor (ECC) in approaches to Milford Haven (KP1.5 to 5.2 and KP14.6 to 14.9);
- Annex I sandbank– within and around ECC at Turbot Bank (KP6.5 to 10.5 and KP14.7 to 17.7);
- Maerl beds – approx. 2.3 km from KP0.5 (landfall) within Milford Haven estuary;
- Seagrass beds – approx. 2.4 km from KP0.5 (landfall);
- Salt marsh (within an inlet) – approx. 5.3 km from KP0.5 (landfall);
- Blue mussel beds – approx. 5.4 km from KP0.5 (landfall);
- Water Framework Directive (WFD) waters and designated bathing waters – approx. 0 to 5.6 km from a central point at KP5.0;
- Herring (higher potential) spawning areas – approx. 1.5 km from KP8.0; and
- Sandeel (higher potential) habitat – within and around the ECC in the vicinity of KP23.0.

6.2 Legislation, Policy and Guidelines

6.2.1.1 The Project is seeking a Section 36 consent, with deemed planning permission, under the Electricity Act 1989 from Welsh Ministers, administered by the Planning and Environment Decisions Wales (PEDW) and a Marine Licence under the Marine and Coastal Access Act (MCAA) 2009 from NRW.

6.2.1.2 A detailed overview of the relevant policy and legislation for the Project is provided in Chapter 5: Policy and Legislation. Details of relevant legislation, policy and guidelines that have been taken into consideration during this assessment are outlined below.

6.2.2 Legislation

6.2.2.1 Coastal processes are not subject to specific topic legislation but are relevant to legislative requirements of other aspects, including the Birds and Habitats Directives, Water Framework Directive etc. due to the potential for pathways of coastal processes effects to impact other aspects. Refer to the topics listed in Section 6.1.1.9 above.

6.2.3 Policy

<u>National Policy Statements</u>

6.2.3.1 Although this Project is seeking Section 36 consent under the Electricity Act 1989 and a Marine Licence under the Marine and Coastal Access Act (MCAA) 2009, as opposed to a Development Consent Order (DCO), its size (up to 100 MW) is similar to the minimum threshold (100 MW) for Nationally Significant Infrastructure Projects (NSIPs). As such, guidance relevant to NSIPs is considered relevant to use for this Project. National Policy Statements (NPSs) were developed to provide guidance in the determination of NSIPs[1]. The following planning policies were reviewed and taken into account (Table 6.1) as part of this assessment:

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

Table 6.1 – NPS EN-3 Assessment Provisions Relevant to Marine 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	Predictions of change to marine and coastal processes that could arise from construction, O&M and decommissioning of the Proposed Development are presented in Section 6.6.
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	The impact of the Proposed Development on coastal processes and geomorphology is considered in Section 0 *et seq.* (for the construction phase), Section 6.6.3.1 (for the O&M phase) and Section 6.6.4.1 (for the decommissioning phase). The vulnerability of the Proposed Development to coastal change is considered in the context of the project design, in Chapter 4: Proposed Development Description.

[1] A period of consultation on a set of revised energy NPS’s, managed by the Department of Business, Energy and Industrial Strategy (BEIS), ended on 29th November 2021.

NPS Requirement	NPS Reference	ES Reference
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	Predictions of change to marine and coastal processes that could arise from the construction, and O&M of the Proposed Development are presented in Section 0 (for the construction phase), Section 6.6.3.1 (for the O&M phase).
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	The embedded mitigation measures relating to cable burial and scour are set out in Table 6.9

UK Marine Policy Statement

6.2.3.2 The Marine Policy Statement (MPS) 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 was adopted by all UK administrations in March 2011. 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 needs to be considered in marine planning. Requirements from the MPS relevant to the Project with regards to marine and coastal processes are outlined in Table 6.2.

Table 6.2 – National and Regional Policy Requirements from the MPS Relevant to Marine and Coastal Processes

Policy Description	Reference	ES Reference
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	A cable landfall assessment is presented in Section 6.6 and the potential impacts during the O&M phase are presented in Section 6.6.3.1. These assessments consider the nature of ongoing shoreline change at the landfall and the potential for cables and other project infrastructure to impact coastal processes. Embedded mitigation measures which seek to minimise and mitigate any geomorphological changes are set out in Table 6.9.

Wales National Marine Plan (WNMP)

6.2.3.3 The Welsh Government published its first marine plan for Welsh inshore and offshore waters, the Welsh National Marine Plan (WNMP), in November 2019. The WNMP was developed in accordance with the MCAA 2009 and the UK MPS. The WNMP covers a 20-year period from its adoption in 2019. The publishing of the WNMP in November 2019 followed a period of consultation from 7 December 2017 to 29 March 2018. The WNMP is discussed further in Chapter 5: Policy and Legislation.

6.2.3.4 The following key objectives of the WNMP are of direct relevance to marine and coastal processes:

- Objective 4: "Provide space to support existing and future economic activity through managing multiple uses, encouraging the coexistence of compatible activities, the mitigation of conflicts between users and, where possible, by reducing the displacement of existing activities";
- Objective 11: "Maintain and enhance the resilience of marine ecosystems and the benefits they provide in order to meet the needs of present and future generations"; and
- Objective 13: "Develop a shared, accessible marine evidence base to support use of sound evidence and provide a mechanism for the unique characteristics and opportunities of the Welsh Marine Area to be better understood".

6.2.3.5 Also of relevance to this Chapter are the WNMP policies described in Table 6.3.

Table 6.3 – National and Regional Policy Requirements from the WNMP relevant to Marine and Coastal Processes

Policy Description	Reference	ES Reference
Proposals should demonstrate how they are resilient to coastal change and flooding over their lifetime.	SOC 08: Resilience to coastal change and flooding	Natural variability and potential changes in climate are described in the baseline Section 6.5 and are considered alongside predicted changes described in the assessment Section 6.6.3.30.
Proposals should demonstrate how they: • avoid significant adverse impacts upon coastal processes; and • minimise the risk of coastal change and flooding. Proposals that align with the relevant Shoreline Management Plan(s) and its policies are encouraged.	SOC 09 Effects on coastal change and flooding	Predictions of change to marine and coastal processes that could arise from the construction, O&M and decommissioning of the Proposed Development are presented in Section 0 (for the construction phase), Section 6.6.3.1 (for the O&M phase) and Section 6.6.4.1 (for the decommissioning phase). Full consideration of Shoreline Management Plans at the coast are taken into account in the landfall assessment (Section 6.6.2.40).

Policy Description	Reference	ES Reference
		An assessment of flood risk is set out within, Chapter 19: Onshore Geology, Hydrogeology and Hydrology.
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 impacts are assessed in Section 6.9 and in Chapter 30: Cumulative Effects.

6.2.4 Guidance

6.2.4.1 Recognisance has been taken of the following best practice guidelines/guidance:

- Natural Resources Wales (2020a). Marine Physical Processes Guidance to inform Environmental Impact Assessment (EIA). Natural Resources Wales, Cardiff;
- Brooks A *et. al*. (2018). Evidence Report No: 243 Guidance on Best Practice for Marine and Coastal Physical Processes Baseline Survey and Monitoring Requirements to inform EIA of Major Development Projects. Natural Resources Wales, Cardiff;
- Pye K, *et. al*. (2017). Evidence Report No: 208 Advice to Inform Development of Guidance on Marine, Coastal and Estuarine Physical Processes Numerical Modelling Assessments. Natural Resources Wales, Cardiff;
- BSI (2015). PD 6900:2015 Environmental impact assessment for offshore renewable energy projects - Guide. BSI Standards Ltd;
- Judd A (2011). Guidelines for Data Acquisition to Support Marine Environmental Assessments of Offshore Renewable Energy Projects. Cefas, Lowestoft;
- JNCC and Natural England (2011). 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;
- ABPmer and HR Wallingford (2009). Coastal Process Modelling for Offshore Wind farm Environmental Impact Assessment: Best Practice Guide. COWRIE;
- ABPmer, *et al*. (2008a). Guidelines in the use of metocean data through the lifecycle of a marine renewables development. ABPmer, Southampton; and
- Cefas (2004). Offshore Windfarms: Guidance note for Environmental Impact Assessment in Respect of FEPA and CPA requirements. Defra Marine Consents and Environment Unit, London.

6.2.4.2 The following studies have also been considered:

- MMO (2014). Review of post-consent offshore wind farm monitoring data associated with licence conditions. A report produced for the Marine Management Organisation, MMO Project No: 1031. MMO, Newcastle;
- ABPmer, *et. al*. (2010). Further review of sediment monitoring data: ScourSed-09. COWRIE;
- Fugro Emu (2014). Review of environmental data associated with post-consent monitoring of licence conditions of offshore wind farms. MMO Project No: 1031;
- BERR (2008). Review of Cabling Techniques and Environmental Effects applicable to the Offshore Wind farm Industry Technical Report. Department for Business Enterprise and Regulatory Reform in association with Defra;
- ABPmer, *et. al*. (2007). Review of Round 1 Sediment process monitoring data - lessons learnt: Sed01. ABPmer, Southampton;
- HR Wallingford, *et. al.* (2007). Dynamics of scour pits and scour protection - Synthesis report and recommendations: Sed02. HR Wallingford, Wallingford; and
- Cooper B and Beiboer F (2002) Potential effects of offshore wind developments on coastal processes. Department of Trade and Industry, London.

6.3 Consultation and Scoping

6.3.1.1 As part of the EIA process, consultation with key stakeholders has been undertaken at all stages of the Project to date and will continue in the future.

6.3.1.2 An EIA Scoping Report (MarineSpace, 2019) was produced and submitted to the regulators, who consulted with the statutory bodies and key stakeholders upon the contents. A formal Scoping Opinion was issued by NRW in January 2020 (NRW, 2020b). Copies of the Scoping Opinion Request (the Scoping Report) and NRW's Scoping Opinion are provided in Volume 3, Technical Appendices 2.1 and 2.2, respectively.

6.3.1.3 Ongoing consultation has taken place with NRW, the Joint Nature Conservation Committee (JNCC) and The Wildlife Trust (TWT) to discuss and agree the suitability of available evidence, assessment methodologies, and forthcoming guidance where appropriate.

6.3.1.4 Responses and feedback relating to marine and coastal processes are addressed throughout this chapter. Table 6.4 provides a summary of key points raised and describes how they have been addressed.

Table 6.4 – Summary of Consultation Relating to Marine and Coastal Processes

Consultee	Response	Applicant Action
NRW (Scoping Opinion) January 2020	All aspects of the Project are included within the assessment of impacts on the physical environment including consideration of the impacts of cabling and cable protection across the receptors identified.	Assessment of impacts from cables and cable protection are provided: for cable installation in Section 0; for making landfall in Section 6.6.2.40 and the potential impacts during the O&M phase are presented in paragraph 6.6.3.1.

Consultee	Response	Applicant Action
NRW (Scoping Opinion) January 2020	Seek NRW advice to clarify how sediment mobility will be considered for the Cable Burial Risk Assessment (CBRA) and foreshore steepening over the project lifetime, should the cable be trenched at landfall.	Assessment of the mobility and stability of the foreshore has been undertaken as part of this assessment: baseline conditions and future evolution are summarised in Section 6.5.15.13, the potential impact of trenching at the landfall is assessed in Section 6.6.2.37. Consultation with NRW on the results of the assessment will be considered and fed back to the CBRA as part of the ongoing Project refinement.
NRW/JNCC (Method Statement Consultation Response Meeting) August 2020	NRW cannot rule out the potential need for further modelling to inform impact assessment. Further evidence required describing the techniques and semiquantitative desk-based assessment models used. Note: Further evidence was provided in the form of other offshore wind farms where ABPmer has completed semi-quantitative assessments of wave and sediment transport blockages along with spreadsheet-based tools for plume extent, concentration and associated changes in bed level.	It is understood the comments relate to the assessment of sediment plumes arising from seabed disturbance. Details on the assessment methodology is provided in Section 6.4 with further details and analysis of sediment dispersion in Volume 3, Technical Appendix 6.1: Marine and Coastal Process Assessment Technical Report. This same method has been successfully applied for Thanet Extension OWF (Vattenfall Wind Power Ltd, 2018) and Hornsea Three (Ørsted, 2018)
NRW/JNCC (Method Statement Consultation Response Meeting) August 2020	Include under seabed morphology, the potential alteration to seabed morphology from the introduction of cable protection. Impacts to consider include the potential for scour if located in soft sediment and the change of habitat caused by addition of cable protection structures (e.g. rock armour, concrete mattress).	Assessment of seabed protection works on seabed morphology is provided in Section 6.6.3.1.

Consultee	Response	Applicant Action
NRW/JNCC (Method Statement Consultation Response Meeting) August 2020	If there is cable protection across the intertidal then assessment of the potential for interruption to the longshore sediment transport pathway and hydrodynamic regime in the nearshore and across the intertidal zone is required.	Full details regarding the Realistic Worst Case for cable protection is set out in Table 6.17. Assessment of the cable landfall is provided in paragraph 6.6.2.37.
NRW/JNCC (Method Statement Consultation Response Meeting) August 2020	Consideration that the mobile bedforms and sandbanks are marine and coastal processes receptors was welcomed. All efforts should be made to avoid active sandwave/bank features where possible when micro siting the cable route. If sandwave avoidance is not possible, the sediment disturbed should remain in the sedimentary cell/system and not be removed (e.g. local mass excavation preferred over dredging).	Assessment of the effects on mobile bedforms and sandbanks is provided in Section6.6.2.16 including potential effects on the sediment budget.
NRW/JNCC (Method Statement Consultation Response Meeting) August 2020	If cable protection is used in the nearshore and across the intertidal then there will be the potential for impacts at the coast over the operational period of the project. This needs to be considered.	Assessment of seabed protection works on nearshore and intertidal morphology is provided in Section 6.6.3.1.
NRW/JNCC (Method Statement Consultation Response Meeting) August 2020	A conceptual understanding of the baseline characteristics for the whole of the project area (offshore, nearshore and intertidal) is required. This should include waves, currents, water depths, sediment transport (bedload and suspended load) as well as the morphodynamics (sandwaves and sand banks) which may play an active role in providing sediment to the coast.	Conceptual understanding of the marine and coastal processes baseline is provided in Section 6.5. The conceptual understanding has been informed by a range of project and non-project specific, measured and modelled (hindcast) data including site specific geophysical and metocean survey data collected in 2020.
NRW/JNCC	NRW questioned the use of Suspended Sediment Climatologies around the UK (Cefas, 2016) and sought	The conceptual understanding of SSC in Section 6.5 is informed by a range of data including the Project specific information

Consultee	Response	Applicant Action
(Method Statement Consultation Response Meeting) August 2020	further data on Suspended Sediment Concentrations (SSC). It noted that it will be important to understand the natural variability of SSC in the water column under calm and storm conditions from inshore to offshore.	collected during the water quality surveys, Cefas (2016) regional satellite SPM observations, supported locally by historical observations and studies in Milford Haven and consistent with qualitative observations made by the Project benthic survey. As assessment of the effects of sediment disturbance at the bed (such as cable installation), which has the potential to raise SSC to levels which are greater than baseline conditions, is provided in Section 0.
NRW/JNCC (Method Statement Consultation Response Meeting) August 2020	NRW requests discussion on the method of assessment for the cable landfall once the site has been identified.	The method of assessment for the cable landfall was discussed. Agreed that the results of the draft ES Chapter will be shared at a suitable time as part of the next stage of engagement. A further technical meeting was scheduled with NRW (22 January 2021) to provide more information about the offshore export cable route, burial plan and landfall design options.
NRW (Consultation Meeting on Preliminary Cable Routing and Burial Design) January 2021	Following from the Aug 2020 meeting on the consultation response, a further meeting was set up to provide NRW a summary of the landfall assessment undertaken on behalf of the applicant.	A list of sensitive receptors (SSC/deposition) was shared with NRW for review and comment. A further technical meeting was arranged for May 2021
NRW, JNCC and TWT (Consultation meeting on Draft Chapter Results for Marine and Coastal Processes) May 2021	Following a summary presentation and discussion of selected preliminary results, NRW, JNCC and TWT requested that a draft copy of the Marine and Coastal Processes ES chapter and supporting Technical Appendix be issued for review ahead of formal ES submission in December 2021.	A draft version of the Marine and Coastal Processes Chapter was shared with NRW/JNCC/TWT in June 2021.

Consultee	Response	Applicant Action
NRW, JNCC and TWT (Draft Marine and Coastal Processes Chapter review) June/July 2021 and NRW and JNCC (Follow-up meeting) September 2021	A number of comments were made by NRW and JNCC largely in relation to the following areas: - Justification of the Realistic Worst Case (RWC) -Turbot Bank – sandwave recovery and sediment supply -Turbot Bank – cable protection and sediment supply -Spreadsheet based plume modelling: clarity around assumptions and input parameters -Landfall: rock protection on beach, at HDD exit pit/ TFP and potential for associated change to coastal morphology	This final ES chapter has been updated to address these comments.

6.4 Assessment Methodology and Significance Criteria

6.4.1.1 Detailed discussion on the EIA methodology can be found in Chapter 2: Overview of EIA Methodology. Impacts to marine and coastal processes are based on the impacts identified within the EIA Scoping Report, and any additional potential impacts which have been identified via consultation with key stakeholders.

6.4.1.2 This assessment has been based on the existing baseline environment, as described in Section 6.5 (see also Volume 3, Technical Appendix 6.1: Marine and Coastal Process Assessment Technical Report), and the PDE as detailed in Chapter 4: Proposed Development Description. Specific parameters that have formed the basis of this assessment are provided in Table 6.17.

6.4.1.3 Impacts have been assessed for the following three distinct phases of the proposed project:

- Construction;
- Operation (and maintenance); and
- Decommissioning.

6.4.2 Study Area

6.4.2.1 The Study Area for the Marine and Coastal Processes assessment is shown in Volume 2, Figure 6.1. Its spatial extent has primarily been determined using expert judgment, informed by conceptual understanding of the marine and coastal processes within the Study Area. This includes (for instance) the spatial footprint of spring tidal excursion ellipses around the array area and ECC, which may be used to determine the maximum extent of sediment plumes associated with disturbance of sediment on the seabed.

6.4.2.2 The Study Area encompasses the outer Bristol Channel (comprising a portion of St George's Channel), the northwestern Bristol Channel running into the southwest coast of Pembrokeshire and Milford Haven up to Mean High Water Springs (MHWS), and includes the array area and ECC. Included in this area is the landfall at West Angle Bay.

6.4.2.3 Key morphological features include St George's Channel and the northwestern Bristol Channel, Turbot Bank (a subtidal sandbank offshore of the entrance to Milford Haven), along with western and eastern channels, through Row's Rocks channel into Milford Haven.

6.4.2.4 The Study Area overlaps with a number of nationally and internationally designated nature conservation sites which contain important geomorphological features. These sites are also illustrated in Volume 2, Figure 6.1 and discussed further in Chapter 8: Offshore Designated Sites. The Project overlaps:

- Pembrokeshire Marine Special Area of Conservation (SAC);
- The West Wales Marine SAC;
- Skomer, Skokholm and the Seas off Pembrokeshire Special Protection Area (SPA); and
- Angle Peninsula Coast Site of Special Scientific Interest (SSSI).

6.4.2.5 The baseline understanding has been developed in accordance with NRW Guidance Note 41 (Guidance on Best Practice for Marine and Coastal Physical Processes Baseline Survey and Monitoring Requirements to Inform EIA of Major Development Projects; Brooks *et al.*, 2018) which requires that attention is given to:

- The identification of the processes maintaining the system, the reasons for any past changes, and sensitivity of the system to changes in the controlling processes;
- The identification and quantification of the relative importance of high-energy, low frequency ("*episodic*" events), versus low-energy, high frequency processes.
- The identification of the processes controlling temporal and spatial morphological change (e.g. longevity and stability of bedforms; cliff recession; loss of beach volume; bank and channel migration; intertidal accretion/erosion), which may require a review of bathymetric and topographic data;
- The identification of sediment sources, pathways and sinks, and quantification of transport fluxes;
- The identification of the inherited geological, geophysical and geotechnical properties of the sediments at the site, and the depth of any sediment strata;
- The interaction of waves and tides and the subsequent quantification of the extent to which seabed sediment is mobilised; and
- The assessment of the scales and magnitudes of processes controlling sediment transport rates and pathways.

6.4.3 Desk Study

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

- Semi-quantitative assessments of wave blockages from the Proposed Development's infrastructure;

- Semi-quantitative assessments of sediment transport blockages from the Proposed Development's infrastructure, also with reference to spatial maps of sediment transport pathways from a high-resolution sand transport model;
- Spreadsheet based tools for extent and concentration of sediment plumes produced via Project installation activities and associated changes in bed level;
- Standard empirical equations describing (for example) the potential for scour development around vertical structures (e.g. foundation components and pile anchors), cables and berms (e.g. Whitehouse, 1998);
- Analytical assessments of Project-specific data; and
- Evidence from analogous projects including other OWFs and subsea cables.

6.4.3.2 The assessments consider likely naturally occurring variability in, or long-term changes to, marine and coastal processes within the Project's lifecycle due to natural cycles and/ or climate change (e.g. sea level rise). This is important as it enables a reference baseline level to be established against which the potentially modified marine and coastal processes can be compared, throughout the Project's lifecycle.

6.4.3.3 The assessment of impacts has been considered over two spatial scales. These are:

- Far-field, defined as the area surrounding the array area and ECC over which indirect changes may occur (i.e. the Study Area); and
- Near-field, defined as the footprint of the array area and ECC.

6.4.4 Approach to assessment of potential increases in suspended sediment concentrations and associated changes to seabed substrate

6.4.4.1 A large evidence base exists with regards to the potential environmental effects of cable installation activities (including increases in suspended sediment concentrations (SSC), e.g. BERR, 2008). This has been considered in conjunction with spreadsheet-based tools (providing estimates of plume extent, concentration and associated changes in bed levels) to inform the assessment.

6.4.4.2 Spring tidal excursion ellipse buffers (based on outputs from the ABPmer SEASTATES hydrodynamic model) have also been used to help inform the potential spatial extent of suspended sediment plumes associated with project related construction/decommissioning activities. Although it is possible that over successive tidal cycles material could advect further than this distance, by this time any plume is expected to be of such low concentration as to be immeasurable in practice.

6.4.4.3 The significance of the magnitude of any increase in turbidity has been evaluated in the context of the expected natural range and the location and nature of identified sensitive receptors.

6.4.5 Approach to assessment of potential changes to sediment transport system by changes in wave and current climate

6.4.5.1 The semi-submersible floating platforms comprise three cylindrical floating chambers connected with a lattice of smaller tubular members. The potential impacts of semi-submersible floating platforms on waves and currents relates to the blockage presented by the component parts; individually, for each of the (small number of) foundations, and, for the array area as a whole.

6.4.5.2 The three main floats/columns presenting the majority of the blockage effect are conceptually similar to traditional monopile foundations at the water surface (presently assumed maximum diameter 11 to 18 m) but will only extend up to 15 m below the sea surface. A similar number of similar type and dimension substructures was considered for the Kincardine Offshore Wind Farm ES (Atkins, 2016); impacts on waves and currents "*was considered*" but were not explicitly assessed "*due to the limited size of the Project*".

6.4.5.3 The maximum surface and subsurface cross section of each foundation has been considered, to assess the potential local extent and magnitude of effect on waves or currents. The assessment has been a semi-quantitative desk-based consideration of the potential for local wave energy or current blockage and recovery downstream. The potential for array scale effects has been considered with respect to the spacing of the individual foundations, in conjunction with the predicted extent of effect from individual foundations.

6.4.5.4 The potential for array scale effects to extend to either the seabed (locally) or to the relatively distant adjacent coastlines has also been considered. The desktop assessment has been informed by knowledge of the local wave and current regimes, relevant wave and hydrodynamic theory, and the many offshore wind farm and engineering related studies that have considered the effect of similar size full water column depth foundations, including numerical modelling.

6.4.5.5 Potential changes to patterns of sediment transport have been assessed on the basis of the extent and magnitude of any predicted changes to the wave and current regimes, relative to the normal natural range of variability in these parameters.

6.4.5.6 Both cable protection measures and (to a much lesser extent) the anchors have the potential to interact with sediment transport pathways locally. This has been assessed as a semi-quantitative desktop exercise, based on the local (baseline) sediment transport potential and the dimensions of the structures.

6.4.5.7 Reference has also been made to a range of existing evidence that has been developed in relation to the assessment of cable protection measures over the last four years for other wind farm projects.

6.4.6 Approach to assessment of potential changes to the morphology of the seabed

6.4.6.1 The assessment has reviewed the proximity of the ECC to designated and non-designated bedform features. Where sandwave features occur and cable routeing around them is not possible, an assessment of the effect of sandwave crest levelling has been undertaken. This has included disturbance to, and the potential recovery of, sandwave crests using a semi-quantitative desktop exercise. The assessment determines the local sediment transport potential and the dimensions of sandwaves, also referring to a range of existing evidence that has been developed in relation to assessments of this nature undertaken over the last five years for other wind farm projects.

6.4.6.2 The spatial extent of potential morphological change to the seabed associated with anchoring structures has been characterised using the information in Chapter 4: Proposed Development Description with consideration given to the size of anchors/anchor chains and potential for any associated scour. This assessment also considers the impact of any mooring chain catenary, along with scour associated with clump weights and/or cable protection deployed on both the inter array and export cables.

6.4.7 Approach to assessment of potential changes in morphology at the coast

6.4.7.1 Where the offshore export cable makes landfall, it must transition through the intertidal zone. The variety of methods available for installing cables in such environments (open-cut trenching, ploughs, Horizontal Directional Drilling (HDD)) may physically disturb or disrupt the present intertidal morphology to differing degrees. At the time of construction, any disturbance will be localised to the landfall site.

6.4.7.2 Although HDD is the preferred solution for installing the offshore export cable at the landfall, open cut trenching is retained in the PDE as a contingency option. Accordingly, the assessment has specifically looked at the potential impact of this activity (trenching) as the realistic worst-case scenario.

6.4.7.3 The short-term physical impact has been assessed as a desktop analysis. The physical nature and extent of the likely disturbance is characterised using the information in Chapter 4: Proposed Development Description and with reference to the wider evidence base. The potential impact on beach morphology, hydrodynamics and sediment transport has been assessed by an experienced coastal geomorphologist in the context of the baseline environment of the landfall site at West Angle Bay.

6.4.7.4 The significance of the magnitude and nature of the localised impacts has been evaluated in the context of the expected naturally occurring variability in morphology at the landfall.

6.4.8 Site Visit/Surveys

6.4.8.1 Project specific geophysical, environmental and metocean surveys have been undertaken. These and other data sources are described in Section 6.5.

6.4.9 Assessment of Potential Effect Significance

6.4.9.1 The assessment of effects upon marine and coastal processes receptors is a systematic process that is determined by considering specific criteria relating to marine and coastal processes that have been developed for the sensitivity and importance of the receptor (Table 6.5) and the magnitude of impact (Table 6.6). Each aspect (sensitivity and magnitude) was considered using the available evidence, including official data sources, feedback from consultation and expert judgement.

6.4.9.2 The magnitude of impact describes the extent or degree of change that is predicted to occur to a receptor. It has been assessed using expert judgement and described qualitatively with a standard semantic scale. These expert judgements regarding the magnitude of impact relative to baseline conditions have been made by experienced marine and coastal process specialists and formed following consideration of the information sources set out in this section.

Sensitivity

6.4.9.3 The sensitivity of the receptor is considered in terms of its ability to avoid, adapt, accommodate or recover from potential impacts. Data sources, feedback from consultation and expert judgement were used to inform the assessment of sensitivity of marine and coastal processes receptors. The criteria of sensitivity used in relation to marine and coastal processes receptors are defined in Table 6.5.

Table 6.5 – Sensitivity Levels for Receptors (Marine and Coastal Processes)

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

Magnitude

6.4.9.4 The magnitude of the impact is based on the spatial extent and duration. Data sources, feedback from consultation, and expert judgement were used to inform the assessment of the magnitude of impacts to marine and coastal processes receptors. The criteria for defining magnitude used in relation to marine and coastal processes receptors are defined in Table 6.6.

Table 6.6 – Magnitude of Impact

Magnitude	Description
High	Permanent changes across the near- and large parts of the far-field, to key characteristics or features of the particular environmental aspect's character or distinctiveness.
Medium	Permanent changes, over the near- and parts of the far-field, to key characteristics or features of the particular environmental aspect's character or distinctiveness.
Low	Noticeable, temporary change (for part of the Project duration), or barely discernible change for any length of time, restricted to the near-field and immediately adjacent far-field areas, to key characteristics or features of the particular environmental aspect's character or distinctiveness.
Negligible	Changes which are not discernible from background conditions.

Significance of Effect

6.4.9.5 The significance of the effect upon marine and coastal processes receptors is determined by correlating the magnitude of the impact and the sensitivity of the receptor, as presented in Table 6.7. On this basis, potential effects are assessed as of negligible, minor, moderate and major significance (definitions are provided in Chapter 2: Overview of EIA Methodology).

6.4.9.6 For the purposes of this assessment, any effects with a significance level of major and/or moderate have been deemed significant in EIA terms, while those of minor or negligible are deemed non-significant.

Table 6.7 – Effect Significance Matrix

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

6.4.10 Receptors and Pathways

6.4.10.1 In most cases, marine and coastal processes are not in themselves receptors but are, instead, 'pathways' which have the potential to indirectly impact other environmental receptors, i.e. benthic ecology, fish ecology etc. Accordingly, whilst potential changes assessed in this chapter may not themselves be significant, it may be the case that they have potential to cause significant effects to other EIA topic receptors, notably those identified within the water quality and benthic ecology chapters. For example, the creation of sediment plumes (which is considered in the Marine and Coastal Processes assessment) may lead to settling of material onto benthic habitats. The potential significance of this change is assessed in Chapter 9: Marine and Coastal Ecology. A full assessment of inter-relationships between chapters is presented in Chapter 29: Inter-related Effects.

6.4.10.2 It is important to note that where the impact is considered to be a marine and coastal process pathway (such as hydrodynamics, waves and sediment transport processes) without any associated receptors, this chapter of the EIA does not consider the resulting significance of effects and will be covered in respective chapters where the receptors are identified (e.g. benthic receptors in Chapter 9: Marine and Coastal Ecology). Only receptors linked to marine and coastal processes are included in this chapter.

6.4.10.3 It is also noted here that there are two designated Geological Conservation Review (GCR) sites located in proximity to landfall at West Angle Bay (West Angle Bay and West Angle Bay (North)). The ECC passes between the two GCR sites, not within the boundaries of the sites. These sites are described in more detail in Chapter 19: Onshore Geology, Hydrogeology and Hydrology, along with other terrestrial geological sites identified as part of the GCR process.

6.4.10.4 The main marine and coastal processes receptor which requires assessment is the coast itself. This could, potentially, be directly impacted during the construction phase, because of offshore export cable installation at the landfall and also in the operational phase if any cable protection (in the form of rock berms) causes disruption to sediment transport.

6.4.10.5 The Study Area overlaps with several nationally and internationally designated nature conservation sites, which contain qualifying geological and geomorphological features. (Table 6.8). This includes potentially mobile macro scale bedform features such as sandbanks (e.g. Turbot Bank), which are also considered as a marine and coastal processes receptor. These are described in the baseline section of this Chapter (Section 6.5). These receptors have been identified on the basis of expert judgement, local and regional specialist experience as well as outcomes of the EIA Scoping process (including consultation with NRW/JNCC and relevant stakeholders) and reference to best practice guidance.

6.4.10.6 This distinction between assessment of pathways and receptors is summarised in Table 6.8 for each of the potential impacts considered within the assessment.

Table 6.8 – Potential Impacts, Pathways and Receptors relevant to Marine and Coastal Processes

Potential Impact	Relevant activities/ infrastructure	Project Phase	Pathway/ Receptor
Potential increases in SSC and associated changes to seabed substrate.	Cable burial/jointing activities Installation of cable protection (array and export cables) Cable repair/remediation events (O&M phase only) Sandwave levelling Drilling of anchors into hard rock seabed/deployment of drag anchors/suction piles Percussive/driven Piling Drilling mud release from HDD operations Open-cut trenching at landfall Creation of flotation pits at landfall	Construction O&M Decommissioning	**Pathway** (Sediment transport)
Potential changes to the sediment transport system by changes in wave and current climate	Installation of cable protection (array and export cables) Presence of semi-submersible floating platforms and WTGs Presence of anchoring structures (drag anchors; clump weights and chains and/or suction piles and/or drilled/driven piles)	Construction O&M Decommissioning	**Pathway** (Hydrodynamics, waves and sediment transport)

Potential Impact	Relevant activities/ infrastructure	Project Phase	Pathway/ Receptor
Potential changes to the morphology of the seabed (including from scour)	Presence of anchoring structures (drag anchors; clump weights and chains and/or suction piles and/or drilled/driven piles) Presence of cable protection (array and export cables) Sandwave levelling	Construction O&M Decommissioning	**Receptor** (Seabed, with particular focus on areas within designated sites, including Turbot Bank, as well as at other receptor locations - see Volume 2, Figure 6.1)
Potential changes in morphology of the coast	Presence of cable protection Cable burial activities Open-cut trenching at landfall	Construction O&M Decommissioning	**Receptor** (The coast)

6.4.11 Standard Mitigation

6.4.11.1 A range of standard mitigation measures has already been applied to the Project, as part of the over-arching site selection and iterative design process (see below and Chapter 3: Site Selection and Alternatives). These have been introduced to minimise (or avoid) potential effects of the Project on any affected receptors.

6.4.11.2 Standard mitigation measures which the Project has already implemented, or is committed to in the future, to minimise (or avoid) potential effects of the Proposed Development are listed in Table 6.9. The EIA is based upon the mitigated design.

Table 6.9 – Standard (Embedded) Mitigation Relevant to Marine and Coastal Processes

Parameter	Mitigation Embedded into Project Design
Array Area and ECC	Scour protection will be used where infrastructure cannot be buried and the bed is erodible.
ECC	Careful routing of the ECC to avoid sensitive features.
	Where practicable, cable burial will be the preferred means of cable protection. This will minimise the requirement for surface laid protection.
	All material that is dredged from the seabed will be disposed of close to the dredge location (within 200 m) to ensure material is retained within the local sediment transport system.
	A Cable Burial Risk Assessment (CBRA) will be undertaken to enable informed judgments with regards to burial depth. This should maximise the chance of cables remaining buried whilst

Parameter	Mitigation Embedded into Project Design
	limiting the amount of sediment disturbance to that which is necessary.
	Development of, and adherence to, a Cable Specification and Installation Plan (CSIP) post consent (if granted), which sets out measures to minimise adverse effects to potentially sensitive receptors.
Landfall	Preferred use of HDD to minimise disturbance at the nearshore and beach.

6.4.12 Additional Mitigation and Assessment for Residual Effect Significance

6.4.12.1 The assessments and conclusions on significance of effect presented in Section 6.6 assume that these standard mitigation measures listed above (Table 6.9) have been successfully implemented. Where significant effects remain, even after these standard measures have been factored in, then project-specific mitigation measures are detailed, and the residual significance of effect presented.

6.4.13 Limitations to Assessment

6.4.13.1 Pre-existing bathymetric surveys, i.e. surveys undertaken before the project-specific surveys in 2020/21 which achieved full coverage of the array/ECC, are only available for some of the array area and ECC and are also of variable resolution. This has inhibited accurate determination of bedform migration rates in some areas.

6.4.13.2 Uncertainty exists with regards to characterisation of the future baseline. Key areas of uncertainty include the extent to which future changes in storminess may occur and the potential associated changes to the wave regime. There is also considerable uncertainty with regards to exactly how the coast may respond to a modified wave climate acting in combination with higher than present sea levels. Finally, there is uncertainty with regards to the future management measures at the landfall and the extent to which the coast will be defended here in future.

6.5 Baseline Conditions

6.5.1 Overview

6.5.1.1 Baseline understanding of marine and coastal processes within the Study Area has been developed through consideration of a range of project-specific and existing data sources. The data have been supported by numerous other studies and reports which are referenced as appropriate in the baseline and assessment. The data used to support the assessment are outlined in Table 6.10.

Table 6.10 – Data Used in the Marine and Coastal Processes Assessment

Source	Summary	Coverage
Site geophysical survey (GEOxyz, 2021)	Bathymetry and geophysical data	Array area

Source	Summary	Coverage
Site geophysical survey (Rovco, 2021a)	Bathymetry and geophysical data	Array area (initial overview) and ECC
Site environmental survey (Rovco, 2021b; Ocean Ecology, 2021)	Seabed habitat data PSA data Water quality data (including SSC)	Array area and ECC
Shallow sub-tidal snorkel survey (Moore, 2021)	Survey of shallow subtidal habitats in West Angle Bay	Landfall
Site metocean survey (Partrac, 2020)	Floating LiDAR (wind data), wave buoy with downward looking current profiler (wave, water level and current data). [Deployment commenced August 2020 and is ongoing. Approximately 3 months of data available at the time of writing]	Array area
Intertidal habitat survey (Ocean Ecology, 2020)	Unmanned Aerial Vehicle (UAV) mapping Core sampling Photographs	Landfall
Project specific numerical modelling (ABPmer)	High-resolution tidal and sand transport models.	Array area, ECC and landfall
Lle and Welsh Coastal Monitoring Centre geoportals (including LiDAR) http://lle.gov.wales/home https://www.wcmc.wales/	Welsh coastal survey data including LiDAR (from 2004 and 2012) and beach topographic survey data (from 2019).	Array area, ECC and landfall
National Tide and Sea Level Facility (NTSLF) https://www.ntslf.org/	Tidal water levels from tide gauge stations	Array area, ECC and landfall
British Oceanographic Data Centre (BODC) https://www.bodc.ac.uk/	Hydrodynamic data from point locations across the Study Area	Array area and ECC
BGS Strategic Environmental Assessment data portal https://webapps.bgs.ac.uk/data/sea/app/search	Geophysical, geotechnical and benthic data from the Study Area	Array area and ECC
Cefas WaveNet	Wave buoy data	Array area and ECC

Source	Summary	Coverage
https://www.cefas.co.uk/cefas-data-hub/wavenet/		
UKCP18 climate change projections https://ukclimateprojections-ui.metoffice.gov.uk/ui/home	Projections in change to mean sea level (Palmer *et al.* 2018)	Array area, ECC and landfall
British Geological Survey (BGS) offshore geoindex https://www.bgs.ac.uk/GeoIndex/offshore.htm	Data on seabed sediments and geology	Array area, ECC and landfall
United Kingdom Hydrographic Office (UKHO) https://seabed.admiralty.co.uk/	Multibeam and single beam bathymetry data, co-tidal charts and flow regime (TotalTide).	Array area and ECC
Countryside Council for Wales (CCW)	Multibeam survey of Turbot Bank (2012)	Turbot Bank
ABPmer SEASTATES https://www.seastates.net/	Hindcast wave data, water level and current data	Array area and ECC

6.5.1.2 Project specific water quality sampling stations (which included the collection of SSC data) were selected where the proposed ECC intersected the Milford Haven Outer and Pembrokeshire South Water Framework Directive (WFD) coastal waterbodies. A total of 26 sampling stations were positioned along the centre of the offshore export cable routes at approximately 500 m intervals.

6.5.1.3 An initial Project ground model has been developed by the Applicant to support concept engineering. This model incorporates Project specific and existing geophysical and geotechnical information and helps inform (amongst other things) understanding of morphological change to the seabed within and nearby to the array area and ECC. The datasets used to inform the Project ground model are set out in Table 6.11 below.

Table 6.11 – Survey and Geological Data used to Inform the Project Ground Model

<table>
<tr><th>Year</th><th>Data Type</th><th>Source</th><th>Summary</th></tr>
<tr><td>2021</td><td>• Bathymetry (depth, backscatter);
• Sidescan Sonar (high and low frequency);
• Sub-bottom Profiler (high frequency parametric and low frequency sparker);
• Magnetometer; and
• Geotechnical CPT and vibracores</td><td>GEOxyz</td><td>Geophysical survey of the array area only; high resolution, full coverage.

Geotechnical campaign of the array area and ECC and nearshore.</td></tr>
<tr><td>2020</td><td>• Bathymetry (depth, backscatter);
• Sidescan Sonar (high and low frequency);
• Sub-bottom Profiler (high frequency parametric and low frequency sparker);
• Magnetometer; and
• Environmental camera, water sampling and grabs (including Particle Size Analysis – PSA).</td><td>Rovco</td><td>Geophysical and environmental data available for array area, ECC and nearshore.</td></tr>
<tr><td>Various</td><td rowspan="3">Bathymetry</td><td>EMODnet</td><td>Low resolution (200 m) dataset</td></tr>
<tr><td>2011-2013</td><td>UKHO</td><td>Various surveys, 1 m to 4 m resolution. No data at the Milford Haven port entrance or around the Project and Valorous sites.</td></tr>
<tr><td>2017</td><td>SEACAMS</td><td>High-resolution (0.5 m) dataset sourced from Bangor University for the Welsh Nearshore area. A sediment filled channel is present within the bedrock.</td></tr>
<tr><td>1972-2012</td><td>Regional geology and historical geotechnical information.</td><td>BGS</td><td>Regional geological boundaries and model. No indication of sediments below seabed level and based on coarse sampling interval.</td></tr>
<tr><td>Various</td><td>Admiralty Charts</td><td>MarineFind</td><td>General wreck/bathymetric information for navigation and only as accurate as the data that are used to create them (i.e. any new infrastructure/discovered wrecks may not be present).</td></tr>
</table>

6.5.2 Water Levels

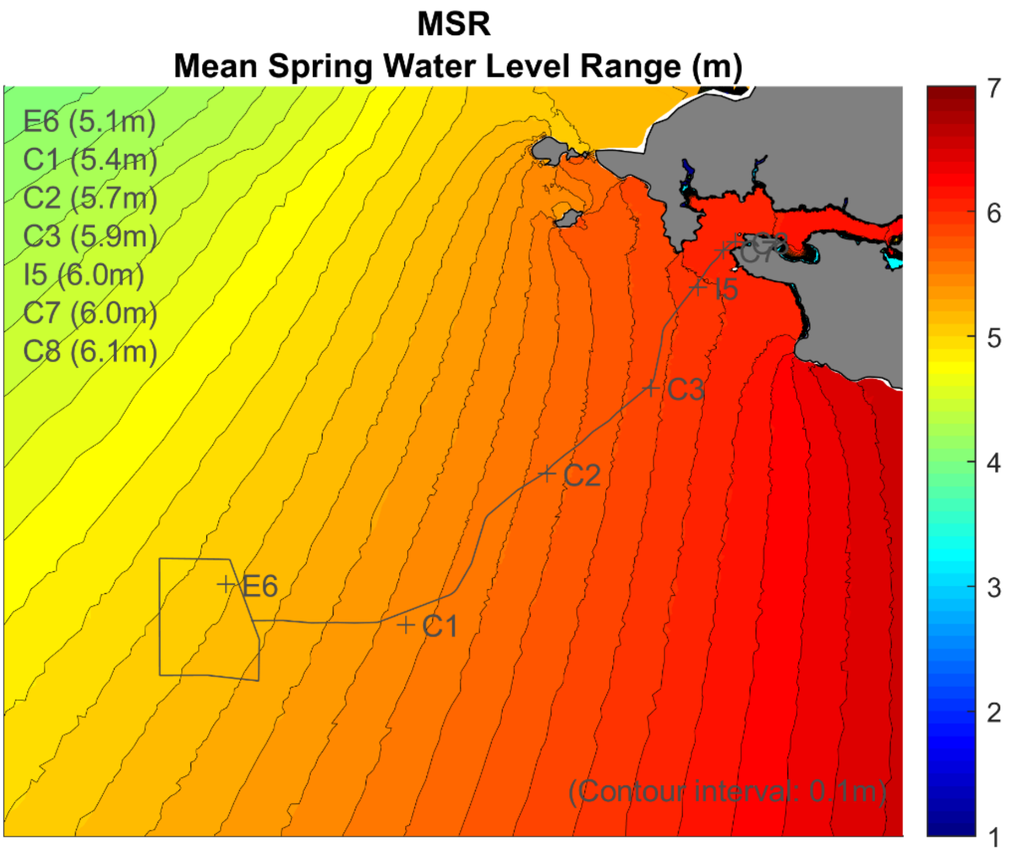
6.5.2.1 The normal tidal range within the wider Study Area is relatively large (macro-tidal). This is consistent with its close proximity to the Bristol Channel and Severn Estuary, which have some of the largest tidal ranges in the world. UKHO Admiralty tide tables (Table 6.12) show that the inner Milford Haven waterway report a mean spring tide range of 6.3 m. Maps of mean spring and mean neap tidal range determined from a project specific high-resolution hydrodynamic model are shown in

6.5.2.2 Graphic **6.1** and Graphic 6.2, respectively. The mean spring tide range decreases gradually and only slightly along the length of the ECC, from 5.1 m at the landfall itself to a mean spring tide range of 5.1 m in the array area. Tide range on a mean neap tide is approximately half the spring tide value.

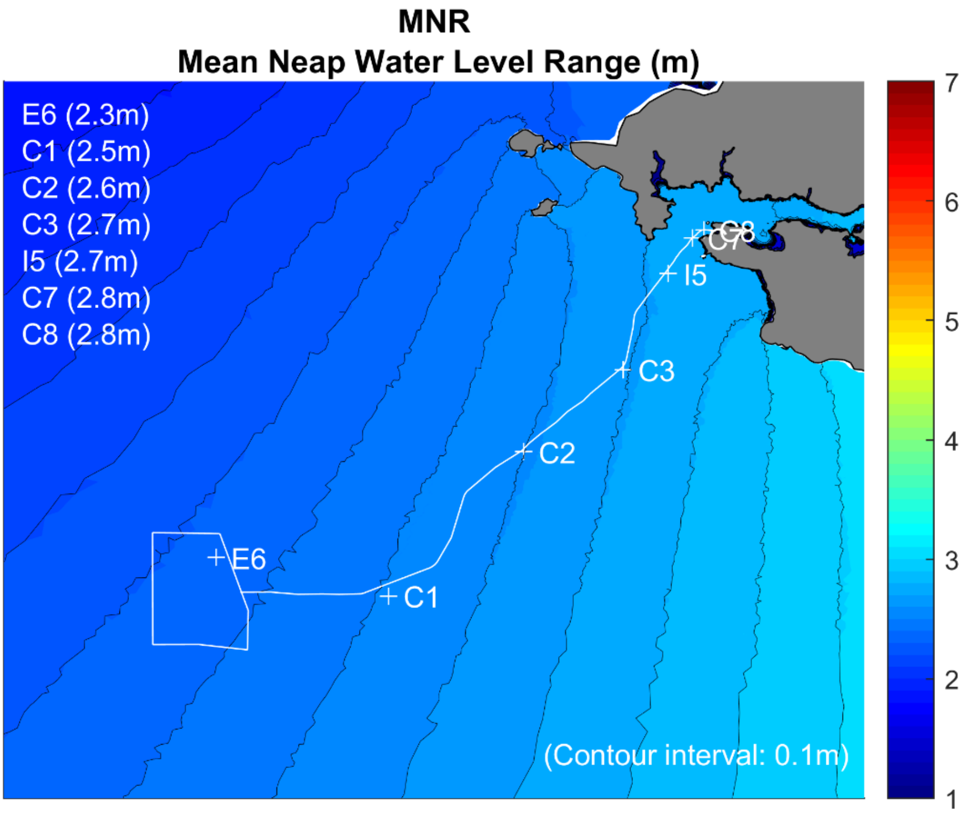
Table 6.12 – Tidal Water Levels at Milford Haven

Tidal level	Elevation (mCD)	Elevation (mODN)
Highest Astronomical Tide (HAT)	7.8	4.09
Mean High Water Spring (MHWS)	7.0	3.29
Mean High Water Neap (MHWN)	5.2	1.49
Mean Sea Level (MSL)	3.85	0.14
Mean Low Water Neap (MLWN)	2.5	-1.21
Mean Low Water Spring (MLWS)	0.7	-3.01
Lowest Astronomical Tide (LAT)	0.0	-3.71
Astronomical Tide Range	7.8	
Mean Spring Range (MSR)	6.3	
Mean Neap Range (MNR)	2.7	

Source: UKHO (2020)

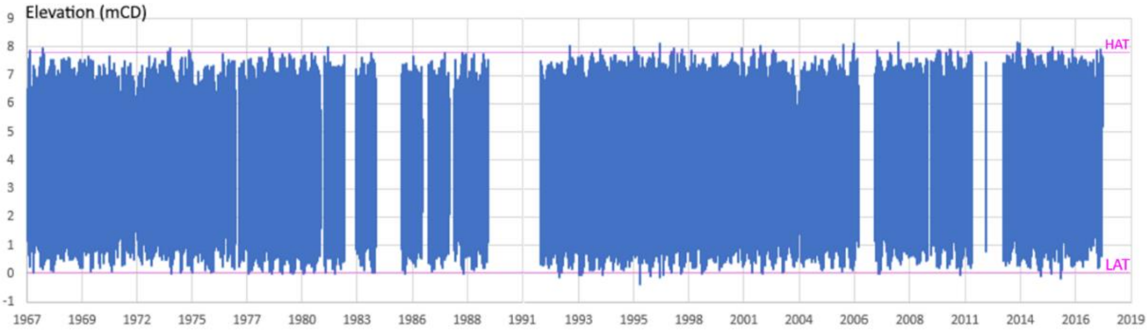


Graphic 6.1: **Tidal Water Level Range (Mean Spring Tide)**



Graphic 6.2: **Tidal Water Level Range (Mean Neap Tide)**

6.5.2.3 Meteorological surges can result in larger than predicted tidal water level ranges, associated with storm events and extremes of barometric pressure. Measured water level data from the National Tide and Sea Level Facility (NTSLF) tide gauge at Milford Haven in Graphic 6.3 shows the range of water level variance between 1967 and 2018. Occurrences of low water levels (slightly) below the LAT elevation and high-water levels (slightly) above that of HAT are evident throughout the record but make only a small relative difference to the overall, tidally dominated water level range.



Source: NTSLF

Graphic 6.3: **Milford Haven measured water levels (1967 to 2018)**

6.5.2.4 The peak measured water level of 8.18 mCD, occurred on 10 March 2008 at 07:45. This coincided with the time of high water on a large spring tide, combined with a moderate surge tide of 0.77 m. The five largest water level events are provided in Table 6.13 giving a breakdown of the astronomic tide and meteorological surge component for each.

6.5.2.5 Each of the top five measured water levels results from a combination of high water on a large spring tide with the additional influence of a moderate meteorological surge. Larger surge events, coincident with lower astronomic water levels, do not generally appear to result in the largest measured water levels, suggesting that tidal processes tend to dominate such events within the Milford Haven waterway.

Table 6.13 – Top Five Peak Measured Water Levels at Milford Haven (1967 to 2018)

Tidal level	Elevation (mCD)		Surge (m)
	Measured	Predicted	
10 March 2008 07:45	8.18	7.41	0.77
3 February 2014 08:30	8.14	7.56	0.58
2 March 2014 06:45	8.13	7.67	0.46
10 February 1997 08:15	8.12	7.73	0.39
8 October 2006 18:45	7.74	7.74	0.37

Source: NTSLF (2021) and UKHO (2020)

6.5.3 Tidal Currents

6.5.3.1 Tidal currents in the Study Area are generally directed from the west-northwest to east-southeast on the flood and reverse in direction on the ebb. Tides are semi-diurnal (i.e. two low waters and two high waters each day). Tidal currents are relatively rectilinear (i.e. closely aligned to the tidal axis throughout the tidal cycle) closer to the coast, but become more rotational with distance offshore. This effect is illustrated by the changing relative width of the tidal ellipses in Volume 2, Figure 6.3, which describe the approximate path of displacement for water during one complete tidal cycle.

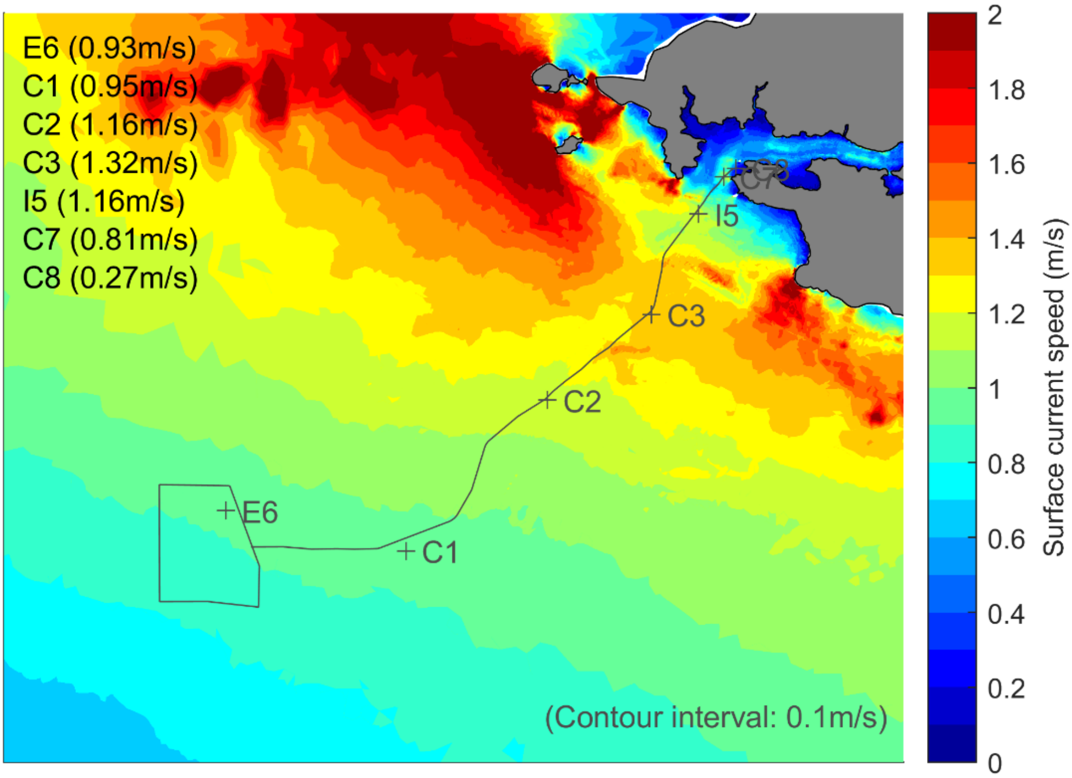
6.5.3.2 The regional distribution of peak tidal current speed is provided by the UKMRER (ABPmer *et al*., 2008b) for mean spring conditions, and by the Project specific high resolution baseline tidal model in Graphic 6.4 (to Graphic 6.6) and Graphic 6.7 for mean spring and mean neap conditions, respectively. The figures indicate that peak current speeds are 0.6 to 0.8 m/s on a mean spring tide within the array area, increasing with distance along the ECC towards the adjacent coastline, up to 1.0 to 1.4 m/s nearshore, decreasing again within Milford Haven Estuary (0.4 to 0.6 m/s on a mean spring tide). Peak current speed on a mean neap tide is approximately half the corresponding mean spring value.

6.5.3.3 The tidal ellipses in Volume 2, Figure 6.3 indicate the maximum tidal excursion distance and general orientation (accounting for rotation of the tide during the tidal cycle). In mean spring tidal conditions, the approximate tidal excursion distance is: 10 km in the array area; 14 to 15 km in the middle of the ECC (around KP20) and 18 to 19 km nearshore (around KP10). Tidal excursion distance on a mean neap tide (not shown) is approximately half the corresponding mean spring value. This distance is a naturally limiting factor when assessing the maximum likely extent of sediment plumes - see Section 6.6.

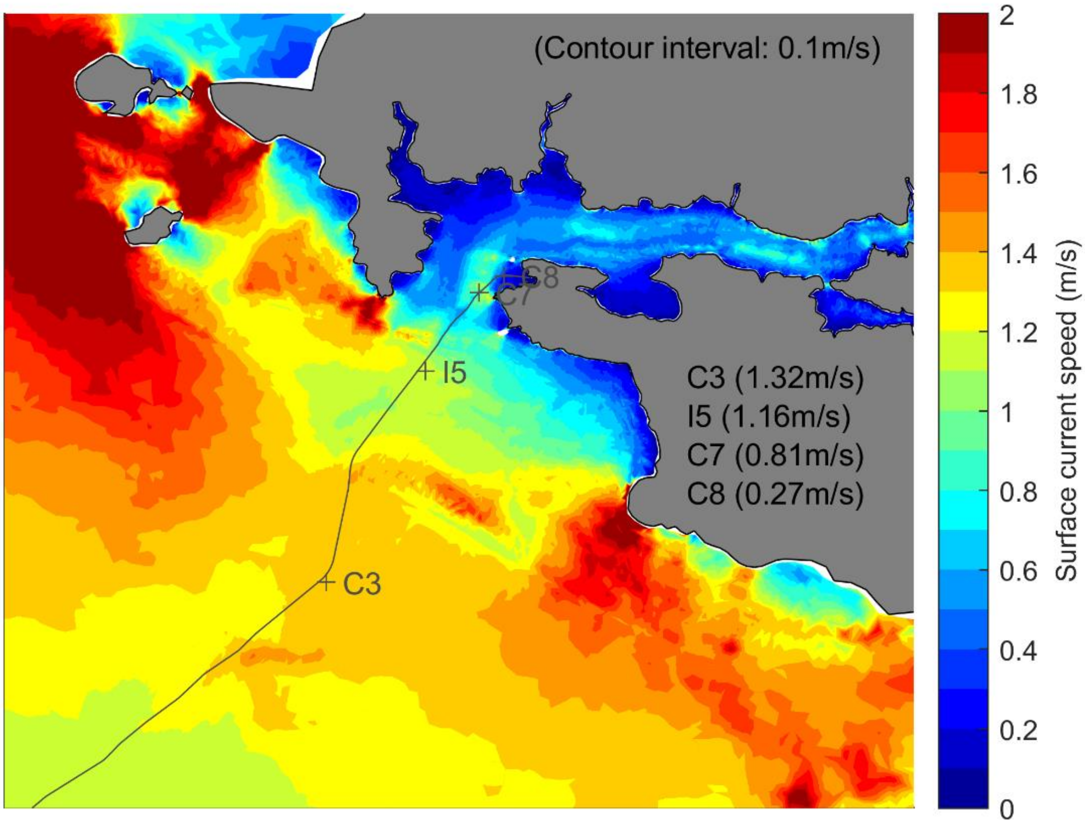
6.5.3.4 The large tidal range means that water exchange and movement through the Milford Haven estuary is also significant. The length of tidal excursion varies throughout the estuary. Williams and Jolly (1975) have suggested an average value of 8 to 10 km on spring tides and 4 to 5 km on neap tides.

6.5.3.5 The rectilinear (rotational) nature of tidal currents offshore, becoming more pronounced in the vicinity of the array area (indicated by the rounded ellipses Volume 2, Figure 6.3) is also evident in Graphic 6.8; which shows measured current data collected from the array area as part of the Project specific metocean survey. This shows that the current speed during spring tidal periods does not decrease below approximately 0.25 to 0.4 m/s, respectively, on the two spring periods shown, i.e. with no slack water period. Rather, there is a correspondingly wider range of current direction as the tide rotates throughout the tidal cycle, as well as accelerating and decelerating during each flood and ebb period. The minimum current speed during spring tides and the degree of rotation will decrease gradually with distance along the ECC in proportion to the width of the tidal ellipses.

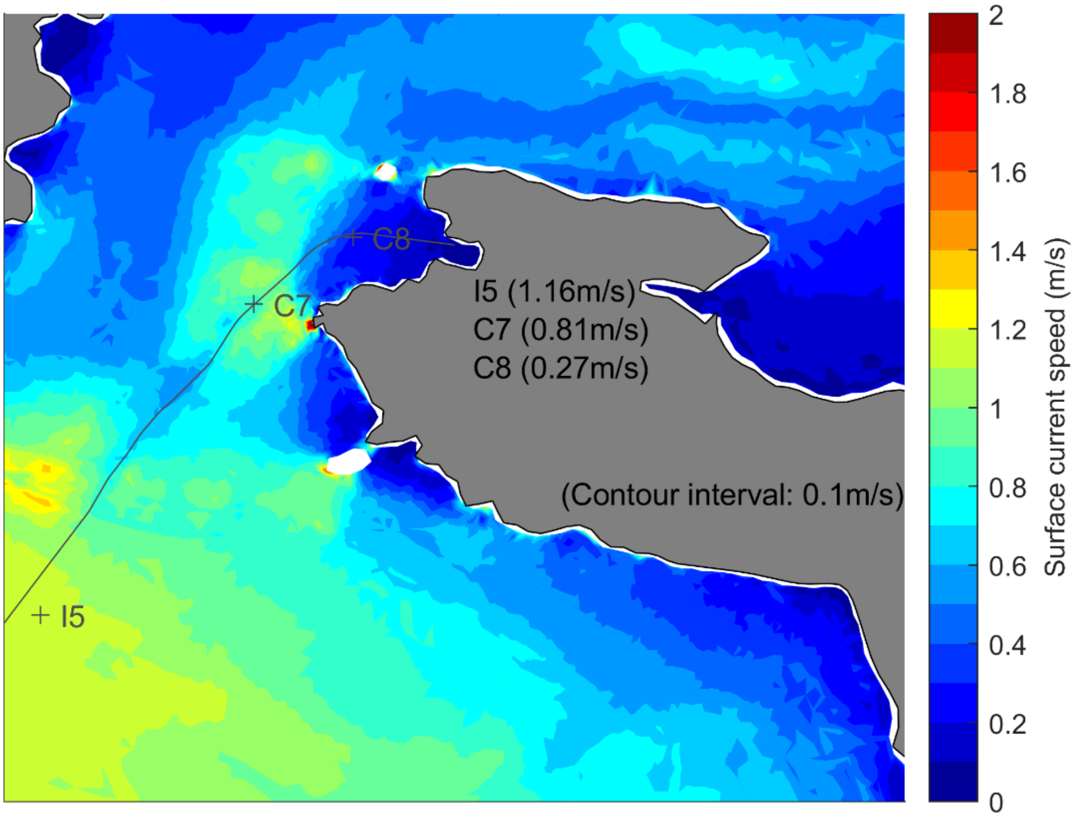
6.5.3.6 Summary current roses (Graphic 6.9) for the Study Area and three analysis locations, and based on 40 years of SEASTATES data, also reflect the predominant west-northwest/east-southeast tidal current axis along the ECC, approximately parallel to the adjacent coastline. Consistent with Volume 2, Figure 6.3 and Graphic 6.4 to Graphic 6.7, current speeds generally increase with distance along the ECC toward the approaches to Milford Haven.



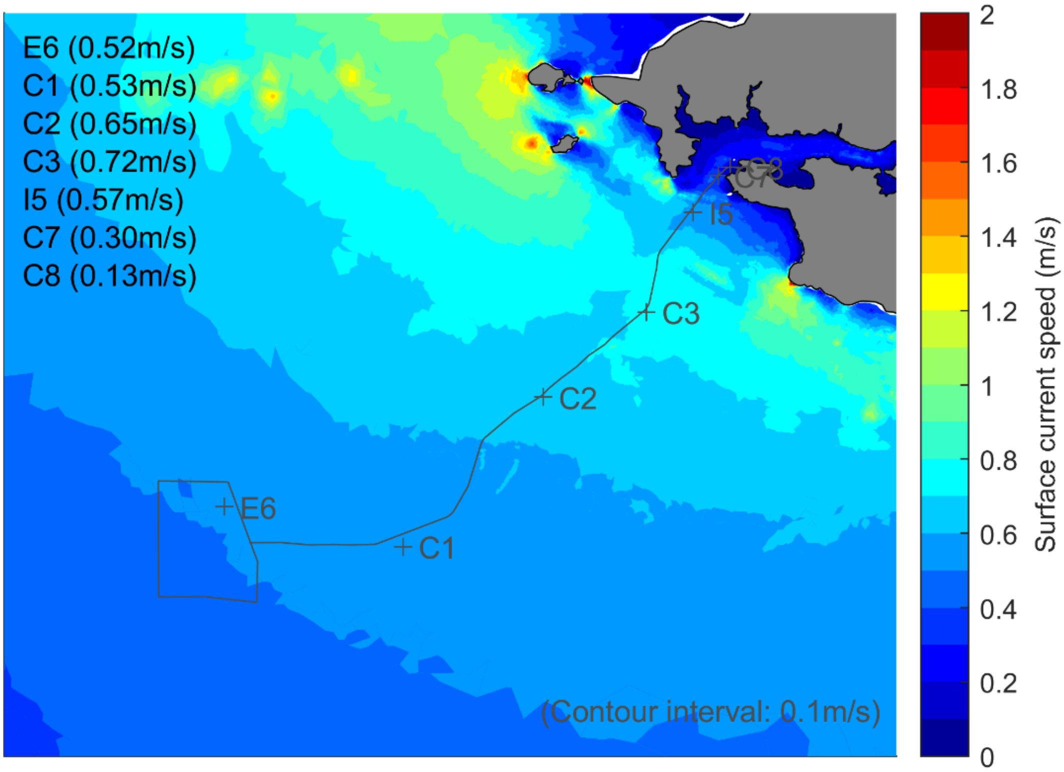
Graphic 6.4: **Peak Current Speed (Mean Spring Tide) – Whole array area and ECC**



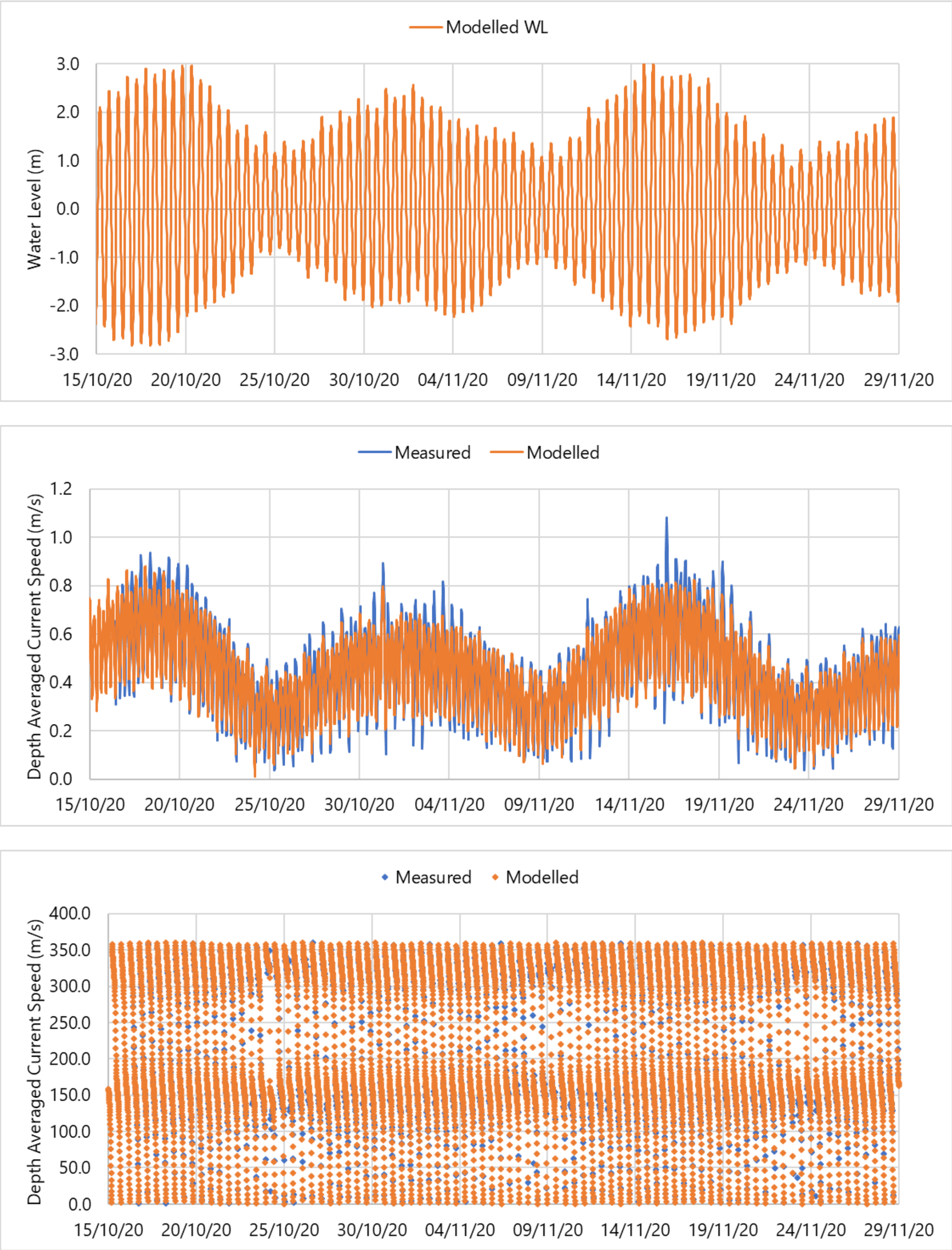
Graphic 6.5: **Peak Current Speed (Mean Spring Tide) – Nearshore parts of the ECC**



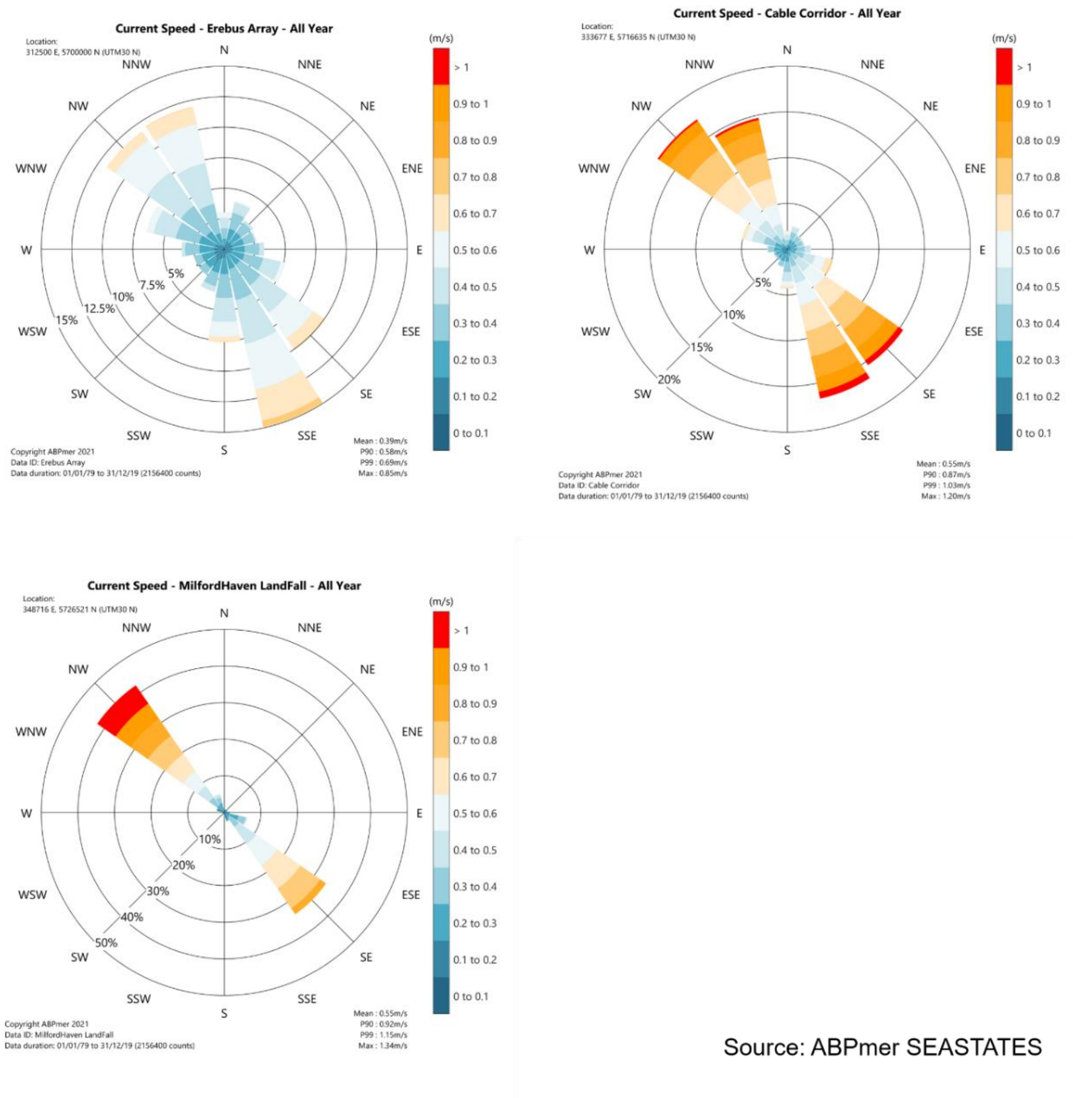
Graphic 6.6 Peak Current Speed (Mean Spring Tide) – Approaches to Milford Haven and West Angle Bay



Graphic 6.7 Peak Current Speed (Mean Neap Tide) – array area and ECC



Graphic 6.8 Comparison of measured (Project metocean survey) and modelled (SEASTATES hindcast) current data within the array area. Water levels from model only



Source: ABPmer SEASTATES

Graphic 6.9: **All-year Tidal Current Roses Across the Study Area**

6.5.3.7 Predicted tidal flows within the entrance channel to Milford Haven have been extracted from the UKHO Admiralty Tide Tables and are presented in Table 6.14 (see Volume 2, Figure 6.2 for location). Peak values on a mean spring tide are around 0.6 m/s on both flood and ebb tidal phases. Neap tide values tend to be around half of the spring values, peaking on flood and ebb at around 0.3 m/s.

Table 6.14 – Predicted Spring and Neap Tidal Flows within Entrance to Milford Haven

Tidal state (h)	Flow direction (°N)	Mean spring rate (m/s)	Mean neap rate (m/s)
Tidal Diamond SN050F (51°41.13'N 5°08.86'W)			
-6	-	0.00	0.00
-5	013	0.15	0.05

Tidal state (h)	Flow direction (°N)	Mean spring rate (m/s)	Mean neap rate (m/s)
-4	023	0.41	0.21
-3	027	0.57	0.26
-2	023	0.51	0.26
-1	017	0.36	0.15
HW	354	0.15	0.05
+1	214	0.26	0.10
+2	207	0.46	0.21
+3	207	0.57	0.26
+4	200	0.57	0.26
+5	187	0.31	0.15
+6	120	0.05	0.05

Source: UKHO (2020)

6.5.4 Wind and Wave Climate

6.5.4.1 Waves within the Bristol Channel are driven by the wind regime, with the largest waves being a result of winds from the longest fetch direction from the southwest, across the Atlantic Ocean. Exposure to largest waves is more pronounced on coasts and submarine shoals facing the longest fetch. Uncles and Stephens (2007) report that parts of the coast of this region are among the windiest in the UK, and that mean hourly coastal wind speeds exceed approximately 3.5 m/s for 75% of the time, and exceed 19 m/s for approximately 0.1% of the time. Uncles and Stephens (2007) also indicate that dominant southwesterly winds blow for approximately 20% of the time, whereas winds from the east blow for about 9% of the time. Uncles and Stephens (2007) conclude that the significant wave height (Hs) in the outer reaches of the Bristol Channel and St George's Channel is greater than about 3 m for 10% of the year (compared with a predicted 50-year extreme of 18 m).

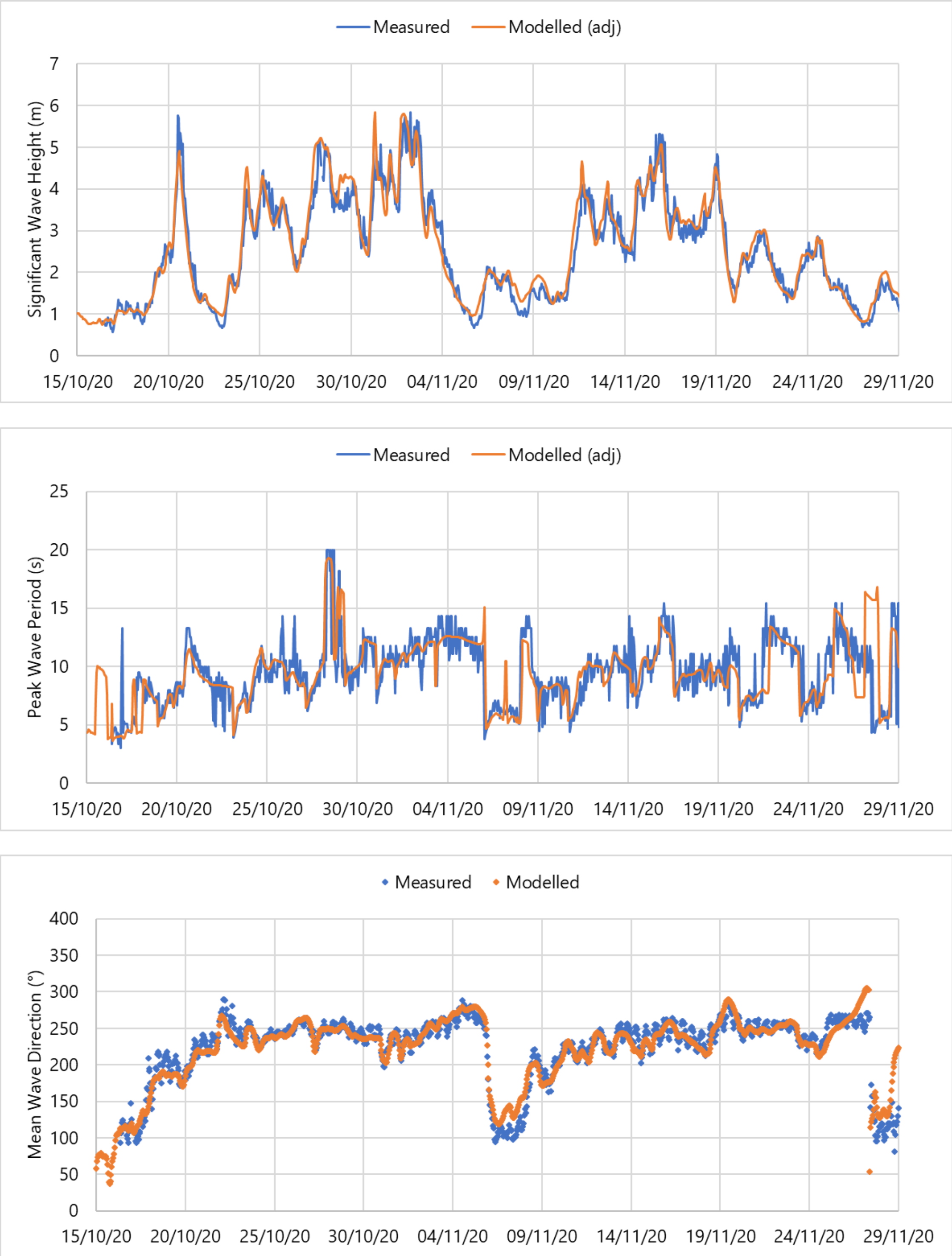
6.5.4.2 Data available from the UKMRER (ABPmer *et al.* 2008b), and shown in Volume 2, Figure 6.4 suggest that both the array area and the wider Study Area generally lie in a zone where the mean Hs is in the range of 1.5 to 2 m, with generally decreasing wave energy to the northeast, towards the adjacent coastlines.

6.5.4.3 Additional data were extracted from the European Shelf Wave Hindcast database for three locations (see Volume 2, Figure 6.2), in the array area and in a central and nearshore location on the ECC, for the 40-year period between 1979 and 2019. The SEASTATES model is validated against measured data from the Project metocean survey (centrally located in the array area) in Graphic 6.10. (The survey is ongoing but data from 31 August 2020 to 30 November 2020 are available at the time of writing). The SEASTATES wave hindcast model data has been adjusted downwards (for all sites) by 10% for Hs and √10% for wave period, to optimise agreement with the measured Hs values and to evenly scale the overall wave energy.

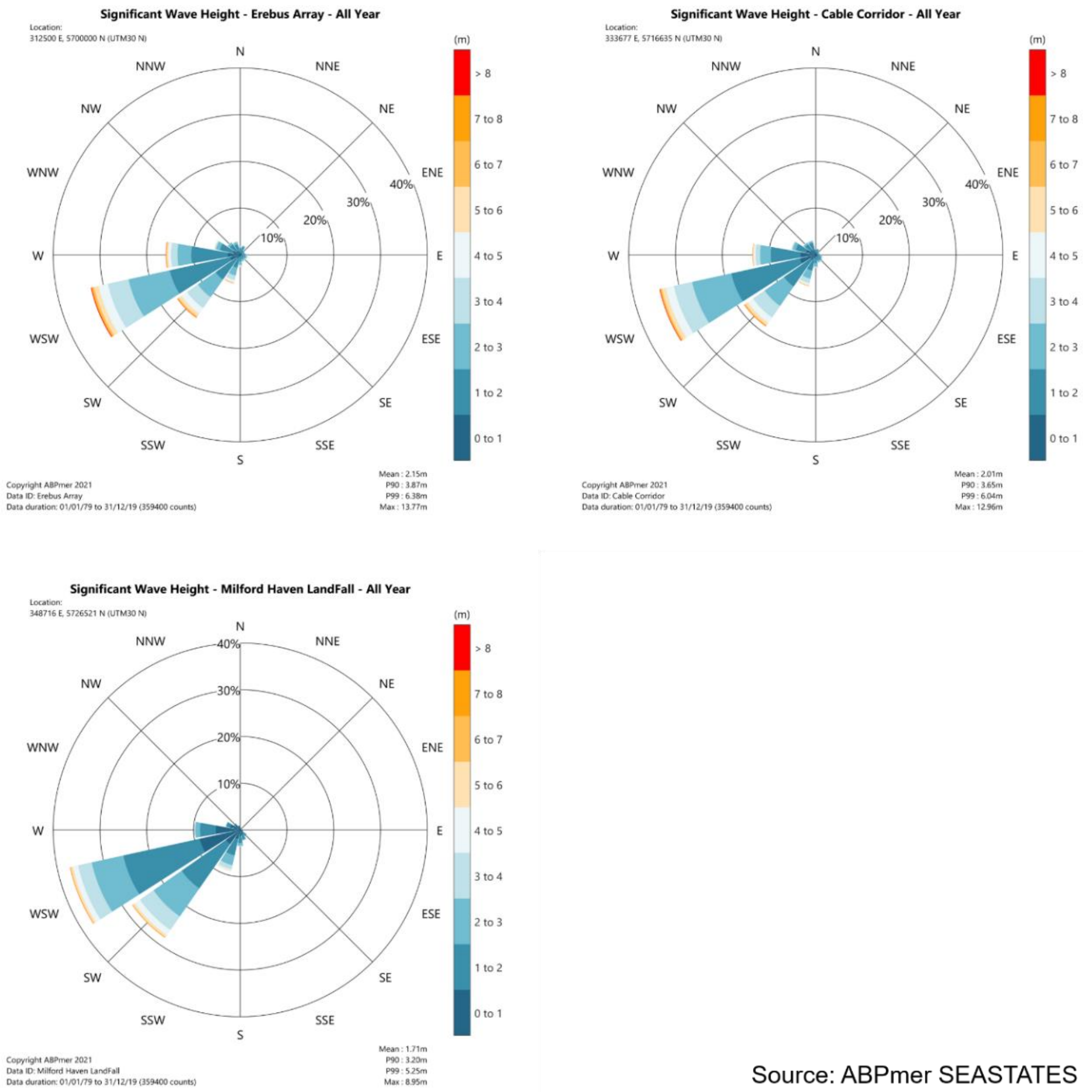
6.5.4.4 Summary wave roses for each location based on the 40 years of SEASTATES data (Graphic 6.11) show waves predominantly approaching from the west-southwest, with extreme Hs values greater than 8 m. The adjusted mean Hs in the array area is 1.89 m. As would be expected, waves tend to be larger offshore, reducing with proximity to the coast and shallower water depths inshore.

6.5.4.5 Another desk-based Metocean study undertaken for the array area (WaveVenture, 2019) found a similar annual mean Hs of 1.91 m for the 26 year period between January 1990 and September 2016, extracted from the ‘ATNE10m’ wave database.

6.5.4.6 Fairley et al. (2017) have previously considered wave buoy data to assess the wave climate off Pembroke. Data was acquired from the UK Met Office for the Turbot Bank buoy (see Volume 2, Figure 6.2), with analysis carried out for the period 01/09/1994 to 30/04/2014. The 100 year return extreme wave height is estimated as 12.5 m and the 10 year return mean wave period as 19 seconds.



Graphic 6.10 Comparison of Measured (Project Metocean Survey) and Modelled (SEASTATES Hindcast) Wave Data within the Array Area

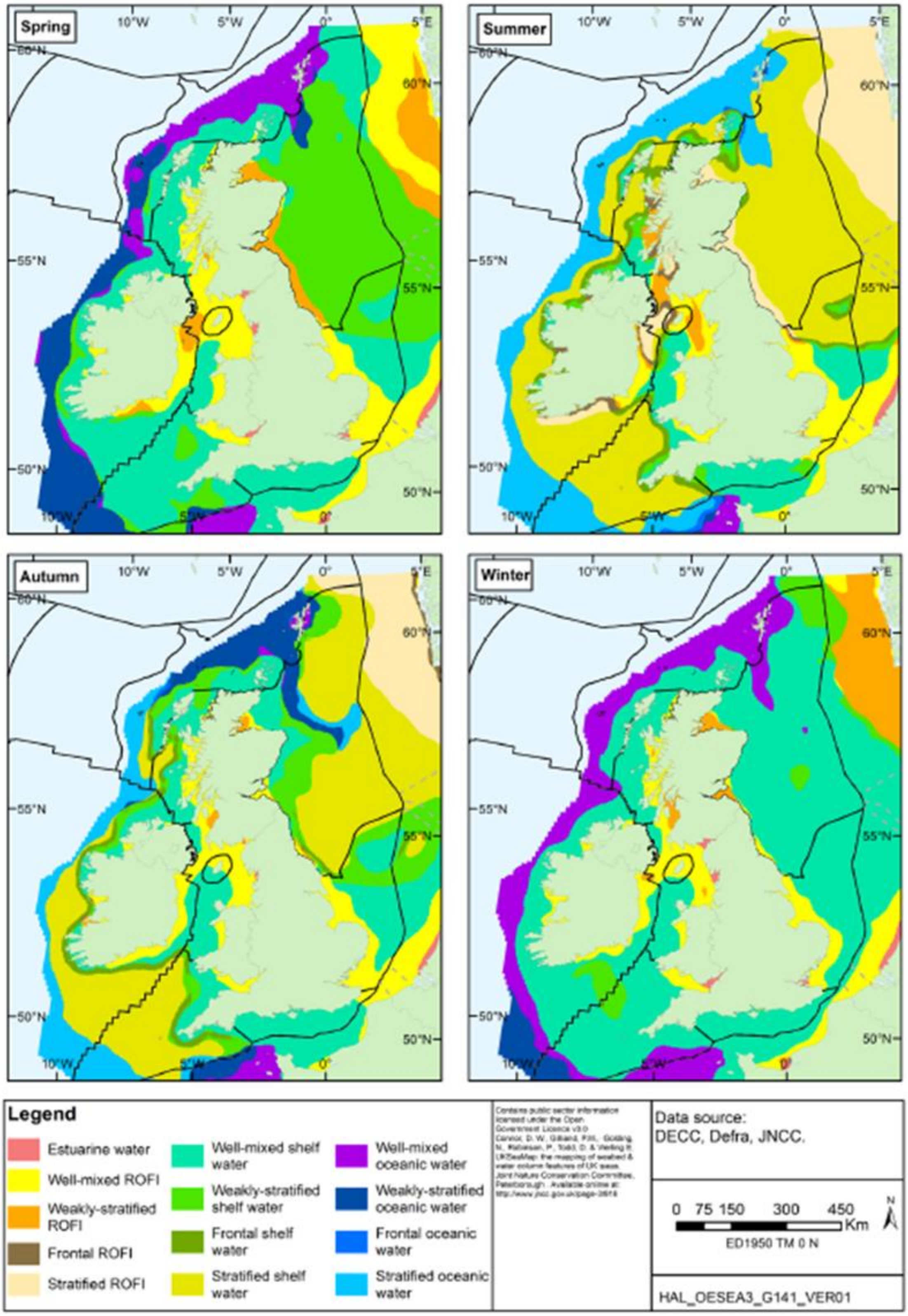


Source: ABPmer SEASTATES

Graphic 6.11 All Year Wave Roses for Three Locations (see Volume 2, Figure 6.2) in the Study Area

6.5.5 Stratification and frontal systems

6.5.5.1 A discontinuity in sea surface temperatures is often observed in the Celtic Sea during the summer periods, indicating a boundary between stratified and vertically mixed regimes during summer months (DECC, 2016). This regional scale stratification is illustrated in Graphic 6.12.



Graphic 6.12 Seasonal Stratification (Source: Department for Business, Energy and Industrial Strategy (2016)

6.5.6 Bathymetry

6.5.6.1 A general summary of bathymetric conditions across the Study Area is set out in the Project ground model based on a range of data sources (Table 6.11). The dominant bathymetric feature of the wider region is the wide trough along the length of the St George's Channel (to the northwest of the array area, between the western-most point of Wales and Wexford in Ireland), where maximum depths are in excess of 100 m below LAT. To the south of the Study Area, within the approaches to the Bristol Channel, main channel depths reach up to 70 to 80 m below LAT. In general, bathymetries shoal to the east, into the Bristol Channel, and water depths reduce further into the Severn estuary.

6.5.6.2 Within the array area, water depths range from around 85 to 65 m below LAT, and from around 70 to 0 m below LAT along the ECC (). Bed slope gradients are generally shallow (average values are typically 1° or less across the wider area) but increase up to 6° along the ECC, primarily associated with large sedimentary bedforms (sandwaves).

6.5.6.3 Volume 2, Figure 6.5 also provides a longitudinal profile of water depths along the ECC. This helps to illustrate where large bedform features within the Study Area overlap with proposed project elements.

6.5.7 Seabed Sediments

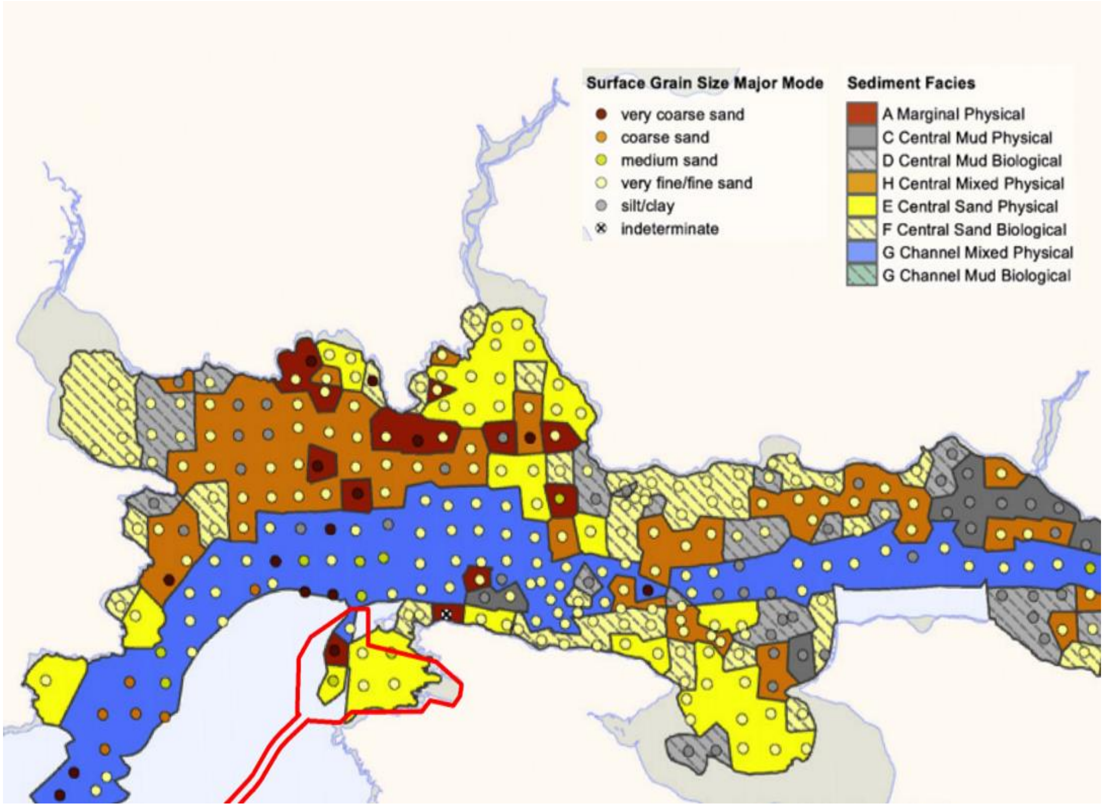
6.5.7.1 Interpolation of data collected during the preparation of the Project ground model provides detail on the likely seabed sediments, both within the array area and also along the ECC (Volume 2, Figure 6.6). More detailed interpretation of seabed sediments based on the project-specific geophysical data is also shown on Volume 2, Figure 6.6. Seabed sediments are characterised in Table 6.15, below:

Table 6.15 – Seabed Sediments Across the Array Area and ECC

Area*	Description
Northern half of the array area	Sandwave features, typically around 6 m, but up to approximately 11.5 m, height and with an average wavelength of around 240 m, comprised mainly of sand and with megaripples, above a thin veneer (1 to 2 m) of sand to gravelly or muddy sand (typically 10 to 20% but up to 50% fines), overlying Pleistocene glacial tills comprising a consolidated poorly sorted mixture of clay, sand, gravel, shells, cobbles and boulders.
Southern half of the array area and western half of the ECC (west of KP25):	A thin veneer (1 to 2 m) of sand, gravelly sand or muddy sand (typically 10 to 20% but up to 50% fines), with megaripples. Found overlying Pleistocene glacial tills comprising a consolidated poorly sorted mixture of clay, sand, gravel, shells, cobbles and boulders. Discreet area of high-density boulders identified between KP36 and KP47.
Eastern half of the ECC (KP25 to 5):	Local accumulations of sediment up to 7 m high/thick, comprising mainly sand and gravelly sand, with sandwaves and megaripples. Otherwise, a thin veneer (1 to 2 m) of sand to gravelly sand with sandwaves and megaripples, overlying Pleistocene glacial tills comprising a consolidated poorly sorted mixture of clay, sand, gravel, shells, cobbles and boulders. Discrete area of high-density boulders identified around KP15 and 19. Sandy gravel/gravelly sand observed between

Area*	Description
	approximately KP7 and 11, where the ECC passes approximately 2 km to the west of the main crest of Turbot Bank.
In the approaches to Milford Haven and West Angle Bay (KP5 to 3)	Rock platform (excluding Row's Rocks channel). Locally thin or absent veneer (<1 m) of sandy gravel or gravelly sand.
Within Row's Rocks channel and West Angle Bay (KP3 to 0):	Row's Rocks channel is incised into the bedrock platform and locally infilled with muddy sandy gravel and sands but also acoustically layered and likely to contain a significant fine-grained component in subsurface sediments. Sediments in Row's Rocks channel are typically 5 to 10 m thick, but thin rapidly at the channel sides where rock sub-crops occur. There are areas of sandy gravel and exposed bedrock in the approaches to West Angle Bay. There is a sandy beach of variable thickness overlying a rocky platform within the shallow subtidal, and intertidal parts of West Angle Bay.
* KP locations shown in Volume 2, Figure 6.1	

6.5.7.2 The general distribution of seabed surface sediments in the lower part of Milford Haven (i.e., in the approaches to the cable landfall) is shown in Graphic 6.13 (Carey *et al*., 2014). At the mouth, where the wave activity is greatest, the seabed and intertidal areas are largely comprised of exposed Sandstone bedrock or with coverage of coarse boulders or pebbles. Where tidal currents are relatively strong (and/or wave activity is high), sediments tend to be poorly sorted, although some well-sorted sands are located in sheltered areas, such as embayments. With increasing distance up-estuary, deposits vary through sands and shell/sand to muddier sediments within the inner Haven. Within West Angle Bay, offshore (shallow subtidal) sediment cover is dominated by coarse to medium sand, fining to fine/very fine sand within the inner parts of the bay.



Graphic 6.13 Seabed Sediments in Milford Haven (from Carey *et al*., 2014)

6.5.8 Subsurface Geology

Bedrock geology

6.5.8.1 The Bristol Channel is floored by Jurassic (201 million to 145 million years ago) and Triassic (252-201 million years ago) rocks with Palaeozoic (541 to 252 million years ago) rocks on the coastal margins. Westward, these are overstepped by the Cretaceous (145 to 66 million years ago) chalk that, in turn, is buried beneath Tertiary (66 million to 2.6 million years ago) strata. The central floor of the Bristol Channel comprises a submarine valley system, extending up into the Severn estuary, which was incised during the late Tertiary to early Quaternary (approximately 2.6 million years ago) (Evans 1982; Mackie et al., 2006). Mackie *et al.* (2006) report that the form and morphology of the present-day seabed includes elements directly related to the erosion and deposition associated with the formation of the submarine valley, e.g. rock platforms.

6.5.8.2 The dominant bedrock types identified in the Study Area are chalk (which is present within and nearby to the array area), mudstone, sandstone and limestone (along most of the ECC) and mudstone and halite in isolated areas (Tappin *et al*., 1994).

6.5.8.3 Bedrock is exposed at the seabed at various locations within the ECC between approximately KP4.2 and KP8.5, with additional areas of shallow bedrock <5 m below seabed present, intermittently, along the ECC. In the array area, bedrock (assumed chalk) is not exposed at the seabed at any point and the minimum depth below seabed it has been interpreted at, is 3.7 m. The deepest the top of bedrock has been observed is 82.4 m below seabed. In general, the top bedrock surface deepens to the west, with various channels incised into it (Rovco, 2021).

Quaternary Geology

6.5.8.4 During the Quaternary, glacial and interglacial events shaped the environment of this part of northwest Europe. During glacial periods regional sea levels were lower than the present (low stands), while during the inter-glacials sea levels were comparable to their current level (high stands).

6.5.8.5 St George's Channel lies in the middle of the Irish and Celtic Sea and was subject to extensive glaciation during the last glacial cycle (Hughes *et al.*, 2015). During the Quaternary the Irish Sea Glacier flowed southwards, on more than one occasion, through St George's Channel and into the northern Celtic Sea, transporting and depositing the Quaternary sediments present today.

6.5.8.6 Tappin *et al*. (1994) summarise the Quaternary Formations present in the Irish Sea and St George's Channel as consisting of the following (youngest to oldest):

- Western Irish Sea Formation;
- Cardigan Bay Formation;
- St George's Channel Formation; and
- Caernarfon Bay Formation.

6.5.8.7 The Cardigan Bay Formation makes up most of the Quaternary seabed deposits underlying St George's Channel and Cardigan Bay. The Cardigan Bay Formation is a till deposit, consisting of a stiff to hard clay containing varying amounts of sand, gravel, shell, cobbles and bounders.

6.5.8.8 Following analysis of the Project specific geophysical data, present maps showing interpreted thickness of recent (Holocene) sediment along the ECC and within the array area (Volume 2, Figure 6.7) along with depths to the top of the rock head (Volume 2, Figure 6.8). Variable thicknesses of recent (i.e. post-glacial Holocene) sediments are found along the ECC with deep glacial channels occurring in two places (~KP20 and 30), separated by a sub-crop of bedrock forming a buried rock plateau. Within the array area, Holocene sediments reach approximately 10 m thickness where sandwaves are present, whilst the older Pleistocene tills reach thicknesses in excess of 50 m in western areas.

6.5.8.9 Nearshore sediments within the Row's Rocks channel are acoustically layered and likely to contain a significant fine-grained component. Sediments are typically 5 to 10 m thick, but thin rapidly at the channel sides where rock sub-crops occur (Blue Gem Wind, in prep.).

6.5.9 Suspended Sediments

6.5.9.1 SSC is spatially and temporally variable throughout the Study Area, dependent on patterns of weather, currents, waves, water depth, local sediment type and proximity to sources of fine sediment input.

6.5.9.2 As part of the Project specific water quality survey, a total of 26 water samples were collected along the nearshore section of the ECC (Volume 2, Figure 6.2) (Ocean Ecology, 2021). The samples were collected in November 2020, during periods of relatively calm weather and seastate. SSC in the water samples range between <5 mg/l and 23 mg/l, with the latter recorded in the sample taken from the bottom of the water column at a sampling location situated just at the entrance to West Angle Bay (Table 6.16).

6.5.9.3 The WFD Directions (Environment Agency, 2015) reported that clear seawater has an annual mean concentration of suspended particle matter <10 mg/l, while seawater of intermediate turbidity has a suspended particle matter annual mean concentration between 10 and 100 mg/l. Based on these reference levels, nine samples had suspended solid concentrations typical of seawater of intermediate turbidity. All other samples and stations had suspended solid concentrations <10 mg/l indicating clear seawater.

Table 6.16 – Summary of Suspended Sediment Concentrations in Water Samples Collected During the Project Specific Water Quality Survey (November 2020)

Statistic	Sample Location	
	Water depths <10 m LAT	Water depths >10 m LAT
Max observed SSC at Seabed	20 mg/l	23 mg/l
Max observed SSC at surface	8 mg/l	11 mg/l
Min observed SSC at seabed	<5 mg/l	<5 mg/l
Min observed SSC at surface	<5 mg/l	<5 mg/l
Approx. average SSC at seabed	5 mg/l	6 mg/l
Approx. average SSC at surface	<5 mg/l	<5 mg/l
Max SSC at seabed during storms	Unknown but likely 100’s to 1000’s mg/l (or greater)	Unknown but likely 10’s to 100’s mg/l

6.5.9.4 The findings from the Project specific water and sediment quality survey data are consistent with the relatively good visibility in the lower water column which is normally observed along the ECC in the drop-down image and video footage collected as part of the environmental survey for the Proposed Development (Rovco, 2021b). However, visibility was noticeably reduced (indicative of relatively higher SSC) following a storm during the survey period.

6.5.9.5 Within Milford Haven, fine suspended sediment is input from a variety of sources, including urban and industrial developments at Milford Haven, Pembroke Dock and Haverfordwest; from riverine input at the head and from the Outer Bristol Channel at the mouth. The Eastern and Western Cleddau rivers are estimated to contribute around 20,000 tonnes of suspended material *per annum*, whilst remote sensing data indicate that the lower estuary holds around 10,000 tonnes of suspended matter (ABP R&C, 1996).

6.5.9.6 Water sampling was undertaken in the main channel of Milford Haven from approximately opposite West Angle Bay, for Pembrokeshire Power Station, and reported in ABP R&C (1996). In general, Milford Haven is understood to have a lower suspended load than other, similar UK estuaries, this is a result of the high proportion of hard rock seabed present in much of the lower estuary. Concentrations of material in suspension generally reduce with distance down-estuary within the Haven. Total Suspended Solids (TSS) concentrations generally ranged between 5 and 10 mg/l (with peaks of up to 44 mg/l). These findings are entirely consistent with that from the project specific water quality survey.

6.5.9.7 Mean surface concentrations of Suspended Particulate Material (SPM, mainly comprising sediment in suspension, but also other organic matter) have been assessed by Cefas (2016) using satellite data, calibrated against measurements from smart-buoys. SPM values are typically low across the Study Area but generally increase from offshore towards the coast, due to progressively shallower water depths, higher current speeds, and proximity to terrestrial sources of fine suspended material (rivers, estuaries, land run-off).

6.5.9.8 During summer months SPM concentrations increase from <1 mg/l across the proposed array area, to around 3 mg/l at the landward end of the ECC. Overall levels increase slightly during winter, but absolute concentrations are still relatively low, increasing from around 3 mg/l at the array area to approximately 8 mg/l in the approaches to West Angle Bay. It is noted, however, that locally stronger tidal currents around the Pembrokeshire coast can cause relatively high sediment resuspension and thus, higher SSC in these areas (DTI, 2007).

6.5.10 Sediment Transport and Bedform Migration

<u>Understanding of sediment transport from existing studies</u>

6.5.10.1 In comparison to other areas around the UK continental shelf (notably the Southern North Sea and Irish Sea), less research has been undertaken on sediment transport and bedform migration in this area. The Strategic Environmental Assessment (SEA) 8 Technical Report – Hydrography (DTI, 2007) - suggests that detailed sediment transport processes in the Celtic Sea and St George's Channel are generally poorly understood but are dominated by tidal currents, rather than waves. This is consistent with the UK scale sand transport mapping undertaken by Kenyon & Cooper (2005), which also suggests a dominant tidal influence on sand transport, with net movement of material to the west-southwest through the array and ECC.

6.5.10.2 Close inshore, the ES for the Greenlink interconnector (Greenlink, 2019) describes active sediment transport close to the beaches of South Pembrokeshire, with tidal and longshore sediment movement covering and exposing a fossil forest on the beach at Freshwater West (to the south of West Angle Bay). Due to the presence of a sandbank off the beach at Freshwater West, Greenlink (2019) also speculates that there may be a sediment transport pathway between the beach and the sandbank.

6.5.10.3 With regards to the proposed landfall location at West Angle Bay, Little (2009) employed sediment trends analysis to analyse the bedload transport pathways within Milford Haven. The results (summarised in Graphic 6.14) reveal a general up-estuary transport along the northern part of the Haven and within the central channel, with a returning down-estuary transport confined to the southern shelf, to West Angle Bay and the outer Bristol Channel. Transport pathways are driven primarily by the tidal regime within the estuary, with wave influence generally limited to the outer region around the entrance.

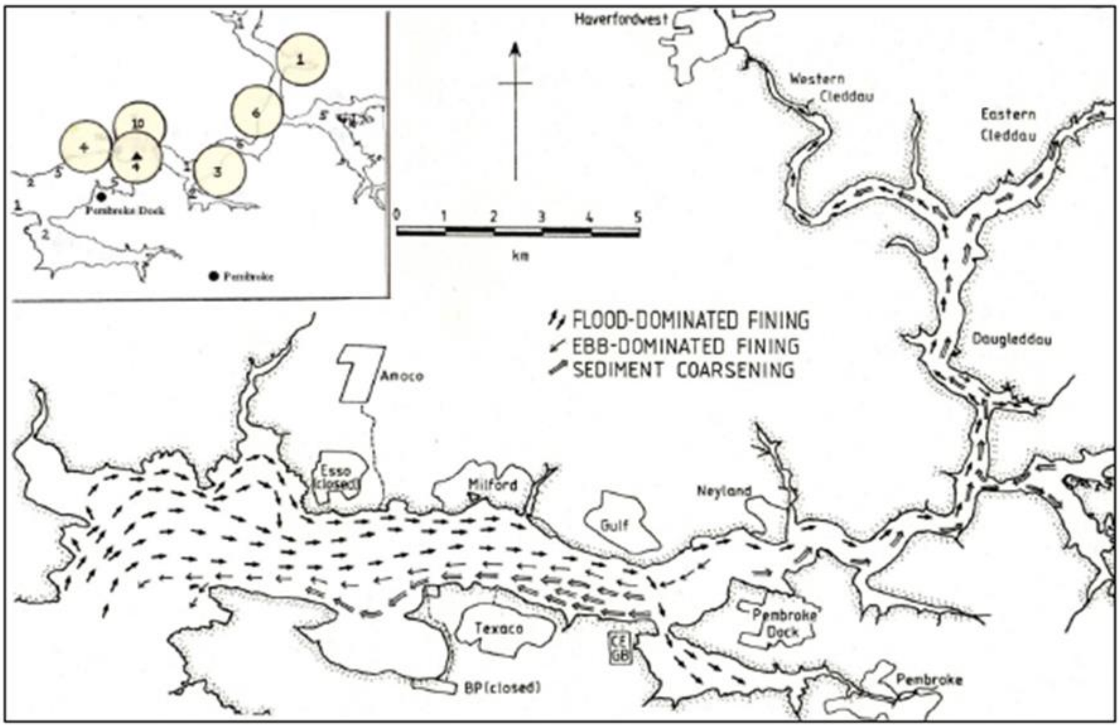
6.5.10.4 Recently, Coughlin et al. (2021) used numerical modelling to assess the role of currents and waves in driving seabed mobility throughout the Irish and Celtic Sea region. Exceedance frequency values were used to calculate a number of sediment disturbance and mobility indices with spatial variability illustrated through a series of mapped layers. On the basis of this research, the Project is found to be largely located within areas of seabed in which disturbance is dominated by tidal forcing rather than waves. Though, in shallower nearshore areas (out to ~KP15), waves become more important. It is also found that sediment mobility in the array area is very low, increasing with distance along the ECC, and with proximity to the coast.

6.5.10.5 King et al. (2019) also used numerical modelling to investigate the relationship between waves, tides and sediment transport processes in the Celtic Sea and have questioned earlier findings with regards to the dominance of tidally driven sediment transport in this region. Their analysis suggests that wave-tide interactions significantly, and in a non-linear manner, enhance sand transport within this macrotidal environment, with waves playing a greater role in than hitherto suggested. Median (50% exceedance) waves were found to enhance transport in the tidal direction whilst extreme (1% exceedance) waves can (occasionally and temporarily) reverse the dominant transport path, shift the dominant transport phase from flood to ebb, and activate sand transport below 120 m depth (i.e. to depths greater than observed in the array).

6.5.10.6 This analysis suggests that in the approaches to the Bristol Channel (i.e. where the array and ECC is located), net sand transport during extreme waves increases by an order of magnitude versus tides alone with sand transport also occurring in regions of negligible tidal sand transport.

6.5.10.7 Across the wider region, Collins (1987) concluded that, within the Bristol Channel, sediment transport occurs in an upstream direction along the coast (i.e. it is flood dominated) while sediment movement is seawards within the central part of the Channel (i.e. ebb dominated). DTI (2007) reports that this results in a scoured central region, with exposed bedrock in much of the central section of the Bristol Channel; with sediment thickness increasing to either side, but especially to the north.

6.5.10.8 The Outer Bristol Channel Habitat Study (Mackie *et al.*, 2007) further confirms the Collins (1987) hypothesis, demonstrating a northward change in sediment type and bedforms from Lundy Island northward. West of Lundy Island, the seabed sediment is coarse grained, gravelly sand and sandy gravel with sand patches and ribbons and isolated sandwaves on outcropping bedrock. Northward there is sand that forms sandwaves up to 10 m high. In deeper water to the south of Carmarthen Bay, there is also an extensive sandwave field (Mackie *et al.*, 2007). The asymmetries of these bedforms also suggest an easterly sediment transport in this part of the Bristol Channel.



Graphic 6.14 Primary Sediment Transport Pathways of Bed Material Within Milford Haven (from Little, 2009)

6.5.11 Understanding of sediment transport from analysis of hydrodynamic and sedimentary data

6.5.11.1 The general relationships between peak surface current speed, sediment availability and bedform development, are illustrated by Belderson et al. (1982). These relationships can be used to indicate whether conditions within the array area and along the ECC are conducive to active bedform development.

6.5.11.2 Graphic 6.6 and Graphic 6.7 illustrates the spatial variation in peak tidal current speed on a mean spring and mean neap range tide over the array area and ECC. The following summary observations are made:

- Sands typically become mobile at current speeds of approximately 0.5 m/s in the range of water depths (30 to 70 m) experienced in the array area and ECC (Soulsby, 1997). Based on the information in the figures, sands and finer sediments are likely to be mobile around times of peak current speed, during spring tides, throughout the offshore region;
- The peak spring current speed and so the potential rate and frequency of sediment mobility generally increases from the offshore array area along the ECC towards the adjacent coastlines. During mean neap tides (peak current speeds approximately half the mean spring value), sediments in the eastern (landward) half of the ECC are still likely to be mobile (although less strongly and frequently); however, sediments in the western (offshore) half of the ECC and in the array area may be largely immobile during neap tides (consistent with the higher proportion of finer sediment observed to be present in seabed sediments in these areas);

- In the approaches to Milford Haven, peak current speeds are generally lower than the nearby offshore areas and are more spatially variable (locally accelerated near to headlands and some constricted flow). Sediment is potentially mobile throughout the area during spring tidal conditions, however, in most places there is a very limited amount of sediment present to transport. A greater thickness of sediment is present in Row's Rocks channel, which is likely mobile during spring tides; and
- In West Angle Bay, current speeds are too low to directly cause sediment mobility. The approaches to the bay are mostly rocky with limited sediment present to transport. A body of sand is present on the beach at the back of the bay; a comparison of aerial images of the beach (see Graphic 6.18) suggest that the beach has been in a relatively stable equilibrium for many decades. Waves entering the bay are likely to locally resuspend some sediment in the shallow subtidal area, which might then be transported either into or out of the bay by weak residual currents. Waves breaking in the intertidal area are likely to cause limited local redistribution of sediments on the beach.

6.5.11.3 On the basis of the documented spatial variance in current speed, and the relationships set out in Belderson et al. (1982), it is found that in all areas outside of Milford Haven current speeds are sufficiently high to form and maintain active (larger) bedform features. The morphology and migration of these bedforms will also be dependent (at least in part) on the local availability of sediment, with (for instance) barchan-type sandwaves generally more prevalent where sediment supply is limited and sandbanks forming where supply is plentiful. In the approaches to the landfall (West Angle Bay), current speeds are generally too weak to support the development of larger bedforms, with ripple sized bedforms expected to represent the largest scale of feature.

6.5.12 Understanding of sediment transport from numerical modelling analysis

6.5.12.1 Numerical sediment transport modelling has been undertaken to quantify the potential rate of sediment transport for medium quartz sand (250 µm diameter grain size) under tidal current forcing.

6.5.12.2 The resulting maps of instantaneous potential sediment transport rate and direction (not shown) closely follow the patterns of current speed and direction. During times of peak current speed on a mean spring tide, the instantaneous potential sediment transport rate in and around the Erebus array area is approximately 10^{-4} $m^3/m/s$ (0.36 $m^3/m/hr$), increasing gradually along the ECC to approximately 10^{-5} $m^3/m/s$ (3.6 $m^3/m/hr$) in the outer approaches to Milford Haven. Potential sediment transport rates are up to two orders of magnitude lower during times of peak current speed on a mean neap tide.

6.5.12.3 The resulting maps of the daily average net sediment transport rate and direction over a representative mean spring-neap cycle are shown in Graphic 6.15 to Graphic 6.17. Also superimposed on the maps are areas identified as exposed rock substrate (black hatched areas) and the crest lines of larger sandwave features (white lines) where they are visible in the available higher resolution bathymetry data.

6.5.12.4 The patterns of magnitude and direction of net transport are consistent with the observed distribution and migration behaviour of sedimentary features. The maps help to identify and differentiate the factors controlling the behaviour of sediment pathways and bedforms in different parts of the study area.

In and around the Array area

- Net sediment transport is to the south at a relatively low magnitude. Sediment is regularly mobilised on spring tides in this area, but the relatively symmetrical patterns on flood and ebb tides result in low net transport over time;

- There is a gradient of net transport magnitude, higher to the north, lower to the south. This pattern results in a net sediment convergence zone where sediment tends to accrete;
- Sandwaves in the northern part of the array area constitute the southern edge of a wider sandwave field that is the result of this sediment convergence. The supply of sediment is somewhat limited and so sediment accumulates as locally thicker sandwaves in an otherwise relatively thin veneer of sediment. The net transport rate is so low in the southern half of the array area that sandwaves do not form; and
- The northern half of the array area is, therefore, characterised as a mainly low transport sink for sediment being transported from the north, and the southern half is largely inactive.

Export cable corridor offshore from KP45 to KP15

- Net sediment transport is to the south to southeast at a relatively low magnitude compared to the surrounding areas. Sediment is progressively more regularly mobilised with distance towards the coast due to increases in tidal current speed but the relatively symmetrical pattern of currents on flood and ebb tides result in low net transport over time;
- This offshore part of the ECC follows the northern edge of a sediment convergence zone. The magnitude of net transport is particularly low at or close to the route (hence the limited presence of sandwaves on the route itself in many areas);
- The sandwaves and other sediment bodies adjacent to the route in these areas are transporting sediment at a slow net rate towards the route, or an area nearby;
- Around KP15, the route passes close to an accumulation of sediment with active sandwave migration to the northwest. Graphic 6.16 shows that, although more locally active, this is only a short transport pathway that terminates before the region of exposed bedrock a few kilometres to the northwest; and
- The ECC from KP45 to KP15 is, therefore, characterised as a mainly low transport sink area for sediment, converging at or nearby to the route.

Export cable corridor nearshore from KP15 to KP5

- Between KP15 and KP10, net sediment transport vectors also generally converge on the location of the ECC. Between KP10 and KP5 (to the west of Turbot Bank), net sediment transport vectors converge on the corridor but then re-orientate north as part of the circulatory pattern around the bank;
- There is an area of strong southeast net sediment transport to the northwest of the corridor - in conjunction with limited sediment supply from the far side of that area, this has resulted in the erosion of most or all sediment cover from this area (shown as the black hatched area in Graphic 6.17). As such, there is presently limited actual sediment transport and supply from this direction. Sediment that is present between KP10 and KP5 is on the edge of the recirculation system around Turbot Bank. Sediment contained within the wider Turbot Bank system approaches the corridor from the southeast at KP10, then migrates north parallel to the route before diverging away from the corridor in a northeastly direction at around KP5;

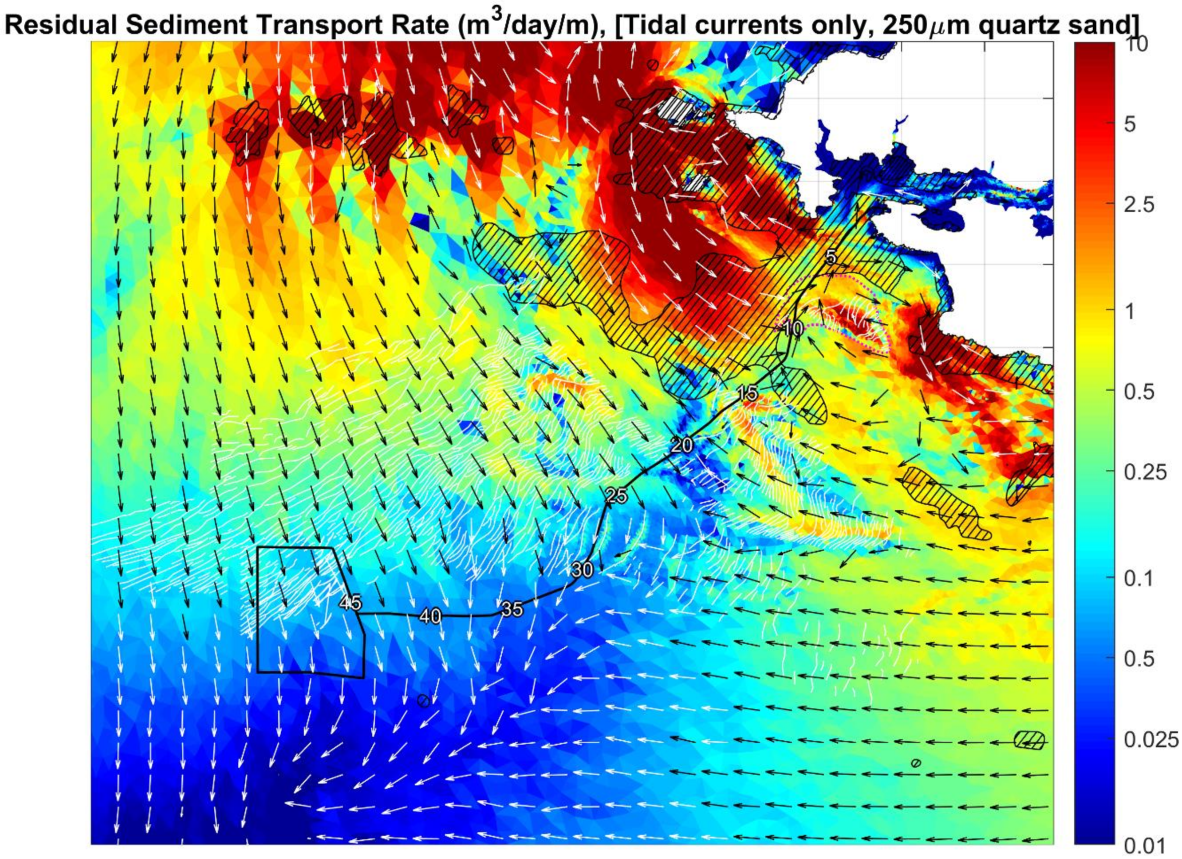
- The location and extent of the main body of Turbot Bank, and the migration of bedforms around it, are, therefore, shown to be controlled and maintained by the local and regional patterns of tidal currents and resulting net sediment transport. The bank itself is only a temporary sink for sediment. Inputs of sediment are likely to come mainly along the pathways visible from the south, with potentially smaller amounts from the west (passing over the exposed bedrock areas). This is likely to be balanced by sediment output from the system along the transport pathway to the southeast of the bank, approximately 3 km offshore and parallel to the adjacent coastline; and
- The nearshore ECC from KP15 to KP5 is, therefore, located and orientated nearly parallel to the outer western edge of the circulatory transport pathway around the Turbot Bank system.

Turbot Bank System, east of KP10 to KP5

- Additional detail of the bathymetry and predicted patterns of sediment circulation around Turbot Bank are shown in Volume 2, Figure 6.9;
- The net sediment transport vectors indicate a clockwise pattern of sediment recirculation around Turbot Bank that is broadly in agreement with the observed pattern of sandwave asymmetry on the flanks of the bank;
- The modelled net transport direction (due to tidal currents only) on the crest of the bank is to the northwest, but appears to be different in practice (based on the bedform orientation and shape) if the long term effect of waves (predominantly from the southwest) are also factored in; and
- Large bedform asymmetry in some areas is not very clearly defined, suggesting a spatially variable response to the balance of short-term sediment transport (orientated to the local tidal axis), and long-term net transport (spatially variable directions, from aligned to perpendicular to the tidal axis). The same balance appears to also affect the resulting final crest alignment, which may be intermediate between the short- and long-term directions.

Export cable corridor in the approaches to Milford Haven and at the landfall, from KP5 to KP0

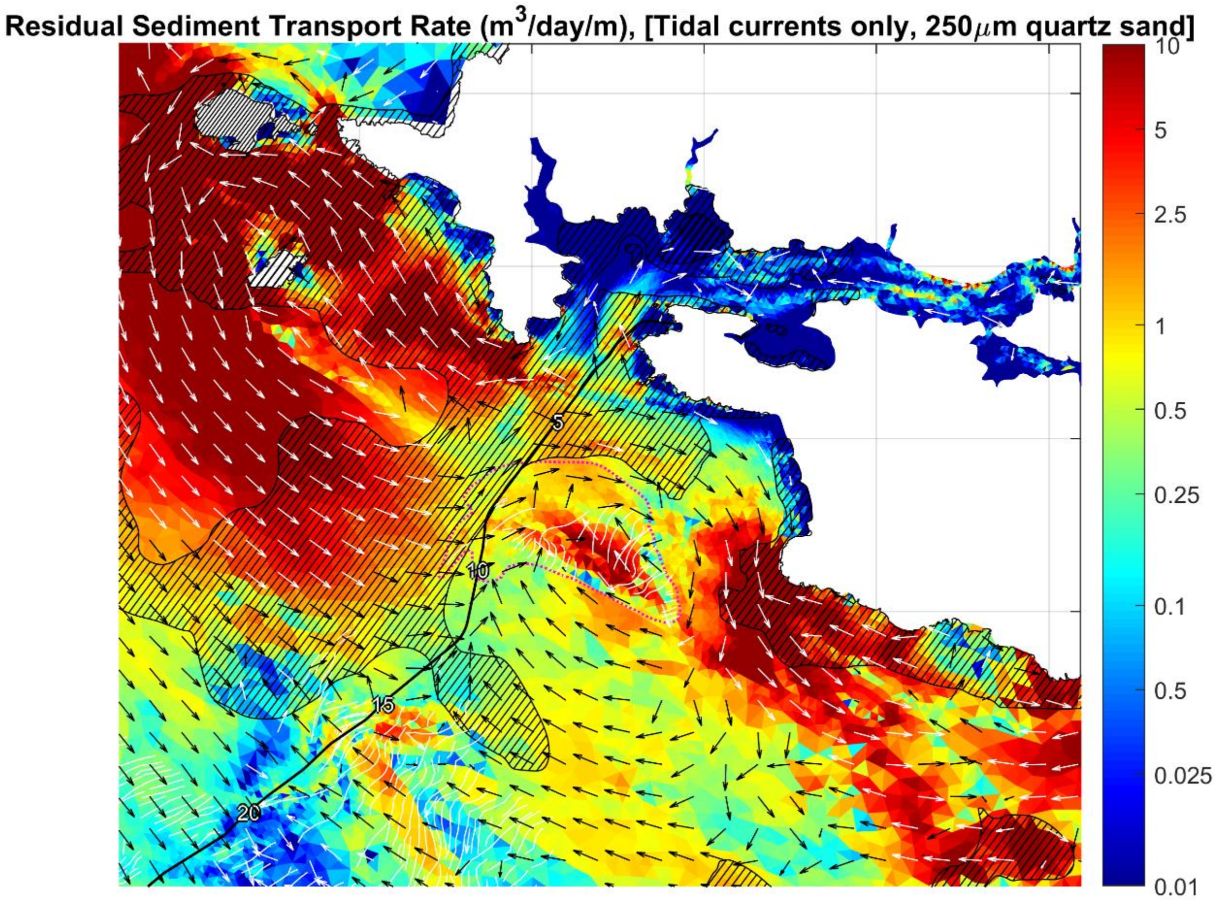
- Between KP5 and KP0, sediment cover is largely absent and so actual sediment transport rates will be limited. The exception to this is the Row's Rocks channel through which the route passes in the entrance to Milford Haven. Infilling sediment is present locally in this area;
- Net sediment transport vectors between KP3 and KP1.5 suggest that the sediment in Row's Rocks channel is being moved gradually north into the estuary. The deeper profile of Row's Rocks channel appears to locally decrease peak current speed and the resulting magnitude (but not the direction) of net sediment transport, relative to the surrounding higher rocky platform seabed;
- Inshore of KP1.5, within West Angle Bay, tidal current speeds are very low and sediment is largely absent in subtidal areas, so actual sediment transport rates are typically negligible. Typical of pocket embayments, small amounts of sediment in suspension (during storms) likely allow limited rates of exchange between the bay and the wider estuary to maintain an equilibrium volume of sediment present in the beach; and
- The ECC from KP5 to KP1.5 gradually and obliquely crosses the net sediment transport pathway into Milford Haven Estuary, within Row's Rocks channel. Tidally driven sediment transport is negligible within West Angle Bay.



Graphic 6.15 Residual tidal sediment transport rate and direction – array area and ECC

A combination of black and white vector arrows are used to improve visual contrast against the underlying colourmap.

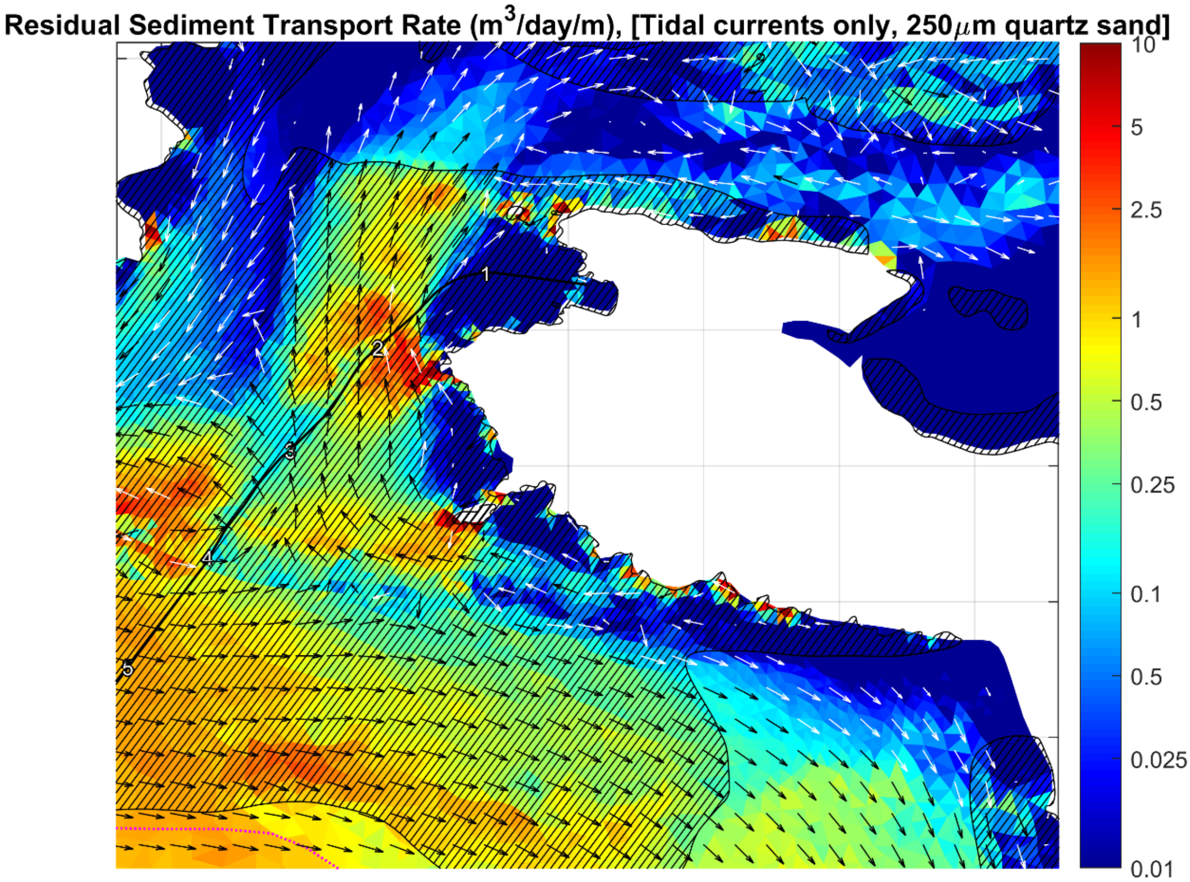
The array area outline and ECC are shown as solid lines. Also shown: (thin dotted magenta line) the defined area of Turbot Bank; (black hatched area) areas of exposed bedrock where sediment cover is absent; (white lines) crests of identifiable sandwaves in the available high-resolution bathymetry data.



Graphic 6.16 Residual tidal sediment transport rate and direction – Nearshore parts of the ECC

A combination of black and white vector arrows are used to improve visual contrast against the underlying colourmap.

The array area outline and offshore ECC are shown as solid lines. Also shown: (thin dotted magenta line) the defined area of Turbot Bank; (black hatched area) areas of exposed bedrock where sediment cover is absent; (white lines) crests of identifiable sandwaves in the available high-resolution bathymetry data.



Graphic 6.17 Residual tidal sediment transport rate and direction – Approaches to Milford Haven and West Angle Bay

A combination of black and white vector arrows are used to improve visual contrast against the underlying colourmap.

The array area outline and offshore ECC are shown as solid lines. Also shown: (thin dotted magenta line) the defined area of Turbot Bank; (black hatched area) areas of exposed bedrock where sediment cover is absent; (white lines) crests of identifiable sandwaves in the available high-resolution bathymetry data.

6.5.13 Understanding of sediment transport from analysis of project specific geophysical data

6.5.13.1 The distribution of bedforms within the array area and ECC, as well as the availability of potentially mobile material is summarised in Volume 2, Figure 6.6 and in Table 6.15. Based on the Project specific geophysical surveys, the following general observations are made regarding sediment type and thickness:

- The array area and ECC are characterised by the presence of sands and gravels, with varying contributions of finer grained material (typically 10 to 20%, but up to 50% fines locally in the array area);
- In the array area, recent (Holocene aged) sediments are found overlying harder Pleistocene glacial tills. Where sandwaves are present, these sediments may be several metres thick beneath crests, whereas in the troughs, sediment may be thin or absent;
- Along the ECC, the thickness of surficial sediment is highly variable. In many parts, similar to the array area, the sediment veneer may be thin or absent except under the body or crest of local sandwave features. Where the ECC passes larger sand bank systems/sandwave complexes (e.g. around KP8 and KP16) the cover of surficial sediment is thicker, sometimes exceeding 10 m; and

- In the approaches to Milford Haven, bedrock is extensively found at or very near to the seabed surface. Conversely, within the Row's Rock channel there is a greater local depth of sediment, typically around 10 m of infill.

6.5.13.2 The following general observations are made regarding sediment bedforms:

- Within and around the array area, large areas of sandwaves are present, along with extensive areas of ripples and megaripples (Volume 2, Figure 6.6);
- Within the array area and ECC these sandwave features have heights of up to approximately 11.5 m and 7 m, respectively. The analysis of Greenlink (2019) identifies sandwaves with heights of between 10 and 15 m and wavelengths of several hundred metres, located approximately 5 km to the northwest of KP8;
- The crests of these sandwave bedform features are typically oriented broadly perpendicular to the local main axis of tidal flow;
- Within the array area, sandwaves are relatively symmetrical in profile, consistent with low observed rates of bedform migration; and
- On and around the ECC, sandwaves are relatively more asymmetric in profile, consistent with variable observed rates of bedform migration (up to 4 m/year).

6.5.14 Understanding of sediment transport from analysis of bedform migration

6.5.14.1 An analysis of historically observed seabed level change and bedform migration rates has been undertaken for the array area and ECC, based on a comparison of recent (Project specific) and older (UKHO/ SEACAMS) bathymetric data (Volume 2, Figure 6.10; Volume 2, Figure 6.11; and Volume 2, Figure 6.12). It is noted that:

- The older single beam data collected in 2003 (both in offshore areas and in Milford Haven) is generally of insufficient resolution to enable movement of individual bedform features to be accurately determined;
- The 2020 and 2021 multibeam surveys for the array are too close in time to enable meaningful determination of bedform migration rates; and
- Analysis of individual seabed profile transects only provides local-scale information which may or may not be consistent with regional transport pathways.

6.5.14.2 However, the available information does provide an indication of spatial variability across the array area and ECC. Key findings are summarised below:

- A comparison of the two high-resolution (multibeam) surveys in the northern part of the array area suggests very little/no measurable migration of the large (up to 11.5 m high) sandwaves present there between 2011 and 2020. This is consistent with the symmetrical profile of the mapped features;
- A comparison of the more recent high-resolution (multibeam) survey and older more sparse (single beam) survey data in the eastern part of the array area is also consistent with very little measurable overall bed level change (and therefore migration of sandwaves) between 2003 and 2020. In the majority of the area of overlap, changes in bed level are typically <0.5 m (i.e. within the accuracy of the survey) and almost all less than 0.5 to 1 m;
- Active sandwave migration is observed elsewhere along the ECC. The fastest rates of migration are associated with sandwaves at the bank system located (approximately) to the southeast of KP15, with rates of up to ~4 m/yr;

- Bedform migration associated with the sediment accumulation east of KP15 appears to be complex, with a general west to east migration along the northern flank of the sandwave field and general east to west migration along the southern flank. This suggests a general clockwise circulation of material and sandwave bedform migration;
- West-north-westerly migration of the large (~7 m high) sandwaves at ~KP30 is observed although rates are estimated to be <1 m/yr; and
- As shown in Volume 2, Figure 6.13, large sandwaves are present around Turbot Bank. The modelled patterns of net sediment transport as a result of tidal currents and the observed asymmetry of the sandwave features indicate a clockwise circulation of sediment via active bedform migration. Due to a lack of repeat surveys of sufficient resolution, the rate of bedform migration cannot be directly measured.

6.5.15 Conceptual Understanding

6.5.15.1 Conceptual understanding of regional scale marine and coastal processes is set out in Volume 2, Figure 6.13 and summarised below. This has been informed by analysis of the existing and Project specific data described and analysed in this section, as well as the geomorphological and terrain mapping set out in the Project specific ground model.

General

6.5.15.2 The available evidence for sediment transport and bedform movement across the array and ECC is, for the most part, consistent: the observational evidence revealing the presence and movement of bedform features agrees with theoretical considerations relating to seabed mobility and sediment transport.

Landfall

6.5.15.3 At the landfall, the export cable alignment enters the Milford Haven waterway at West Angle Bay - a sediment covered basin with local rock outcrops. To KP4.5, the alignment follows the axis of the East Channel (Row’s Rock channel), a sediment filled trough within a rock platform either side of the channel.

6.5.15.4 Within Milford Haven (and especially the approaches to West Angle Bay), flow speeds are generally much lower than for offshore and nearshore areas. The seabed in these areas is generally expected to be stable and this observation is consistent with the available evidence of bathymetric change within Milford Haven and the eastern end of Row’s Rocks channel.

Nearshore

6.5.15.5 From KP4.5 to KP6.0, the ECC falls 20 m over a sloping wedge of sediment extending from the mouth of the East Channel towards a rugged basin marked on Admiralty Charts as a ‘Spoil Ground’ – small patches of megaripples and isolated boulders are present throughout this section.

Offshore

6.5.15.6 From KP6.0 to KP9.0, megaripples become more widespread. The ECC passes approximately 2 km to the west of the crest of Turbot Bank at approximately KP9.0. A series of minor sandwaves (approximately 2 m wave height and 100 to 200 m in wavelength) are present. Sandwave asymmetry in this area indicates slow west-northwest migration of sandwaves in this area, although rates are unclear due to a lack of comparative datasets in this area.

6.5.15.7 Between KP9.0 and KP30.0, seabed geomorphology alternates between areas of sandwaves and megaripples over sandbanks, and sandwaves and megaripples over interbank lows. In almost all areas, the underlying geological strata are concealed by these sedimentary features, with the exception being very small areas of rugged ground around KP15.0.

6.5.15.8 On the basis of the available observational evidence, it is anticipated that the seabed between (approximately) KP13 and 17 will be amongst the most dynamic areas within the Project boundary, with observed rates of sandwave migration of up to 4 m/yr.

6.5.15.9 The seabed between KP7 and 11 associated with Turbot Bank is similarly (or more) dynamic, with large sandwaves present and actively mobile. The rate of sandwave migration is assumed to be spatially variable and similar to, or greater than, 4 m/yr at KP13 and 17 but cannot be directly measured without overlapping bathymetry data of sufficient resolution.

6.5.15.10 For the remainder of the ECC (KP30.0 to KP39.5) megaripples occur over a largely planar seabed with extensive megaripple cover up until the array area. The array area itself comprises a planar megaripple field in the south and an extensive sandwave field with megaripples in the north.

6.5.15.11 Although very large (10 m+) sandwaves are found within the array area and offshore areas of the ECC (around KP30), it does not follow that these areas will necessarily offer the potential for the greatest seabed variability throughout the lifetime of the Project. Instead, very slow (<1 m/yr) observed migration rates for these features suggests overall seabed stability and comparatively low variability in elevation due to large bedform migration over the period of years to a few decades. Low rates of bedform migration in these areas are mainly the result of locally symmetric patterns of sediment transport on flood and ebb tides, rather than simply low rates of sediment transport.

6.5.15.12 Smaller ripple features (order of 0.2 to 0.3 m height and 10 m wavelength) are present in most areas where sufficiently high-resolution data are available to resolve them. Such ripple features are expected to be actively mobile on timescales of days to weeks.

Coastlines, Beaches and Nearshore Processes

6.5.15.13 The landfall location in West Angle Bay is covered by the Lavernock Point to St Ann's Head Shoreline Management Plan (SMP2; Halcrow, 2012). St Ann's Head is located directly across the entrance of Milford Haven from West Angle Bay; consequently, the SMP2 document covers the wider Study Area coastline throughout Milford Haven. More specifically, the proposed landfall at West Angle Bay falls within the Shoreline Management Plan Policy Unit PU18/3 - Freshwater West to Thorn Island (Thorn Island being the small rocky outcrop offshore of the headland to the north of West Angle Bay).

6.5.15.14 As is characteristic of the Pembrokeshire Coast National Park, the coastline is dramatic with several notable coastal geomorphological features such as natural arches, stacks and caves. The coastline within the wider Policy Scenario Area 18 (St Govan's Head to Thorn Island) is characterised by limestone cliffs to the south and sandstone cliffs to the north, separated by the dunes at Frainslake Sands and Freshwater West. These dune systems (around 5 to 6 km to the south of West Angle Bay) have developed in the shelter provided by the rocky headlands to the north and south, although their seaward edges are eroding and there are large blow-outs in places. The wider shoreline is important for the landscape and habitats that it supports and is within the Limestone Coast of South West Wales SAC and Castlemartin Coast SPA (as well as several SSSIs).

6.5.15.15 West Angle Bay is located within the Angle Peninsula Coast SSSI and is one of the richest sites for marine flora and fauna in southwest Wales. Of particular importance are the cushion stars, and a rare ostracod. Geologically, it is important for its structures, and also the section from the Devonian Ridgeway Conglomerate up into the Lower Carboniferous Main Limestones (Pembroke Limestone Group). A number of notable features are present here including beds of macerated plant remains with occasional fish teeth and bivalves of upper Devonian age (383 million–359 million years ago). West Angle cliffs are also notable for the late Pleistocene deposits (from 140,000-10,000 BP), which contain sequences associated with glaciation of the Irish Sea (Geologists' Association, 2020).

6.5.15.16 Recently, a new species of fossil crinoid (*Hylodecrinus cymrus*), was described from the Pembroke Limestone Group (Mississippian, Tournaisian, Courceyan) of West Angle Bay (Howells and Kammer, 2014). This specimen represents the first report of this genus from Europe, which has previously been identified in North America.

6.5.15.17 West Angle Bay is the only defended frontage within the wider policy area, with a short length of seawall reducing the risk of coastal erosion and flooding to a small number of coastal assets (including the Wavecrest Café and the adjacent car park). This defence extends approximately 100 m along the northern part of West Angle Bay at the rear of the fronting beach as illustrated in Volume 2, Figure 6.14. The ECC will make landfall towards the northern end of these defences.

6.5.15.18 The recommended policy along much of the wider Policy Area 18 frontage is No Active Intervention (NAI) to allow the coastline to evolve naturally and preserve the environmental interest. It is considered unlikely that public funding will be made available to maintain existing defences at West Angle Bay due to the limited socio-economic value of assets at risk, and therefore a policy of NAI is recommended in future, which will allow existing defences to fail. Existing defences could be maintained (or even improved) subject to the availability of private (or other) funding and obtaining necessary consents, licences and approvals (Halcrow, 2012).

6.5.15.19 Review of historic aerial imagery (available from Google Earth and from Dyfed Archaeological Trust Historic Environmental Records) between 1946 and 2020 is provided in Graphic 6.18. These images generally show very little evidence of change in the coastline around West Angle Bay (noting the tidal elevation varies between images). This observation is consistent with analysis of LiDAR data (from 2004 and 2012) and topographic survey data (from 2019) which shows very little change in vertical beach profile over this approximate 15-year period (see inside graph on, Volume 2, Figure 6.15.

6.5.15.20 Reporting on an excavation site in the field along the southern cliff of West Angle Bay, Dyfed Archaeological Trust (2010) provides evidence of some cliff erosion in the area. The report indicates that the angle of the bedrock strata funnels the waves along the fault lines and exposed deposits of softer geology. This is, reportedly, most evident on the offshore-exposed coastline, which shows evidence of the harder shale headlands being left projecting into the sea.

Graphic 6.18 Historic aerial imagery from 1946 to 2020 (source: Google Earth and Dyfed Archaeological Trust/RAF)

6.5.15.21 Milford Haven is located approximately 6 km along the coastline, west of Neyland. This is Wales' largest port and is strongly associated with the petrochemicals industry, with major oil refineries at Waterston to the east and Robeston West to the northwest. In 2009, two major new liquefied natural gas (LNG) terminals opened at South Hook and Dragon LNG.

Future Baseline

6.5.15.22 The baseline is expected to evolve in response to natural variation (for example, the lunar nodal cycle, North Atlantic Oscillation etc.), wider changes in climate expected over the lifetime of the Proposed Development, and anthropogenic management of the coast. These are discussed below.

6.5.15.23 Mean sea level in the Study Area is likely to rise slightly over the lifetime of the wind farm (expected 25-year minimum operational period). This change is generally accepted to include contributions from global eustatic changes in mean sea level and regionally varying vertical (isostatic) adjustments of the land.

6.5.15.24 Information on the rate and magnitude of anticipated relative sea level change during the 21st Century is available from UKCP18 (Palmer *et al*., 2018). It is predicted that by 2050, relative sea level at the landfall could have risen by approximately 0.25 m above present day (2021) levels (Representative Concentration Pathway (RCP) 8.5; 95th percentile), with rates of change increasing over time.

6.5.15.25 A rise in sea level would, potentially, allow larger waves, and therefore more wave energy, to reach the coast in certain conditions and, consequently, result in an increase in local rates or patterns of erosion and the equilibrium position of coastal features. Sea level rise may also result in a loss of intertidal habitat through the process of 'coastal squeeze' caused by the presence of coastal defences preventing natural roll back of the coast.

6.5.15.26 UKCP18 also includes projections of changes to storm surge magnitude in the future, as a result of climate change. However, it is found that UKCP18 projections of change in extreme coastal water levels are dominated by the increases in mean sea level with only a minor (less than 10%) additional contribution due to atmospheric storminess changes over the 21st Century (Palmer *et al.*, 2018).

6.5.15.27 Modification of the wave regime may also occur in response to changing patterns of atmospheric circulation, although this is associated with much uncertainty (Palmer *et al*., 2018).

6.5.15.28 The existing Shoreline Management Plan 2 (Halcrow, 2012) and National Park Authority Local Development Plan 2 (Pembrokeshire Coast National Park Authority, 2020) outline future management policies for the coast. Notwithstanding this, there is some uncertainty regarding how the coastline at the landfall will be managed over the coming decades. Should the coastline no longer be defended, it is reasonable to assume the morphology of the coast could change over the lifetime of the Proposed Development.

6.6 Potential Environmental Effects

6.6.1.1 This section identifies the potential effects of the Project on marine and coastal processes. Each effect is not necessarily relevant to all stages of the Project, and thus effects have been assessed within the stage of the Project at which they will occur (construction, operation and maintenance, and decommissioning). Further information on the EIA process and methodology is outlined in Section 6.4 and Chapter 2: Overview of EIA methodology.

6.6.1.2 The assessment is based on a set of project parameters that represent the Realistic Worst Case (RWC). These parameters are provided in Table 6.17 for each of the potential effects identified during Scoping and from subsequent discussions with stakeholders as part of the stakeholder engagement and technical meetings process.

6.6.1.3 The RWC is defined by the PDE (Chapter 4, Proposed Development Description) and includes standard (embedded) mitigation. The RWC for each assessment is identified from all possible options using a ‘Rochdale Envelope’ approach, whereby the conclusions of the resulting assessment are conservative representative of or exceed all other possible design option combinations.

Table 6.17 – Project Design Envelope Parameters Relevant to Marine and Coastal Processes

Potential Pathway Change/Impact	Realistic Worst-Case Scenario	Justification
Construction		
Potential increases in SSC and associated changes to seabed substrate.	<u>Drilling for anchor installation</u> • Maximum number of pile anchors: 35 • Maximum dimensions of drilled pile section: 2.5 m diameter, 55 m length (up to 3 m of which may protrude above the seabed). • Maximum volume of material per pile: 270 m^3 • Maximum volume of material all piles: 11,340 m^3 • Drilling rate: 5m/hr	Corresponds to (a combination of) the greatest amount of material disturbed, the largest dimensions and number of pile anchors, the largest dimensions of trenching, the greatest depth of seabed lowering/levelling and the greatest

Potential Pathway Change/Impact	**Realistic Worst-Case Scenario**	**Justification**
	Array Cable installation • Maximum total length of trenches: 23.9 km • Trench dimensions: 1 m wide; 3 m deep; 'U' shape profile • Excavation method: Trenching by jetting or mass flow excavator (MFE) Offshore export cable installation • Maximum number of trenches: 1 • Maximum total length of trench: 49 km • Trench dimensions: 1 m wide; 3 m deep; 'U' shape profile • Excavation method: Trenching by jetting or MFE Sandwave levelling (within array area) • Maximum volume of material that will be subject to levelling/temporary removal: 6,000 m^3 (for mooring lines); 15,000 m^3 (for anchors) and 160,600 m^3 (for offshore inter array cables). Total = 181,600 m^3. Sandwave levelling (within ECC) • Number of sandwaves: 6 • Maximum volume of material that will be subject to levelling/temporary removal: 403,000 m^3 • Area of seabed subject to sandwave levelling: 150,000 m^2 • Maximum depth of levelling: half height of sandwave. • Levelling method: Trailing Suction Hopper Dredger (TSHD) or MFE HDD/Drilling fluid release (at landfall) • Number of HDD exit/release events: 2 • Maximum volume of drilling fluid in one HDD conduit: 1,200 m^3. • Maximum concentration of bentonite in drilling fluid: 80,000 mg/l. Open-Cut Trenching (at landfall) • Maximum number of trenches: 1 • Trench dimensions: 3 m wide; 3 m deep; 650 m length • Depth range of intertidal works: 0 m to 7 m above LAT	geographical extent of the impact. No. of pile anchors shown is based on 7 x semi-submersible floating platforms, each with 5 mooring lines (35 in total). 5 mooring lines per semi-submersible floating platform are only required on the larger semi-submersible floating platform, i.e. the ones that would be used if only 7 x semi-submersible floating platforms /WTGs were installed. If 10 x semi-submersible floating platforms were used, these would be smaller (to accommodate smaller WTGs) and would, therefore, only require 3 mooring lines per semi-submersible floating platform (apart from the lead platform which would require 5. Therefore, 9 x 3 = 27; 1 x 5 = 5; 27 + 5 = 32 Thus, 35 piles/anchors were used as the basis of the assessment for increased SSC via seabed disturbance The fastest rate of progress is used to assess the greatest rate of sediment disturbance or release.

Potential Pathway Change/Impact	**Realistic Worst-Case Scenario**	**Justification**
	• Excavation method: combination of land-based equipment in intertidal areas and specialist dredging/trenching/ cutting tools for subtidal areas • Cofferdam duration: 12 weeks Nearshore Floatation Pits (NFP) • Maximum number of NFPs: 1 • Maximum dimensions: 160 m long x 45 m wide x 5 m deep (Footprint of 7,200 m^2) • NFP duration: construction up to 3 weeks; open up to 12 weeks	Other anchor types (embedment anchors, piled and suction pile anchors) will cause a lesser rate and duration of sediment disturbance than drilling. The installation of scour protection will cause a lesser rate and duration of sediment disturbance than cable installation (trenching). Boulder clearance is not considered here as the activity does not represent a RWC in terms of potential increases in SSC and associated changes to seabed substrate.
Potential changes to sediment transport system by changes in wave and current climate	(See justification notes)	The RWC for blockage associated with partially installed cable protection, semi-submersible floating platforms and/or the presence of anchoring structures cannot readily be defined. However, it will be no greater than that set out for the fully built and operational project. Refer to the operation section of this table (below).
Potential changes to the morphology of the seabed (including scour).	Sandwave levelling (within array area) • Maximum volume of material that will be subject to levelling/temporary removal: 6,000 m^3 (for mooring lines); 15,000 m^3 (for anchors) and 160,600 m^3 (for offshore array cables). Total = 181,600 m^3.	Corresponds to (a combination of) the greatest amount of material disturbed, the greatest depth of seabed lowering and the geographical extent of the impact.

Potential Pathway Change/Impact	**Realistic Worst-Case Scenario**	**Justification**
	Sandwave levelling (within ECC) • Maximum no. of sandwave crests requiring levelling: 6 • Maximum volume of material: 403,000 m^3 • Area of seabed subject to sandwave levelling: 150,000 m^2 • Maximum depth of levelling: half height of sandwave. • Levelling method: TSHD or MFE	
Potential changes in morphology of the coast.	HDD • HDD number: 2 (Water Depth approximately 5 m below LAT) • HDD duration: ~21 weeks total (for 2 HDD) Exit pit dimensions: 15 m long x 10 m wide x 4 m deep (2 no.) • Transition Jointing Bay (TJB) above MHWS Open-Cut Trenching • Maximum number of trenches: 1 • Trench dimensions: 3 m wide; 3 m deep; 650 m length • 10 m width of disturbance assumed, inclusive of 3 m wide trench and access/spoil disposal either side of the trench • Depth range of intertidal works: 0 m to 7 m above LAT • Excavation method: combination of land-based equipment in intertidal areas and specialist dredging/trenching/ cutting tools for subtidal areas • Rock cutting tools for loose or hard substrates are likely to result in a mixture of majority sand to gravel or larger clast sizes • Cofferdam duration: 12 weeks Nearshore Floatation Pits (NFP) • Maximum number of NFPs: 1 • Maximum dimensions: 160 m long x 45 m wide x 5 m deep (Footprint of 7,200 m^2) NFP duration: construction up to 3 weeks; open up to 12 weeks Cable protection • Rock protection not currently anticipated along intertidal sections	Sets out construction activities that give rise to the greatest (direct) disturbance to the beach and provide the greatest potential to interact with coastal processes responsible for maintaining the baseline form and function of the beach.

Potential Pathway Change/Impact	Realistic Worst-Case Scenario	Justification
Operation and Maintenance		
Potential changes to sediment transport system by changes in wave and current climate.	<u>Semi-submersible floating platforms</u> • Maximum number of foundations: 10 • Maximum diameter of main columns (inc. contingency): one larger column 21.96 m and two smaller columns 20.64 m • Maximum draught of main columns: 17.4 m • Diameter of secondary bracing (inc. contingency): 4 m <u>Mooring system and Electrical cables</u> • Maximum number of mooring lines, suction pile anchors and electrical cables present in the water column: 54 • Diameter of mooring lines: 0.32 m • Diameter of electrical cable: 0.30 m • Dimensions of suction pile anchors once installed: 6.5 m diameter, 3 m above seabed.	Largest individual foundation dimensions causing blockage to waves and currents. Largest number of largest foundations leading to largest total blockage cross section for foundations. Largest number of moorings and cables (54) associated with: up to 10 foundations, 9 with 3 moorings each and 1 with 5 moorings = 32, + 20 array cable and 2 export cable connections. A short length of the ground chain, including clump weights, will be suspended above the seabed at the end of each mooring line. This near-bed section of each mooring will have only limited interaction with waves or currents. Embedment anchors will be completely buried and will not interact at all with waves or currents. Drilled piles may also extend up to 3 m above the seabed but have a smaller diameter (up to 2.5 m).
Potential changes to the morphology of the seabed (including scour).	<u>Mooring system and electrical cables</u> • Maximum number of moorings and electrical cables present in the water column: 54	See above for justification of number of moorings and electrical cables.

Potential Pathway Change/Impact	Realistic Worst-Case Scenario	Justification
	• Dimensions of mooring chain: links 0.81 m long x 0.67 m wide x 0.2 m diameter. • Swept area for mooring chain: 50 m lateral motion at touchdown • Dimensions of individual clump weights: 2 m long x 2 m wide x 1 m high • Diameter of electrical cable: 0.30 m • Dimensions of suction pile anchors once installed: 6.5 m diameter, 3 m above seabed. <u>Cable protection</u> • Applied to up to 16% (7.5 km) of the total export cable length • Applied to up to 100% (22.5 km) of the total array cable length in contact with the seabed • Rock protection berm or mattress • Maximum dimensions: 11 m base width x 2 m height (2 m berm crest width). Typical array cable protection dimensions 5 m base width x 1 m height, (rock bags). • Rock armour unit size: 2 to 30 cm	Embedment anchors will be completely buried and will not interact at all with waves or currents. Drilled piles may also extend up to 3 m above the seabed but have a smaller diameter (up to 2.5 m).
Potential changes in morphology of the coast	<u>Cable protection (inter array and export cables)</u> • Maximum dimensions: 11 m base width x 2m height (2 m berm crest width) • Duration: project lifespan (25 years) <u>HDD</u> • HDD duct exit protection: rock berm 21 m long by 5 m wide by 1.2 m high.	Maximum permanent change of coastal morphology resulting from removal of cable(s).
Potential increases in SSC and associated changes to seabed substrate.	<u>Cable Repair and Remediation (ECC)</u> • Estimated cable repair number during lifespan: 5; • Estimated cable repair length: 1 km length (50 m wide) • Estimated cable repair area impacted (per repair): 50,000 $m^{2;}$ • Total estimated export cable repair area: 250,000 m^2 • Duration of each cable repair: 2 weeks;	Maximum values for disturbance through repair and maintenance during Proposed Development lifespan

Potential Pathway Change/Impact	Realistic Worst-Case Scenario	Justification
	• Cable remediation events – reburial: 12; • Footprint of seabed disturbance during remediation event: 150,000 m^2; • Total footprint of seabed disturbance for (maximum) 12 remediation events: 600,000 m^2. <u>Array area</u> • Estimated cable repair number during lifespan: 5; • Footprint of seabed disturbance during remediation event: 301,050 m^2; • Total footprint of seabed disturbance for (maximum) 5 repair events: 1,505,250 m^2.	
Decommissioning		
Potential increases in SSC and associated changes to seabed substrate.	• Buried cables and mooring systems to be removed (but to be determined in consultation with key stakeholders as part of the decommissioning plan and following best practice at the time) • Cable protection removed or left *in-situ* • Decommissioning activities lasting up to a year	Maximum disturbance of seabed sediments and morphology.
Potential changes to sediment transport system by changes in wave and current climate.		
Potential changes to the morphology of the seabed (including scour).		
Potential changes in morphology of the coast.	• Removal of export cables from trenches within intertidal/shallow subtidal • Decommissioning activities lasting up to a year	Maximum disturbance of coastal morphology resulting from removal of cable(s).

6.6.2 Construction

<u>Potential increases in suspended sediment concentrations (SSC) and associated changes to seabed substrate (pathway)</u>

Overview

6.6.2.1 During construction of the project, sediment will be disturbed and released into the water column. This will give rise to suspended sediment plumes and localised changes in bed levels as material settles out of suspension. The main activities resulting in disturbance of seabed sediments are:

- Drill arisings released at the water surface during drilling for pile anchors;
- Dredging including overspill and local dredge spoil disposal, and/or use of MFE, for sandwave levelling;
- Pre-lay cable trenching or cable installation using a plough, jetting or MFE tool(s) at the seabed;
- Drilling fluid release associated with HDD at the landfall;
- Material released from open-cut trenching at landfall; and
- Construction of flotation pits near landfall.

6.6.2.2 Details of the RWC for sediment disturbance events are set out in Table 6.17. The potential changes to SSC and associated sediment deposition caused by these activities have been assessed using numerical spreadsheet models. The full details and results of each assessment are set out in Volume 3, Technical Appendix 6.1: Marine and Coastal Process Assessment Technical Report.

6.6.2.3 The locations identified for sandwave levelling and the preliminary assessment of cable burial and/or cable protection requirements are shown in Volume 2, Figure 6.16.

6.6.2.4 The sediment release events considered in this assessment have been designed to capture the full range of RWC scenario outcomes in terms of:

- Maximum plume concentrations;
- Maximum plume (spatial) extent;
- Maximum vertical change in bed level; and
- Maximum spatial extent of change in bed level.

6.6.2.5 The above will be governed by a range of factors including:

- The rate at which material is disturbed;
- The total mass of material disturbed;
- The characteristics of material that is disturbed (e.g. coarse, fine, consolidated etc);
- The height within the water column the material is released; and
- Whether the sediment disturbance occurs at a fixed location or moves over time).

Conceptual understanding of change

6.6.2.6 Where sediment is disturbed, a plume of increased SSC is created. The initial local increase in SSC is directly proportional to the mass of sediment disturbed or released, and the volume of water it is initially dispersed into. The evolution of SSC over time is then dependent on the rate of dilution and dispersion of the sediment that remains in suspension, and the rate at which sediment settles out of suspension. The sediment plume may be also advected at the speed and direction of any ambient tidal currents, which tends to limit the duration of time that changes to SSC are experienced at any one location. The thickness of sediment that may be redeposited locally is dependent on the area over which the (limited) total volume of sediment is deposited. A smaller area will correspond to a greater thickness and *vice versa*; however, the maximum area of effect for a given thickness of deposit is fundamentally limited by the volume of sediment being released.

6.6.2.7 The maximum distance (and therefore the overall spatial extent) that any local plume effects might be (temporarily) experienced can be reasonably estimated as the spring tidal excursion distance (illustrated in Graphic 6.6). The tidal excursion distance is the approximate distance over which water (or a section of plume with elevated SSC) is advected during one flood or ebb tide. Areas beyond the tidal excursion distance and footprint are unlikely to experience any measurable change in SSC from a sediment plume.

6.6.2.8 The tidal excursion distance varies in proportion to the peak current speed on a given tide. As such, the distance may also be smaller than shown, during smaller than average spring, intermediate, and neap conditions; and only very occasionally may be larger than shown during above average spring conditions.

6.6.2.9 The potential changes caused by longer duration activities causing sediment disturbance (such as drilling, dredging overspill, pre-lay cable trenching, or cable installation using a jetting or MFE tool) are summarised below. These are based on the quantitative spreadsheet-based modelling results presented in Volume 3, Technical Appendix 6.1: Marine and Coastal Process Assessment Technical Report:

- The maximum plume extent will be up to one tidal excursion distance along the flood/ebb tidal axis from the activity (on spring tides: 10 km in the array area; 14 to 15 km in the middle of the ECC; 18 to 19 km nearshore; and 5 to 8 km within Milford Haven estuary);
- Within small distances (<50 m) of the activity, SSC will be in the order of thousands to hundreds of thousands of mg/l, reducing rapidly with time and distance (through settlement and dispersion) to the order of hundreds or tens of mg/l;
- Where sediment is released at the water surface, SSC is unlikely to exceed 150 mg/l beyond approximately 100 m away for gravels, 500 m for coarse sand, 1.5 to 2 km for medium sand, and approximately 5 km for finer sands. The time required for redeposition of sands and gravels following release at the water surface is in the order of a few minutes to 1.5 hours;
- Only finer (silt and mud) sized sediments are likely to persist in suspension for long enough to cause any effect in SSC beyond the above distances. SSC due to the limited quantity of fines present is expected to be up to 50 mg/l, up to approximately 2 km downstream of the activity; decreasing to 1 to 5 mg/l within 1 to 3 days through progressive dilution and dispersion;

- Where there is only a relatively low height of initial suspension from the seabed, sediments are likely to deposit within a distance proportional to their grainsize/settling rate. Assuming a 3 m height of ejection and representative 1 m/s current speed at the time of disturbance, the maximum extent is approximately 5 m for gravels, 30 m for coarse sand, 90 m for medium sand, and ~250 to 300 m for finer sands. The time required for redeposition of sands and gravels following low height disturbance is in the order of seconds to a few minutes;
- Sands and gravels may cause a measurable thickness of sediment deposition within the above-described distances for SSC. In practice, the thickness and extent will depend on the volume of sediment locally displaced, the height of ejection, the current speed at the time of the release, and the nature of the sediment. Thicknesses greater than 0.05 m and 0.3 m are possible in all cases, but the maximum area of effect is inherently limited by the finite volume of sediment disturbed (see Volume 3, Technical Appendix 6.1: Marine and Coastal Process Assessment Technical Report for detailed results of a range of realistically possible outcomes); and
- Fines are expected to become widely dispersed (order of several kms) and so will not resettle with measurable thickness locally.

6.6.2.10 The potential changes caused by sudden sediment release activities (such as dredge spoil disposal) detailed in Volume 3, Technical Appendix 6.1: Marine and Coastal Process Assessment Technical Report can be summarised as follows:

- The maximum plume extent will be up to one tidal excursion distance along the flood/ebb tidal axis from the activity (on spring tides: 10 km in the array area; 14 to 15 km in the middle of the ECC; 18 to 19 km nearshore; and 5 to 8 km within Milford Haven estuary);
- Within small distances (<50 m) of the activity, SSC can be in the order of hundreds of thousands to millions of mg/l, reducing rapidly with time and distance (through settlement and dispersion) to the order of hundreds or tens of mg/l;
- Although the sediment mass is released at the water surface, sediment is shed from the mass into suspension evenly through the water column. SSC is unlikely to exceed 150 mg/l beyond approximately 100 m away for gravels, 500 m for coarse sand, 1.5 to 2 km for medium sand, and approximately 5 km for finer sands. The time required for redeposition of sands and gravels following release at the water surface is in the order of a few minutes to 1.5 hours;
- Only finer (silt and mud) sized sediments are likely to persist in suspension for long enough to cause any effect in SSC beyond the above distances. SSC due to the limited quantity of fines present is expected to be up to 50 mg/l, up to approximately 2 km downstream of the activity; decreasing to 1 to 5 mg/l within 1 to 3 days through progressive dilution and dispersion;
- The main mass (90% volume) of spoil deposit will descend directly to the seabed and result in a sizable deposit of variable (not predictable) shape, extent and thickness. The sediment in suspension may settle out over a wider area with greater extent but proportionally smaller thickness. Distances and extents will likely be within the above-described distances for SSC. In practice, the thickness and extent will depend on the actual volume released, the spread of the material on impact with the seabed, the current speed at the time of the release, and the nature of the sediment put into suspension. Thicknesses greater than 0.05 m and 0.3 m are possible in all cases, but the maximum area of effect is inherently limited by the finite volume of sediment released (see the detailed results for a range of possible outcomes); and

- Fines in the suspended plume are expected to become widely dispersed (order of several kms) and so will not resettle with measurable thickness locally. Fines in the main body of the spoil deposit will remain buried within that mass.

6.6.2.11 The potential changes caused by a release of drilling fluid at HDD punch-out near the landfall are set out below. This is a summary of a more detailed quantitative assessment presented in Volume 3, Technical Appendix 6.1: Marine and Coastal Process Assessment Technical Report, which considers information on hydrodynamics and seabed sediments at the landfall alongside empirical relationships describing lateral dispersion and settling velocity (e.g. Soulsby, 1997), to determine the spatial and temporal extent of change:

- The release of bentonite and drill cuttings in the form of drilling fluid from the planned HDD operations will result in a localised and temporary plume of elevated SSC, specifically comprising bentonite clay (a natural non-toxic mineral). Where the plume has measurable SSC that might be of concern (e.g. to bathing water quality), the duration and footprint of the plume will be small in absolute and relative terms (e.g. order of <10 mg/l over footprints larger than 500 m over a period of days; or, order of tens to low hundreds of mg/l over footprints less than 500 m over a period of minutes to one hour);
- In any case, the HDD exit point is located several hundred metres offshore of the beach at West Angle Bay, in or near to the main channel. The majority of the plume will be advected in the direction of the ambient tidal currents, which are aligned to, and will largely follow the path of, the main channel of Milford Haven estuary. The direction of transport (into or out of the estuary) will depend on the state of the tide (flood or ebb) at the time of the release. Plumes that are initially advected into the estuary may disperse more widely but may otherwise remain within the estuary. Plumes that are initially advected out of the estuary are likely to be rapidly advected and dispersed alongshore and are unlikely to fully re-enter the estuary on subsequent tides. It is expected that the plume would be dispersed to relatively low concentrations within hours of release and to background concentrations within a few tidal cycles;
- The bentonite in the drilling fluid is expected to remain in suspension for at least hours or days. It will be widely dispersed before settling and is not expected to accumulate anywhere in measurable thicknesses. Importantly, this holds true for the maerl beds in Milford Haven (which are located in the waters to the north and east of Stack Rock, in the vicinity of the South Hook LNG terminal on the north side of the estuary (Volume 2, Figure 6.1). The closest distance between the maerl beds and the Project boundary is circa 1.7 km and, given that the bentonite is expected to remain in suspension for a period of hours to days, it is reasonable to assume that material will be advected over a distance greater than 1.7 km in this time period. However, it is important to note that the maerl beds and landfall are separated by the main (east to west orientated) channel, with flows in the channel strongly aligned to the bathymetric contours. Because of the direction of these flows, the potential for smothering of the maerl beds by the bentonite – even by a few mm and over a short time period - is considered to be very low.
- If, however, bentonite and/or drill cuttings did accumulate in or around the HDD exit pit, the volume of the pit could theoretically contain the majority of that material. Any accumulated material is expected to be reworked and redistributed to not-measurable concentrations and thicknesses over time by wave and tidal action; and

- The bentonite in the drilling fluid normally has an overall density and viscosity similar to seawater and so is expected to behave (advect, mix and disperse) in a similar manner. If the drilling fluid behaves as a slightly more dense fluid, it may either accumulate in the HDD exit pit or move over the adjacent seabed downslope under gravity, i.e. in an offshore direction and away from nearshore areas.

6.6.2.12 A summary of the changes in SSC and seabed deposition likely to be experienced at the location of the identified environmental receptors shown in Volume 2, Figure 6.17 and Volume 2, Figure 6.18 and in Table 6.18 .

Table 6.18 – Summary of SSC impacts on key Project Receptors (construction phase)

Receptor Name	Location	Spatial Extent of Increased SSC Plume	Increased SSC values	Duration of increased SSC	Extent/ Thickness of sediment deposition
Receptors close to the location of potential disturbance					
Annex I bedrock and stony reef	Within and around ECC in approaches to Milford Haven (KP1.5 to 5.2 and KP14.6 to 14.9)	Within a few tens of metres and at the time of active disturbance Within a few tens of metres more than 1 hour after end of active disturbance	Very high (>thousands of mg/l) No change	For the duration of active disturbance plus up to 30 minutes following end of disturbance N/A	Sands and gravels may deposit in local thicknesses of tens of centimetres to several metres. Fine sediment is unlikely to redeposit in measurable thickness. See notes* below regarding the relationship between thickness and extent.
Annex I sandbank	Within and around ECC at Turbot Bank (KP6.5 to 10.5 and KP14.7 to 17.7)				
WFD waters and designated bathing waters	Crossing West Angle Bay (KP0) and up to approx. 0.5 km from ECC (centred on KP5)				
Sandeel (higher potential) habitat	Within and around the ECC (in the vicinity of KP23)				
Receptors relatively distant from the location of potential disturbance					
Maerl beds	Approx. 2.3 km from KP0.5 (landfall) within Milford Haven estuary	More than 500 m and up to one tidal excursion distance downstream and at the time of active disturbance	Tens to low hundreds of mg/l as a result of remaining fines in suspension, only within a narrow	Decreasing rapidly to ambient values within one day after end of active disturbance	No measurable thickness of accumulation likely for widely dispersed fine sediments.
Seagrass beds	Approx. 2.4 km from KP0.5 (landfall)				

Receptor Name	**Location**	**Spatial Extent of Increased SSC Plume**	**Increased SSC values**	**Duration of increased SSC**	**Extent/ Thickness of sediment deposition**
The Gann flats (sheltered muddy gravel)	Approx. 5.3 km from KP1.5 (landfall)	More than 500 m and up to one tidal excursion distance downstream more than 1 hour after end of active disturbance	plume (tens to a few hundreds of metres wide. Within 6 hours very low (up to tens of mg/l). Thereafter no change.	N/A	No measurable thickness of accumulation likely for widely dispersed fine sediments.
Salt marsh (within an inlet)	Approx. 5.3 km from KP0.5 (landfall)				
Blue mussel beds	Approx. 5.4 km from KP0.5 (landfall)				
WFD waters and designated bathing waters	Approx. 0.5 to 5.6 km from ECC (centred on KP5)	Any distance, but not closely aligned to the sediment disturbance along the local tidal axis.			
Herring (higher potential) spawning areas	Approx. 1.5 km from KP8		No change	N/A	No measurable thickness of accumulation likely for widely dispersed fine sediments.
Sandeel (higher potential) habitat	Within and around the ECC (in the vicinity of KP23)				

* The realistically possible extent and average thickness of accumulation is inherently linked to, and limited by, the total volume displaced and locally deposited. The actual outcome will depend on the activity type and method, and the environmental conditions at the time of disturbance. Examples within a range of potential combination for each activity type are provided in Volume 3, Technical Appendix 6.1: Marine and Coastal Process Assessment Technical Report.

Assessment of Significance

6.6.2.13 All of the identified marine and coastal processes receptors will be insensitive to elevated levels of SSC. However, the potential for these changes to impact other EIA receptor groups is considered elsewhere within the ES, in particular:

- Chapter 7: Marine Seabed and Water Quality;
- Chapter 8: Offshore Designated Sites;
- Chapter 9: Marine and Coastal Ecology;
- Chapter 10: Fish & Shellfish Ecology;
- Chapter 11: Offshore Ornithology; and
- Chapter 12: Marine Mammals.

Potential changes to sediment transport systems by changes in wave and current climate (pathway)

6.6.2.14 The installation of offshore export cable protection, semi-submersible floating platforms and WTGs and/or the presence of anchoring structures all have the potential to result in a localised blockage of waves, tides and sediment transport. This blockage will commence when offshore construction begins, increasing incrementally up to the RWC, which is represented by the fully operational Project. Construction is expected to commence at the start of 2026 and be complete within approximately 8 months.

6.6.2.15 All changes to sediment transport systems due to modification of the wave and current climate will be no greater than that identified for the operational phase (see Section 6.6.3.1) and, therefore, is not considered further here.

Potential changes to the morphology of the seabed including from scour (receptor)

Overview

6.6.2.16 The presence of anchoring structures and offshore export cable protection measures both have the potential to impact seabed morphology. This impact will commence when offshore construction begins, increasing incrementally up to the RWC which is represented by the fully operational project. However, morphological change arising from the presence of these structures will be no greater than that identified for the operational phase (see Section 6.6.3.14) and, therefore, is not considered further here.

6.6.2.17 In addition to the above, some levelling of sandwaves is expected during the construction phase which has the potential to alter the local seabed morphology. This would be achieved by MFE or dredging (Table 6.17), although it is noted that any sediment removed from the seabed would, preferentially, be deposited close to the dredge location. The potential extent of change and likely timescales over which feature recovery may occur is considered further in this section.

Conceptual understanding of change

6.6.2.18 A detailed analysis and discussion of sandwave clearance and recovery, including numerous examples of pre-dredge, post-dredge and partial recovery surveys of the Race Bank Offshore Wind Farm was produced as part of the Habitats Regulation Appraisal for the Hornsea Project Three Offshore Wind Farm (ABPmer, 2018a). Similar analysis was also undertaken for the Norfolk Vanguard and Norfolk Boreas Export Cable Route (ABPmer, 2018b).

6.6.2.19 The assessment below draws on, and is consistent with, the evidence and conclusions presented in the above references with regards to the observed underlying mechanisms for sandwave recovery, whilst acknowledging and accounting for differences in the environmental setting that might affect the rate of recovery. The observations of sandwave levelling and recovery in the above references are from another location, mainly in the export cable corridor for Race Bank offshore wind farm, outer Wash, east coast UK.

6.6.2.20 Similarities include the sediment type (predominantly sandy), general mobility (sediments are regularly mobilised), peak current speeds (1 to 1.25 m/s on a mean spring tide for Race Bank, compared to 0.8 to 1.2 m/s for the locations of sandwaves to be levelled in the ECC). Differences mainly relate to water depth (10 m for Race Bank but 20 to 50 m for the Proposed Development). The greater depths associated within the Proposed Development will mainly act to reduce the contribution of any wave action, and the effectiveness of currents, to cause sediment mobility and bedform evolution in the ECC.

6.6.2.21 A summary of the available evidence is as follows:

- Where bedforms are present and mobile, this is the natural state of that environment; the processes that are active are conducive to the development and dynamic evolution of such features. Local perturbations to existing sandwaves that do not change the fundamental conditions of the setting (tidal and wave regime, volume of mobile sediment present) will continue to evolve through the same naturally occurring processes and will therefore recover towards a new equilibrium state over time;
- Bedform recovery occurs as a result of the ongoing sediment transport processes (local transport of sediment volume into the levelled area that is retained) and general bedform migration through the system. Estimated recovery rates for sandwaves at Race Bank were mainly the result of local sediment accretion and were projected to occur in the order of several years under similar tidal forcing conditions but based on a smaller displaced volume and in shallower water depths; and
- The proposed bed levelling is not likely to pose a barrier to sediment transport within, or to locations beyond, the wider sandwave/sandbank system.

6.6.2.22 The volume of material to be displaced from individual sandwaves will vary according to the local dimensions of the sandwave (height, length and shape) and the level to which the sandwave must be reduced (also accounting for stable sediment slope angles and the capabilities and requirements of the cable burial tool being used). Based on the available geophysical data, it is anticipated that the bedforms requiring localised levelling are likely to be up to 6 m in height. The RWC for levelling corridor dimensions and sediment disturbance by sandwave levelling prior to cable installation are set out in Table 6.17 and Table 6.19.

6.6.2.23 The sediments comprising the sandwave features will be predominantly sand, although a small proportion of fines and gravel (each comprising up to <5 to 10%) may also be present. Individual sandwaves will require removal via MFE or by multiple dredging cycles to complete the required corridor. If dredging is undertaken, the preference is for the dredge spoil to be returned to the seabed in the vicinity of the dredged area. The number of dredging cycles required and changes to SSC and seabed deposition associated with dredging for the individual sandwaves is assessed in Volume 3, Appendix 6.1: Marine and Coastal Process Assessment Technical Report.

6.6.2.24 Sandwave levelling totalling 403,000 m^3 is proposed at seven locations along the ECC (Volume 2, Figure 6.16 and Table 6.19). Localised sandwave levelling totalling a further 181,600 m^3, as conservative estimate based on current layout options, will also be undertaken at multiple, presently unconfirmed locations within the array area. The levelling will be associated with the installation of mooring lines, anchors and offshore array cables. Within the array area, the available evidence suggests that sediment is mobile but sandwaves are either stationary or migrating very slowly (i.e. <1 m/yr). Conversely, with the exception of KP8 (where no overlapping bathymetry data are available), the sandwaves at the identified locations along the ECC have been confirmed as active features (Volume 2, Figure 6.12).

6.6.2.25 The tidal current regime (peak current speeds on a mean spring tide of 0.6 to 1.4 m/s along the ECC) is sufficiently strong at and around each location to cause mobility of sand on a regular basis. The crests of sandwaves at KP12, KP14-17 and KP29/30 are observed to be migrating by approximately 1 to 4 m per year, on average (Volume 2, Figure 6.12). The tidal current regime will not measurably change as a result of the localised levelling, or as a result of any other aspect of the Proposed Development. The volume of sediment available in each local system will be locally redistributed by the local levelling (via MFE) and/or dredging and disposal of removed material back into the water column nearby but will not change in an overall net sense. As the controlling factors will also not change, it is certain that the levelled areas and sandwave features can recover in time to a new (dynamically evolving) natural state.

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

6.6.2.27 The rate and timescale of recovery will vary in proportion to the rate of sediment transport and accumulation. Faster infill and recovery rates will be associated with periods of higher local flow speeds and more frequent wave influence at the seabed. The following factors will all influence the rate of recovery:

- In the array area: sediments are mobile (up to 0.36 m3/m/hr during peak spring tidal currents), but with very slow rates of bedform migration (<1 m/yr) due to relatively symmetrical patterns of transport during flood and ebb tides;
- In the ECC: sediments are increasingly mobile towards the approaches to Milford Haven (up to 0.36 to 3.6 m3/m/hr during peak spring tidal currents), with measurable but relatively slow rates of bedform migration (1 to 4 m/yr) due to the higher rate and slight asymmetries in transport;
- The width of the dredged corridor (50 m);
- The wavelength of the features (in the order of 200 m); and
- The relatively large volume of sediment being displaced due to the large height of some sandwave features.

6.6.2.28 The exact timescale for recovery cannot be calculated with certainty. Based only on the overall rate of observed bedform migration (which is not the main or only mechanism for recovery and is proportional to the long term net sediment transport rate), the timescale for recovery in the more energetic parts of the ECC is estimated to be in the order of 10 years; longer timescales of 'at least' 10 years can be inferred for the array area, based on the negligible observed rate of bedform migration. However, short-term sediment mobility will also contribute to local sandwave recovery, and these rates are known to be higher than negligible in these areas

6.6.2.29 A shorter estimated timescale is obtained when considering the instantaneous rate of transport during higher flow periods. As shown by the detailed sand transport modelling, instantaneous transport rates (increasing from the array area along the ECC) of 0.36 to 3.6 m^3/m/hr may be active up to four times per day (peak flood and ebb) for a few days either side of the peak of spring tides. At a representative mid-level rate of 1 m^3/m/hr, and assuming a representative 50 m wide corridor and a volume of 50,000 m^3 sediment displaced (see Table 6.19), it could take in the order of (50,000 m^3/[1 m^3/m/hr x 50 m x 4 hr/day x 4 days]) 62.5 spring tidal cycles (~2.4 years) to move the displaced volume of sediment back into the levelled area. The rate of transport and so the rate of recovery can be around three times faster closer to Milford Haven, but also around three times slower in the array area. The overall rate of recovery would also vary in proportion to the volume displaced (relative to the representative value of 50,000 m^3).

6.6.2.30 The recovery may be gradual or episodic. Rates of sandwave bedform recovery are likely to be relatively faster closer to the landfall (higher current speeds and shallower depths lead to greater and/or more frequent sediment mobility). Varying states of partial recovery will be achieved in a shorter timescale. As the recovery is due to natural processes of sediment transport, the nature of the seabed surface sediments in the recovering area will not be measurably different to that on the surrounding seabed and adjacent sections of undisturbed sandwave. In all locations, surficial sediments will continue to be mobilised at the natural ambient rate and direction under sufficiently energetic current and wave conditions, with the associated development and migration of smaller (e.g. ripple and mega-ripple) bedforms. Where the dredge spoil is returned to the seabed in the vicinity of the dredged area, the volume and supply of sediment in the local system is not changed.

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

6.6.2.32 The levelled areas are not considered likely to create a barrier to onward sediment transport. Evidence from aggregate dredging activities indicates that if any changes occur to the flow conditions or wave regime, these are localised in close proximity to the dredge pocket (with widths and lengths of several kilometres). The proposed works will be at a much smaller scale and footprint, with trench widths expected to be in the order of up to 50 m, in water depths of at least 30 m. This means there is likely to be little to no influence on the flow or wave regime, which in turn means little to no change to the regional scale sediment transport processes across the array area and ECC.

Table 6.19 – Dimensions of areas identified for sandwave levelling within the ECC

Area	KP Interval	Corridor Width (m)	Bedform crest elevation above mean undisturbed seabed level (m)	Cross sectional Area - triangular shaped (m^2)	Corridor Length (m)	Estimated Volume (m^3)
1	8.0 - 8.5	50	4	100	200	20000
2	12.5 - 13.0	50	2	50	300	15000
3	13.5 - 14.0	50	2	50	400	20000

Area	KP Interval	Corridor Width (m)	Bedform crest elevation above mean undisturbed seabed level (m)	Cross sectional Area - triangular shaped (m^2)	Corridor Length (m)	Estimated Volume (m^3)
4	15.0 - 15.5	50	4	100	400	40000
5	15.5 - 16.5	50	5	125	600	75000
6	29.0 - 30.0	50	6	150	600	90000
7	45.3 - 46.3	50	4	100	500	50000
Total Sandwaves Clearance Volume in the ECC (30% Safety factor to account for any variability in bedforms geometry)						**403,000**

Assessment of Significance

6.6.2.33 The receptor under consideration is the Annex I sandbank within and around the ECC at Turbot Bank, and the seabed areas within the Pembrokeshire Marine SAC, West Wales Marine SAC and the Skomer, Skokholm and the Seas off Pembrokeshire SPA (note that levelling of sandwaves is not proposed within the Pembrokeshire Marine SAC). Although internationally designated, the seabed in these areas is highly dynamic and is assessed to have some capacity to recover from disturbance associated with sandwave levelling. Accordingly, it is assessed to be of medium sensitivity.

6.6.2.34 The magnitude of impact to the seabed resulting from levelling is considered low. This is because although direct impacts to the seabed will occur, the seabed is expected to recover in response to the occurrence of short-term seabed mobility (occurring during peak flood and ebb currents on spring tides in all locations, but also more frequently and at other times in parts of the ECC closer to Milford Haven) and observed natural migration of bedforms in the ECC (lower rates of migration in the array area, higher in other parts of the ECC, dependant on local patterns of net sediment transport).

6.6.2.35 The overall level of effect significance has been determined by combining the assigned rating for receptor sensitivity (medium) and impact magnitude (low), as shown in Table 6.7. The result is a **minor adverse** effect, and therefore not significant in EIA terms.

Additional Mitigation and Residual Effect

6.6.2.36 None of effects identified above are major or moderate adverse (significant in EIA terms). Therefore, no additional mitigation is required to reduce the significance to non-significant in EIA terms and the significance of residual effects remain as detailed above.

Potential changes in morphology of the coast

Overview

6.6.2.37 The offshore export cable will make landfall at West Angle Bay. The bay is a sediment covered basin with localised rocky outcrops of limestone and sandstone (Volume 2, Figure 6.14). The shallow subtidal sediment cover is dominated by coarse to medium sand, fining to fine/very fine sand within the inner parts of the bay. Some muddy sand is locally present (Volume 2, Figure 6.6). The coastline here is currently defended, with a short length of seawall reducing the risk of coastal erosion and flooding to a small number of coastal assets. However, longer term a policy of 'No Active Intervention' is likely (Halcrow, 2012).

6.6.2.38 The preferred cable installation method at the landfall is HDD, however as a precaution in case of failure of the HDD, the installation may involve the use of open cut trenching (potentially requiring coffer dams). The availability of vessel may necessitate the use of Nearshore Floatation Pits (NFPs) for vessels of greater draft that cannot fast to the ground whilst installing the cables. These NFPs will allow the installation vessel to remain floating at low tide and avoid being grounded.

6.6.2.39 There are several source/pathways via which the morphology of the landfall at West Angle Bay could theoretically be impacted. These are:

- Open cut trenching through intertidal and shallow subtidal areas;
- Excavation of NFPs;
- Excavation of HDD exit pits; and
- HDD drilling operations.

6.6.2.40 These are discussed individually, below. It is noted here that changes to the nearshore wave regime/sediment transport due to the presence of cable protection measures is considered separately, within the Operations and Maintenance phase (Section 6.6.3.1) No coastal defences are known to be below MHWS. An assessment of the impact of open cut trenching through the existing coastal defences (along with reinstatement) is considered within the onshore assessment (Chapter 19: Onshore Geology, Hydrogeology and Hydrology).

Conceptual understanding of change

6.6.2.41 Trenching through intertidal/ shallow subtidal areas: Under the RWC, nearshore (KP0.0 – KP1.5) export cable installation will be associated with the excavation and side-casting of material along one trench:

- The trench will start at a depth of approximately 5 m below LAT and extend ~ 650 m (i.e. to MHWS at the top of the beach in West Angle Bay);
- The trench will have a width of approximately 3 m and be up to 3 m deep along most of its length. A nominal width of disturbance of 10 m for the trench has been assumed in the assessment, which is inclusive of the actual trench width (3 m) and any areas of access/spoil disposal either side of the main trench;
- It is presently unknown where side-cast material will be stored but will be informed by (amongst other things) understanding of sediment dynamics within the bay. A worst-case assumption is made here that material will be left *in-situ*, adjacent to the trench;

- On completion of the cable installation works, the side cast material will be used to infill the trench. Under the RWC, extraneous material may be imported to site for backfill purposes; and
- Cofferdams may be installed to provide trench shuttering to minimise the extent of the excavation works and provide safe trench support from the seaward side of the inshore area to the onshore duct entry point (e.g. above MHWS). These cofferdams may be in place for up to a total of 12 weeks. The maximum length of the cofferdams is not known at this stage but is expected to be around 100 m long (extending form the beach into the adjacent intertidal area).

6.6.2.42 The beach at West Angle Bay is arcuate in form. This is a function of wave diffraction and refraction about the headlands in the approaches to the bay, resulting in wave crests arriving mainly parallel to the shoreline (shore normal). The observed morphology of the embayed (or pocket) beach shown in Volume 2, Figure 6.14 reflects this wave distribution: longshore currents are minimal resulting in a broadly symmetrical shape to the beach.

6.6.2.43 Given that the trench (and any associated cofferdams) will be shore normal (Volume 2, Figure 6.6), on the basis of the above it can reasonably be assumed that the presence of the trench/cofferdam structures will have a limited influence on wider beach morphology. This is because net rates of longshore sediment transport are negligible and therefore the structures will not be acting as a barrier to the movement of sediment. Notwithstanding the above, it is reasonable to assume that some larger storm events may occur in the time that the cofferdam(s) are present, especially if the construction period overlaps with winter months.

6.6.2.44 During storms, waves will have the potential to interact with the cofferdam structures at the top of the beach, potentially resulting in some localised scouring and redistribution of sediment adjacent to the structure (depth in the order of tens of centimetres to one metre; extent in the order of metres to tens of metres). However, once the structures are removed, it is expected that the beach will return to its baseline form very quickly (order of days to weeks of tidal inundation, or in a matter of hours during larger wave conditions).

6.6.2.45 It is noted here that the design and use of temporary cofferdams in intertidal/nearshore areas is a mature and common engineering practice which, by using industry best design practices developed through experience, will help ensure minimal negative effects on the surrounding coastal area. Examples of uses for cofferdams include HDD exit and transition pits for wind farm export and interconnector cable landfalls, sub-sea pipeline landfalls, coastal defence construction and archaeological excavations.

6.6.2.46 Once the offshore export cable has been installed in the open-cut trench, the cofferdam structures will be removed and trench back filled, returning the beach to its baseline condition. The only way in which the offshore export cable could then interact with coastal processes would be via cable exposure following erosion of the overlying beach sediments.

6.6.2.47 A full Cable Burial Risk Assessment (CBRA) will be undertaken to determine appropriate burial depths, taking into consideration the geotechnical properties of the material into which the cables are buried and understanding of historic morphological change. Qualitative and quantitative analysis of the available evidence suggests that the beach here is stable (Volume 2, Figure 6.14 and Graphic 6.18).

6.6.2.48 Excavation of the open cut trench with a plough will likely result in the formation of sediment berms either side of the trench. Based on the maximum dimension of the trench, and given that the displaced material is expected to be predominantly sandy in nature and assuming an angle of repose for sand of ~30 degrees, the maximum sediment berm height will be approximately 1.1 m and the total width of the berms and trench approximately 10 m.

6.6.2.49 Excavation of loose and hard substrates from the open cut trench with rock cutting tools remains an option. The dimensions of the trench and therefore the volume of material displaced are the same as described above for ploughed loose sediment. If the majority of cuttings are sand sized, then the likely dimensions of the side berms will also be similar to that described above. If the majority of cuttings are gravel sized or larger, then they may form a steeper berm, potentially reducing the lateral extent, with a proportional increase in height. By design, rock cutting tools are unlikely to convert a large proportion of the cut material to grains finer than sand.

6.6.2.50 It is possible that whilst the trench is open (potentially up to 3 months), the material in the berms could be mobilised and locally redistributed by the combined action of tidal currents and waves. Accordingly, the potential extent of changes to beach/intertidal morphology could include a wider area than the immediate footprint of the trench and berms described above. In the event that the remaining material volume is insufficient for backfill, it is assumed that additional material would be imported to site for this purpose. If material is brought in externally to fill the trench, in as far as is practicably possible it will mimic the native material.

6.6.2.51 Given that the berms would only be present for a relatively short period of time, any associated changes to hydrodynamics and sediment transport would also be limited and there would be no potential for longer term change to the (mainly rocky) coastal morphology.

6.6.2.52 Within the intertidal/shallow subtidal, it is anticipated that reworking by waves will quickly (in the order of days to several weeks) redistribute and smooth any remaining local disturbances after the trench has been backfilled, returning the area of the trench (and associated works) to a natural state (e.g. elevation and sediment type) that will be in equilibrium with the baseline environment.

6.6.2.53 <u>Excavation of NFPs:</u> the selected cable installation vessel for the project should be capable of operating in very shallow waters, with grounding capabilities (i.e. a flat keel), equipped with spud cans or anchor spread. However, where there is the requirement to enable the installation vessel to operate in the shallow water (approximately 7 m below LAT or less) near to the West Angle Bay landfall, NFPs might be required. These will allow the installation vessel to float at low tide and avoid being grounded on the seabed surface. Typical dimensions of each of NFP are: 160 m x 45 m and 5 m deep. Once offshore export cable installation works are completed (up to 5-month duration) the NFPs will be infilled with the material that was excavated. It is presently unknown where the excavated material will be side-cast or temporarily stored elsewhere; preference is noted to be stored locally and returned to location on completion.

6.6.2.54 Potential changes to the wave regime resulting from the presence of the NFPs are described below:

- Changes to short period, low amplitude wind waves will be largely immeasurable at all states of the tide as the proposed temporary changes to water depths will be insufficient to alter wave characteristics;
- Longer period, higher amplitude storm waves could theoretically be more affected by the presence of the NFPs, possibly resulting in some wave refraction. However, the dimensions of the NFPs will be comparatively small relative to the wavelengths of storm waves, limiting the potential for sizeable refraction. Any change to the wave regime will also diminish with increasing distance away from the NFPs and at higher states of the tide when water depths are greater;

- Since the largest waves approach from the southwest, any changes to the wave regime inshore from the NFPs would generally occur towards the northeast of the pits. Localised and minor changes to the wave regime may also occur to the east of the NFPs (i.e. within West Angle Bay) as refraction of larger offshore southwesterly waves, as they enter Milford Haven, will mean these waves will have a slightly more westerly component as they arrive at the NFPs; and
- The presence of the NFPs could potentially enable wave energy associated with storm waves to propagate further inshore as larger waves will shoal less, enabling them to remain marginally higher immediately in the lee of the NFPs. However as larger waves travel inshore from the NFPs across the beach, the shoreline gradient/water depths and rocky outcrops will increasingly become the limiting condition on wave form.

6.6.2.55 Given that the prevailing waves are from the southwest, the greatest change in wave climate will generally be to the northeast of the NFPs (just to the north of West Angle Bay). However, the coastline here comprises hard rock with very little surficial mobile sediment present and therefore will be largely insensitive to such small-scale changes in incident wave energy.

6.6.2.56 Waves propagating into Milford Haven from the southwest will refract and become more aligned to the coast as they approach West Angle Bay. However, even with this refraction, it is probable that only some the waves reaching the beach in West Angle Bay will have passed across the footprint of the NFPs. Even allowing for the occurrence of waves passing across the footprint of the NFPs, associated morphological change to the beach is expected to be limited:

- As larger waves travel inshore from the NFPs across the beach, the shoreline gradient/water depths and rocky outcrops across the entrance to the bay will increasingly become the limiting condition on wave form;
- The extent of change will be greatly limited by the underlying hard rock geology which can be at or close to the surface here (Volume 2, Figure 6.14); and
- Change across the upper beach will be associated with wave driven sediment transport at higher states of the tide. Importantly, owing to the macro tidal setting at the export cable landfall, water depths in the vicinity of the NFPs will be approximately 12 m (or greater), since MHWS at the landfall is 7 m above LAT and the shallowest setting that the NFPs can occupy is -5 m LAT. In such depths of water, the potential for modification to waves as they propagate across the NFPs will be very much reduced in comparison to equivalent size waves at low water. Accordingly, the wave energy reaching the upper beach will remain similar to baseline conditions with the NFPs in place.

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

6.6.2.58 The extent to which a small section of beach morphology could potentially be altered by trapping of sediment will be dependent upon the frequency and magnitude of storms during the operational period of the NFPs. If a NFP were to be entirely infilled, this would represent ~36,000 m^3 of material ‘lost’ from the beach. However, this is extremely unlikely to happen given the short duration of time that the NFPs will be operational and their distance from the beach, as well as the preferred reinstatement of the removed material in creating the NFPs.

6.6.2.59 Given that winter storms may occur during the operational period of the NFPs, it is theoretically possible that some maintenance dredging of the NFPs may be required. Should this be required, any dredged material will be deposited in close proximity (and landward of) the NFP. Accordingly, no mobile beach material will be lost from the local system but will instead remain available for beach resupply.

6.6.2.60 <u>Excavation of HDD exit pits:</u> The offshore export cable (prior to bundling in the ECC) may require an exit pit to be excavated at the punch-out location, up to two exits. These would be (up to) 21 m long by 10 m wide by 4 m deep and located (approximately) 3 to 5 m below LAT and be open for up to 5 months.

6.6.2.61 The potential mechanisms by which the presence of these pits could impact the coast at the landfall are the same as for the NFPs, principally via the modification for waves and interception of sediment. Both the size of individual pits and total number of pits will be less than the that of the NFPs and so changes attributable to the presence of the HDD exit pits will be less than for the NFPs. However, it is acknowledged that any effects will be additive to the NFPs as both the exit pits and NFPs will be open at the same time.

6.6.2.62 <u>HDD drilling operations:</u> HDD works could be used to create an underground conduit between the shallow subtidal (3 to 5 m below LAT) and onshore parts of the route. HDD will cause minimal direct disturbance to the existing coastline because, if correctly designed, it will not interact directly with, or leave any infrastructure exposed, in the active parts of the beach (between the entry and exit points of the drill) and so will not impact upon littoral processes in these areas. Provided that the cables remain buried beyond the exit of the HDD, there is no possibility for it to interact with, or have any effect on nearshore beach processes or morphology. The design of the HDD operation will take this into account.

6.6.2.63 Owing to the uncertainty surrounding the future shoreline management policy at the landfall, it will be important for a full assessment of coastal variability to be undertaken under a range of coastal management and climate change scenarios. This will enable appropriate set back distances for the transition jointing bays to ensure that they are unaffected by the possibility of coastal retreat due to either natural erosion or sea level rise due to climate change.

<u>Assessment of Significance</u>

6.6.2.64 The coast at the landfall is considered to be of medium sensitivity. Although nationally designated (as part of the Angle Peninsula Coast SSSI), the rocky outcrops and intertidal areas will be insensitive to changes in waves, tides and sediment transport. The pocket beach within the bay itself will be more sensitive change although will have some capacity to recover from disturbance.

6.6.2.65 The magnitude of impact is predicted to be (no greater than) low for all of the impact source/pathways outlined in this section. Where direct disturbance takes place to the beach/shallow sub-tidal seabed (e.g. via trenching), the impact will only be present for the duration of the construction works and will therefore be temporary in nature. Indirect impacts of longer-term duration (e.g. any changes to the seabed/beach morphology arising from modification of the hydrodynamic/wave regime in response to cable protection) will be highly localised in nature.

6.6.2.66 The overall level of effect significance has been determined by combining the assigned rating for receptor sensitivity and impact magnitude, as shown in Table 6.7. The result is a **minor adverse** effect, and therefore not significant in EIA terms.

Additional Mitigation and Residual Effect

6.6.2.67 None of effects identified above are major or moderate adverse (significant in EIA terms). Therefore, no additional mitigation is required to reduce the significance to non-significant in EIA terms and the significance of residual effects remain as detailed above.

6.6.3 Operation and Maintenance

Potential changes to the sediment transport system by changes in wave and current climate (Pathway)

Overview

6.6.3.1 The presence of cable protection on the seabed, and the semi-submersible floating platforms with associated moorings and array cables in the water column, has the potential to present local blockage or resistance to the passage of currents and waves. The direct change is most likely to appear as a wake or shadow feature in the lee of the obstacle, where the baseline or ambient conditions may be modified. Due to the limited depth, height, or other dimensions of the obstacles being introduced as part of the Proposed Development, changes are likely to be of limited scale and extent.

6.6.3.2 As a result, indirect changes to sediment transport rate and direction, controlled by the current and wave regimes, are also not likely (where measurable changes to currents and waves do not extend to the seabed), or would be limited to the same relatively small scale and local extent (up to tens of metres for cable protection and hundreds of metres for semi-submersible floating platforms).

6.6.3.3 The potential for offshore export cable protection to cause changes to coastal morphology at the landfall are assessed separately later in this section (Section 6.6.3.14).

Conceptual understanding of change

6.6.3.4 Installation of cable protection within the array area and along the ECC: Cable protection might be applied to (up to) all array cables and up to 16% of the offshore export cable (7.5 km total), with proposed locations set out in Volume 2, Figure 6.16. The protection will most likely take the form of a rock berm, with the worst case parameters of a 11 m base width, (maximum) 2 m overall height, and sloped sides up to a 2 m wide berm crest (noting this is mainly for the ECC, the array cables would likely be less at 5 m wide, 1 m high rock bags). However, there will also be variations on these parameters, all less than this worst case, depending on the depth of burial. The berm will comprise either concrete mattresses, or rock placement or rock bags with clast sizes in the approximate range 2 to 30 cm.

6.6.3.5 The purpose of cable protection is to provide protection to the cable and remove risk to local sea users. It is also designed to prevent sediment scour. Where protection is applied, no scour will be caused by the protected cable itself, however, a small amount of localised secondary scour may form at the edges of the berm, in proportion to the overall berm dimensions and the clast size used.

6.6.3.6 Water depths are approximately 85 to 65 m below LAT within the array area, approximately 50 to 70 m below LAT in offshore areas of the ECC, 30 m below LAT in the approaches to Milford Haven estuary; and 10 to 20 m below LAT in the approaches to West Angle Bay. Changes to marine and coastal processes due to the installation of cable protection in these areas is described below.

<u>In the array area and offshore areas of the ECC (water depths 40 to 85 m below LAT; ~KP10 to 47):</u>

- The cable protection height (max. 2 m) is only a very small proportion of the total water depth. On the limited occasions, during large storm events, when waves are sufficiently large to interact at all with the berm, it is still unlikely that the berm will present a sufficient obstacle to cause changes to their size or direction;
- The long axis of any potential berm may be more or less aligned to, or perpendicular to, the main tidal current axis, depending on exact location within the array area or along the ECC. However, the cable protection height (max. 2 m) is a very small proportion of the total water depth and so, together with the sloped sides of the berm, will present a minimal obstruction to tidal currents (no measurable effect more than a few tens of metres from the berm and restricted only to the near-bed);
- The berm axis also, therefore, lies across the natural sediment transport pathways, which may present some obstruction to sediment transport as bedload (sediment transport in suspension will not be affected);
- An initial period of sediment accumulation may occur within and around the berm, as a limited volume of sediment in bedload transport is trapped within any open surface voids. A surface accumulation of sediment may develop over the updrift side (appearing similar to a groyne on a beach). The volume of sediment accumulated will vary in proportion to the size of the voids and so the clast size used (anticipated 2 to 30 cm), but will be a small absolute volume and is expected to occur in a relatively short period of time (order of weeks to a few months). The slope of the berm (1:3) already provides an approximate 18˚ slope angle, which is within the range of naturally stable bed slopes (<32˚ for sands). When sufficient sediment volume has been accumulated on the updrift surface to present a naturally stable sediment slope and surface, sediment transport will thereafter continue over the berm at the natural ambient rate and direction;
- No measurable change to the seabed is expected more than a few metres from the updrift edge of the berm. A small local depression (scour) of proportionally small dimensions (i.e. a few tens of centimetres depth and within a few metres of the berm edge) may form on the downdrift side of the berm as a result of the temporary reduction in sediment supply during the initial accumulation process;
- The patterns and dimensions of sediment accumulation or scour may vary over the operational lifetime of the berm, due to natural fluctuations in sediment supply and transport rates and directions. Changes may be seasonal or episodic in nature (e.g. during or following larger storms, then gradually returning to another state associated with purely tidal conditions); and
- The nature of the seabed (sediment type and texture) around the berm, including within any areas of local accretion or scour, is not expected to be measurably very different to the surrounding seabed.

<u>In the approaches to Milford Haven Estuary (water depths around 40 to 50 m below LAT; KP5 to 10):</u>

- The cable protection height (max. 2 m) is only a small proportion (5%) of the total water depth (at LAT). Where currents and waves interact with the berm, it is unlikely that the berm will present a sufficient obstacle to cause changes to their magnitude or direction beyond the very local near-bed area;

- Where the berm axis is more closely aligned to the sediment transport direction, little to no measurable change to the seabed is expected more than a few metres from the edges of the berm. A small volume of sediment might accumulate gradually in the surface voids of the berm, but not likely in sufficient quantities to cause measurable changes to the surrounding seabed level. Where the berm axis is at a more acute angle to the sediment transport direction, see the description above for offshore areas; and
- The closest distance to the coast that cable protection is proposed is approximately 2.3 km (between KP4.6 and 6.6). As discussed above, any changes to waves, tides, and sediment transport are expected to be localised and will therefore not extend to the adjacent coast. Similarly, any changes to waves, tides and sediment transport associated with the installation of cable protection between KP7.1 - 7.3 will not extend to Turbot Bank, the main crest of which is located around 2 km to the east. (It is however, recognised that the cable protection is located within the Annex I designation associated with the wider Turbot Bank feature).

Nearshore/within Milford Haven estuary (water depths from less than 20 m below LAT; ~KP1 to 5):

- The cable will be routed through a local deep-water channel (Row's Rocks) in the approaches to Milford Haven estuary; 20 to 25 m water depth within the channel, approximately 100 m wide, compared to 15 m water depth in the surrounding area. No rock protection is proposed in this area. Cable protection may be required at the entrance to Row's Rock channel (between KP6.6 to 4.6).

At the landfall (water depths from less than 20 m below LAT; ~KP0 to 1):

- Should HDD be used, a small amount of rock protection may be required to protect the HDD duct exit (approximately 5 m LAT) if burial is not achieved. This could involve the installation of rock protection 21 m long by 5 m wide by 1.2 m high at each exit. Cable protection within intertidal areas will be achieved by burial and the requirement for additional rock protection is not anticipated.
- In theory, the installation of cable protection measures such as these could cause a morphological response via (for instance) modification of the local nearshore wave regime and associated patterns of sediment transport. However, whilst it can reasonably be expected to be the case that there will be some localised change to waves and hydrodynamics immediately within the vicinity of the rock berms, the potential for wider morphological change to the beach at the landfall is considered to be limited, owing to the limited scale of the rock protection proposed;
- The landfall is located in a macro-tidal setting, with a mean spring range in excess of 6 m. Whilst some wave breaking can be expected in the lee of the berms at lower states of the tide, for the majority of the time when total water depth is greater, waves are unlikely to interact with or be affected by the small and localised relative change in total water depth; and
- Finally, it is noted that tidal current speeds within the bay are so low that they do not contribute measurably to sediment transport. Any local obstacle presented by a berm or other near-bed cable infrastructure will not cause any meaningful change in tidal current speed or direction.

6.6.3.7 Presence of semi-submersible floating platforms and presence of anchoring systems: The effect of the semi-submersible floating platforms on tidal currents within the array area will be to locally reduce current speed and increase turbulence in a narrow wake behind the cross section of each semi-submersible floating platform column (up to one larger column 21.96 m and two smaller columns 19.2 m diameter), and to a lesser extent behind the smaller cross-bracing members (up to 4 m diameter).

6.6.3.8 The individual columns will be separated by approximately 70 to 80 m centre to centre. Currents underneath the foundations will not be directly affected by the main structure but will interact to a much lesser extent with the very small blockage presented by the mooring lines (up to five per foundation, 0.32 m diameter) and electrical cable (up to three per foundation, up to 0.30 m diameter) between the base of each foundation and the seabed. The majority of the mooring chain length will be on the seabed and will not interact with currents. The majority of any pile or suction bucket anchors, and all of any embedment anchors, will be buried, and so will not interact with currents. However, the top 3 m of suction piles (6.5 m diameter) and drilled or driven piles (2.5 m diameter) may remain above the seabed and so may interact with currents locally.

6.6.3.9 Chain links and clump weights, anchor pile tops, and cable protection that are above seabed and interact with near-bed currents may result in local flow patterns and seabed scour effects (considered in Section 6.6.3.14) but are individually of relatively small scale and so are unlikely to cause a change in overall patterns of flow or sediment transport through the array area. Measurable effects on currents are therefore likely to only be associated with the main semi-submersible floating platforms and so largely confined to surface and near surface waters, and so any change to currents caused by individual foundations or the array will have no consequential effect on the overall rate or direction of sediment transport at the seabed.

6.6.3.10 The surface and upper water column wake features behind each column of the semi-submersible floating platforms may remain separate or may coalesce depending on the relative angle of the current to the foundations individually, and to the array as a whole. Overlapping wake features may become slightly more pronounced, but will recover in the same manner and will also have a smaller overall extent. The wake features/effects will recover rapidly with distance downstream, likely becoming not measurable within a few hundreds of metres (less than the distance between the semi-submersible floating platforms, min. 1 km). The maximum distance to which any (cumulative) effect might propagate from the array area is, in any case, limited to one tidal excursion distance (the distance over which water is displaced during one flood or ebb tidal cycle), approximately 10 km under mean spring conditions for the array area (Graphic 6.6).

6.6.3.11 The local effects of the semi-submersible floating platforms on waves will be limited to an area downwind of the array area, to a distance up to approximately the width of the site (relative to the wave coming direction). Beyond that distance, the seastate will recover to the ambient condition through natural spreading and dispersion of wave energy (see OWF impact modelling studies including East Anglia Offshore Wind, 2012; Moray Offshore Renewables Ltd, 2012; Navitus Bay Development Ltd 2014).

6.6.3.12 A larger proportion of smaller waves (wave periods <8 s) are more likely to be blocked (by reflection or breaking) within the cross section presented by the semi-submersible floating platform; whereas larger waves (wave periods >10 s) will tend to bypass the semi-submersible floating platform with less interaction and consequential energy loss. In any case, for most of the time, waves over the array area will not be large enough (in comparison to the relatively large water depth) to cause any measurable contribution to sediment transport nearby to the array area, therefore, any change to waves that are caused by the array are unlikely to have any consequential effect on the rate or direction of sediment transport.

Table 6.20 – Summary of sediment transport impacts via key project infrastructure (operational phase)

Project Component	Location	Summary of Potential Impact on Sediment Transport Processes
Export/ array cable protection	Array area/ KP10 to 47	Changes in sediment transport extending (up to) 10's of metres from cable protection. Water depths too great for cable protection measures to measurably alter the passage of waves and tides
Export cable protection	Inshore (KP5 to 10)	
Export cable protection	Nearshore (KP1 to 5)	Cable protection will be located >2 km away from the coast in water depths > circa 40 m LAT. Any changes to the wave regime will be extremely small, limited to large storms and will not extend to the adjacent coast.
HDD exit point rock berm	Landfall (KP0 to 1)	Localised changes to waves and hydrodynamics immediately within the vicinity of the rock berms. But associated morphological change limited by the small scale/low profile of the rock protection, the macrotidal setting and very low current speeds.
Semi-submersible floating platforms and associated anchors	Array area	Wake effects extending (up to) hundreds of metres from platforms and associated mooring/anchor systems. Associated changes in sediment transport theoretically possible in this footprint Scour around suction or drilled piles extending (up to) several metres from structure.

Assessment of Significance

6.6.3.13 The changes described in this section are to 'pathways' as opposed to receptors. The significance of potential impacts to marine and coastal processes receptors arising from modification of the sediment transport regime is considered in Section 6.6.3.14. and 6.6.3.30.

Potential changes to the morphology of the seabed including from scour (receptor)

Overview

6.6.3.14 This section describes impacts to seabed morphology focusing on areas within designated sites arising from changes to sediment transport associated with the presence of cable protection, anchoring systems and the semi-submersible floating platforms during the operational phase. Seabed areas within the following designated sites are considered within this assessment:

- Pembrokeshire Marine SAC;
- The West Wales Marine SAC; and
- Skomer, Skokholm and the Seas off Pembrokeshire SPA.

Conceptual understanding of change

6.6.3.15 Installation of cable protection: the presence of offshore export cable protection berms during the operational phase has the potential to cause changes to the local seabed level (scour) as a result of local flow interaction between the body and surface of the berm, and any near-bed current and wave action. The potential for cable protection to cause larger scale changes to the tidal, wave or sediment transport regimes is very limited, as discussed in Section 6.6.3.1.

6.6.3.16 The purpose of cable protection is to maintain stable cover over the lifetime of the Project. By design, it aims to minimise the risk of scour associated with both the offshore export cable and the protection itself. The berm dimensions (11 m base width x 2 m height, 2 m berm tip width) result in relatively low angle slopes (18°) and a low overall height relative to the water depth, which limits the potential for form-related flow disturbance and scour, even when flows are perpendicular to the berm.

6.6.3.17 The individual rock armour units that comprise the berm will be approximately 2 to 30 cm in diameter. Turbulence may become locally elevated in water flowing close to the surface of the berm, which may result in a limited depth and extent of secondary scour (order of a few tens of centimetres deep and up a few metres from the berm). The seabed surface in the scoured area will generally be similar to the surrounding seabed but the texture may coarsen due to preferential winnowing of finer sediment grains.

6.6.3.18 As discussed in Section 0, any changes to waves, tides and sediment transport associated with the installation of offshore export cable protection between KP7.1 - 7.3 will not extend to Turbot Bank, the main crest of which is located around 2 km to the east. Accordingly, no morphological change to the bank is expected to occur with cable protection in place.

6.6.3.19 Presence of semi-submersible floating platforms and associated mooring/anchoring systems: the presence of the semi-submersible floating platforms during the operational phase has the potential to cause changes to the local seabed level (scour) as a result of local flow interaction between the near-bed elements of the foundation moorings and electrical cables, and any near-bed current and wave action. The potential for the main body of the semi-submersible floating platforms themselves to cause larger scale changes to the tidal, wave or sediment transport regimes is very limited, as discussed in Section 6.6.3.7 to 6.6.3.12.

6.6.3.20 The main body of the semi-submersible floating platform is located in the upper water column and is too distant from the seabed to cause a change in the near-bed local flow field or, therefore, any local scour. Where the moorings meet the seabed, the moorings will comprise large chain links (up to 0.81 m long x 0.67 m wide x 0.2 m diameter) with clump weights (up to 2 long x 2 m wide x 1 m height).

6.6.3.21 Buried sections of the chain, clump weights, buried sections of anchor (suction or piled) and any embedment anchors (also completely buried) will not interact at all with the local flow field and so will not cause any scour. Where the chain links and clump weights are partially or completely exposed, increased flow turbulence may cause local scour in proportion to the size of the object, (order of a few tens of centimetres deep and up a few metres from the obstacle).

6.6.3.22 Exposed ends of suction pile anchors (6.5 m diameter, 3 m high) or drilled or driven pile anchors (2.5 m diameter, 3 m high) may cause a greater depth of local scour in proportion to their diameter; however, the limited height of these obstacles disrupts and limits the patterns of flow acceleration that can form, reducing the likely maximum dimensions of scour to the order of a few metres depth and up to ten metres extent, which is less than would be expected from a full water column height obstacle.

6.6.3.23 A section of each mooring chain may occasionally move in response to the movement of the semi-submersible floating platform, the ‘swept area’ may be up to 50 m in two predominant directions. The frequency and distance of movement for individual moorings will depend on the particular mooring configuration and the scale and direction of the force being applied to the semi-submersible floating platform. The movement of the chain over or through the seabed is expected to be generally slow (not causing energetic sediment resuspension) and may include both lateral and vertical movement.

6.6.3.24 This action may cause a ‘ploughing’ or ‘sweeping’ of sediment, redistributing sediment volume locally into linear accumulations with a maximum height proportional to the dimensions of the chain and clump weights (up to 1 m high). The net effect may be an area of disturbed seabed morphology in the swept area (up to 100 m wide in a sector or arch shaped pattern). Any patterns formed will be gradually redistributed to a natural state by ambient sediment transport processes over time. The nature of the seabed sediments and the rate of sediment transport through the affected area are unlikely to be changed by this process.

Assessment of Significance

6.6.3.25 Based on preliminary cable burial and protection studies done to date, offshore export and array cable protection is predicted to be required within the boundary of the Pembrokeshire Marine SAC, the West Wales Marine SAC and the Skomer, Skokholm and the Seas off Pembrokeshire SPA. The latter also partly overlaps the array area. Although internationally designated, the seabed in these areas is highly dynamic. Accordingly, it is assessed to be of medium sensitivity.

6.6.3.26 The magnitude of impact to the seabed resulting from the presence of offshore export and array cable protection is considered low. This is because no measurable change to the morphology of the seabed is expected more than a few metres either side of the rock protection berm.

6.6.3.27 With regards to morphological impacts arising from the presence of semi-submersible floating platforms and associated mooring/anchor systems, impacts are expected to be negligible. This is because changes to tidal currents and waves are expected to be very small and therefore any related changes to the surrounding seabed are expected to be difficult to discern from those which may occur under baseline conditions. The assertion that changes to hydrodynamics, waves and sediment transport will be very small in absolute and relative terms is entirely consistent with numerical modelling and observational evidence from wind farms constructed with monopiles whose total water column blockage far exceeds that of the Proposed Development.

6.6.3.28 The overall level of effect significance has been determined by combining the assigned rating for receptor sensitivity and impact magnitude, as shown in Table 6.7. The result is a **minor adverse** effect, and therefore not significant in EIA terms.

Additional Mitigation and Residual Effect

6.6.3.29 None of effects identified above are major or moderate adverse (significant in EIA terms). Therefore, no additional mitigation is required to reduce the significance to non-significant in EIA terms and the significance of residual effects remain as detailed above.

<u>Potential changes in morphology of the coast (receptor)</u>

Overview

6.6.3.30 This section describes potential impacts to seabed morphology at the coastline near to the landfall, arising from changes to currents, waves and associated sediment transport (or other coastal processes) potentially caused by the presence of hard infrastructure within 5 km of the coast, namely:

- Cable protection (the closest being ~2.3 km from the coast at KP4.6);
- Rock protection at the HDD exit pits; and
- Rock bags within intertidal areas, installed in the event of cable exposure

6.6.3.31 Potential impacts on the morphology of the coast from other Project infrastructure >5 km from the coast (including all the infrastructure within the array area) have been scoped out due to the distance between any effects created by these structures and adjacent coastlines.

Conceptual understanding of change

6.6.3.32 Cable protection: where the offshore export cable is buried in the seabed and not protected, there is no potential for cable related scour to occur. If and where the offshore export cable becomes exposed, then a small, localised, area of scour may occur as a result of currents interacting with the exposed part of the cable. The exact dimensions of the scour will depend on the height of the offshore export cable relative to the seabed but will be in proportion to the small diameter of the cable (up to 0.3 m diameter) and no more than described for the cable protection in Section 6.6.3.14.

6.6.3.33 The use of cable protection could, theoretically, cause measurable changes to currents, waves and associated sediment transport during the operational phase. However, the dimensions of such infrastructure in terms of both plan area and height above the seabed relative to water depth are small. They have been assessed in Section 6.6.3.4 to have a very limited potential to cause more than a small scale of local change (order of metres to tens of metres) to waves, tides and sediment transport processes which will not extend to the adjacent coast which, at its closest point, is situated over 2 km away.

6.6.3.34 <u>Rock protection and rock bags at the landfall:</u> should HDD be used, a small amount of rock protection may be required to protect the HDD duct exit if burial is not achieved. This could involve the installation of rock berms 21 m long by 5m wide by 1.2 m high at each exit. Localised use of rock bags (5 x 5 m footprint) could also potentially be required in intertidal areas in the event of cable exposure. However as discussed in Section 0 to 0, whilst localised changes to waves and hydrodynamics may occur immediately within the vicinity of the rock berms, associated morphological change at the landfall is expected to be very limited. This is due to the small scale/low profile of the rock protection, the macrotidal setting and very low current speeds.

<u>Assessment of Significance</u>

6.6.3.35 The coast at the landfall is considered to be of medium sensitivity. Although nationally designated, the rocky outcrops and intertidal areas will be largely insensitive to changes in waves, tides and sediment transport. The beach within West Angle Bay itself will be more sensitive change although will have some capacity to recover from disturbance.

6.6.3.36 The potential for morphological change to the Angle Peninsula coast in response to the use of cable protection in the approaches to Milford Haven is considered negligible. This is because the nearest adjacent coastline to the cable protection measures is over 2 km away and any associated changes to the wave regime will be small owing to the relatively deep water setting in which the cable protection will be situated (~40 m below LAT or greater). It is also the case that the closest adjacent coastline is rocky and would not be impacted at all by very minor changes to waves.

6.6.3.37 Rock berms to protect the HDD duct exits, as well as any requirement for remedial measures (such as rock bags) in the event of cable exposure, would be associated with a minor magnitude of impact to the morphology of the beach at the landfall. This is because any associated indirect changes to the seabed/beach morphology arising from modification of the hydrodynamic/wave regime would be highly localised in nature.

6.6.3.38 The overall level of effect significance has been determined by combining the assigned rating for receptor sensitivity and impact magnitude, as shown in Table 6.7. The result is a **minor adverse** effect**,** and therefore not significant in EIA terms.

Additional Mitigation and Residual Effect

6.6.3.39 None of effects identified above are major or moderate adverse (significant in EIA terms). Therefore, no additional mitigation is required to reduce the significance to non-significant in EIA terms and the significance of residual effects remain as detailed above.

Potential increases in suspended sediment concentrations (SSC) (pathway) via cable repairs/remediation

Overview

6.6.3.40 The PDE assumes that a series of cable repairs and/or cable remediation will be required over the lifetime of the Project, with up to 5 repairs anticipated in the array area and 5 within the ECC.

Conceptual understanding of change

6.6.3.41 Offshore export cable repairs and/or remediation activities are expected to result in some localised seabed disturbance accompanied by temporary increases in SSC. It is expected that equipment similar to that used to install the offshore export cable will be used for re-burial/remediation. Accordingly, the area of seabed impacted during the removal of the offshore export cable would be similar to (but no greater than) the area impacted during the installation of the offshore export cable.

6.6.3.42 For all of the above, the changes in SSC and accompanying changes to bed levels associated are expected to be no greater than that associated with construction. Further information is provided in the construction phase assessment (Section 0).

Assessment of Significance

6.6.3.43 All of the identified marine and coastal processes receptors will be insensitive to elevated levels of SSC and localised changes in bed level. However, the potential for these changes to impact other EIA receptor groups are considered elsewhere within the ES, in particular:

- Chapter 7: Marine Seabed and Water Quality;
- Chapter 8: Offshore Designated Sites;
- Chapter 9: Marine and Coastal Ecology;
- Chapter 10: Fish & Shellfish Ecology;

- Chapter 11: Offshore Ornithology; and
- Chapter 12: Marine Mammals

6.6.4 Decommissioning

Potential increases in suspended sediment concentrations (SSC) (pathway).

Overview

6.6.4.1 The following decommissioning activities could potentially give rise to increases in SSC and associated deposition of material within the array area and ECC:

- Removal of WTG mooring/anchoring systems;
- Removal of cable protection; and
- (Possible) removal of array and offshore export cable from the seabed.

Conceptual understanding of change

6.6.4.2 The removal of WTG mooring/anchoring systems is expected to result in some localised seabed disturbance accompanied by temporary increases in SSC. For the purposes of the EIA it has been assumed that all offshore export cable will be removed from the intertidal zone and seabed during decommissioning. It is probable that equipment similar to that used to install the offshore export cable, could be used to reverse the burial process and expose the offshore export cable. Accordingly, the area of seabed impacted during the removal of the offshore export cable would be similar to the area impacted during the installation of the offshore export cable.

6.6.4.3 For all of the above, the changes in SSC and accompanying changes to bed levels associated with decommissioning activities are expected to be no greater than that associated with construction. Further information is provided in the construction phase assessment (Section 6.6.2.14).

Assessment of Significance

6.6.4.4 All of the identified marine and coastal processes receptors will be insensitive to elevated levels. However, the potential for these changes to impact other EIA receptor groups are considered elsewhere within the ES, in particular:

- Chapter 7: Marine Seabed and Water Quality;
- Chapter 8: Offshore Designated Sites;
- Chapter 9: Marine and Coastal Ecology;
- Chapter 10: Fish and Shellfish Ecology;
- Chapter 11: Offshore Ornithology; and
- Chapter 12: Marine Mammals.

Potential changes to sediment transport system by changes in wave and current (pathway)

6.6.4.5 Cable protection, semi-submersible floating platforms and/or the presence of anchoring structures all have the potential to result in a localised blockage of waves, tides and sediment transport. However, the number of installed structures (and therefore overall blockage) will be no greater than that assessed for the operational phase (Section 6.6.3.1) and therefore is not considered further here.

Potential changes to the morphology of the seabed including from scour (receptor)

Overview

6.6.4.6 This section describes impacts to local seabed morphology in designated sites arising from local changes to flow and sediment transport (scour) associated with the removal, or ongoing presence of cable protection and foundation moorings if left in situ, during and following the decommissioning phase.

Conceptual understanding of change

6.6.4.7 The potential dimensions of local scour as result of the cable protection, semi-submersible floating platforms and associated moorings present during the operational phase are assessed in Section 6.6.3.19.

6.6.4.8 Where some or all cable protection is left in situ during or following the decommissioning process, the potential for scour is the same as described and assessed for the presence of cable protection during the operational phase in Section 6.6.3.15.

6.6.4.9 Where some or all of the mooring systems of the semi-submersible floating platforms are left in situ during or following the decommissioning process, the potential for scour is the same as described and assessed for their presence during the operational phase in Sections 6.6.3.19.

6.6.4.10 Where cable protection is removed, or where no cable protection was installed, and the offshore export cable is left in situ during or following the decommissioning process, then as long as the offshore export cable is buried there is no potential for offshore export cable related scour to occur. If and where the offshore export cable becomes exposed, then a small, localised, area of scour may occur as a result of currents interacting with the exposed part of the offshore export cable. The exact dimensions of the scour will depend on the height of the offshore export cable relative to the seabed but will be in proportion to the small diameter of the offshore export cable (up to 0.3 m diameter) and no more than described for the cable protection in Section 6.6.3.15.

6.6.4.11 Where cable protection and foundation moorings are removed during the decommissioning process, the physical obstacle and associated flow conditions which potentially caused scour during the operational phase will be removed. Some physical impression may be initially visible within the operational footprint of the berm or mooring line. For cable protection, some individual protection clasts (3 to 30 cm diameter) may remain on or within the seabed. For moorings, the removal of more deeply buried chain and anchors may cause a morphological disturbance to the seabed with dimensions proportional to the items being removed (chain links 0.67 m wide x 0.2 m diameter and anchors up to 9 m long/wide).

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

Assessment of Significance

6.6.4.13 Cable protection may be present and considered for decommissioning within the West Wales Marine SAC, Pembrokeshire Marine SAC and the Skomer, Skokholm and the Seas off Pembrokeshire SPA. The latter partially overlaps the array area. Although internationally designated, the seabed in these areas is highly dynamic. Accordingly, it is assessed to be of medium sensitivity.

6.6.4.14 The magnitude of impact to the seabed resulting from the presence or removal of cable protection measures is considered low. This is because no measurable change to the seabed is expected more than a few metres either side of the rock protection berm if it remains, as the worst case. With regards to morphological impacts arising from the presence of semi-submersible floating platforms and anchoring structures, morphological impacts are expected to be negligible. This is because changes to hydrodynamics are expected to be very small and therefore any related changes to the surrounding seabed are expected to be difficult to discern from those which may occur under baseline conditions.

6.6.4.15 The overall level of effect significance has been determined by combining the assigned rating for receptor sensitivity and impact magnitude, as shown in Table 6.7. The result is a **minor adverse** effect, and therefore not significant.

Additional Mitigation and Residual Effect

6.6.4.16 None of effects identified above are major or moderate adverse (significant in EIA terms). Therefore, no additional mitigation is required to reduce the significance to non-significant in EIA terms and the significance of residual effects remain as detailed above.

Potential changes in morphology and sediment transport at the coast (receptor)

Overview

6.6.4.17 The RWC in terms of the potential for impacts to coastal feature receptors would be the total removal of all offshore export cable and associated infrastructure at the landfall.

Conceptual understanding of change

6.6.4.18 Should the offshore export cable require removal at the end of its operational life, it will be removed through the same soils and sediments disturbed during installation. This removal process does not necessarily require the same scale of sediment displacement (trenching or sandwave levelling) as for installation. This process could, however, result in short-term elevations in SSC and localised changes in bed level (i.e. within the near-field).

6.6.4.19 It is anticipated that the working areas for removal will also be restricted to the same area used for installation; accordingly, any impacts would be no greater in magnitude or extent than for the construction phase. If the offshore export cable is left in the seabed at the end of the Project lifespan, impacts will be the same as those described previously for the operation phase in Section 6.6.3.14.

6.6.4.20 Where infrastructure is removed from very nearshore or intertidal areas during the decommissioning process, the physical obstacle and associated potential modification to current and wave conditions during the operational phase will be removed. Some physical impression may be initially visible within the original footprint of a berm or other structure. For cable protection, some individual protection clasts (2 to 30 cm diameter) may remain on or within the seabed.

6.6.4.21 The removal of more deeply buried hard infrastructure may cause a morphological disturbance to the seabed, with maximum dimensions proportional to the items being removed. Any impression left, and any initially remaining scour, will be no larger than the original footprint. Depressions will become infilled and high points (comprising accumulated mobile sediment) will be levelled out by ambient sediment transport over time. The seabed sediment type will either remain or return to the ambient baseline condition within a similar or shorter time period as new sediment is deposited or underlying (previously undisturbed) sediments are exposed.

6.6.4.22 If the installed infrastructure caused measurable changes to currents, waves and associated sediment transport or other coastal processes that extended to the adjacent seabed or coastline during the operational phase, then the morphology in and around the affected area could have evolved in dynamic equilibrium with that change. If some, or all of the installed infrastructure is removed during decommissioning, then the affected seabed or coastline will evolve instead towards a new equilibrium state within the future baseline environment.

6.6.4.23 The dimensions of such infrastructure in terms of both plan area and height above the seabed are however relatively small and have been assessed in Section 6.6.3.1 to have a very limited potential to cause more than a small scale of local change.

6.6.4.24 Given the rocky nature of the coastline at the landfall, such changes are likely to be mainly related to the particular distribution of mobile sediment on the seabed and intertidal area, in the approaches to and on West Angle Bay beach. As such, the new equilibrium state of the local seabed and beach is likely to be achieved within a relatively short time of the infrastructure being removed, estimated to be in the order of days to weeks of tidal inundation, or following one or more larger storm events.

Assessment of Significance

6.6.4.25 The coast at the landfall is considered to be of medium sensitivity. Although nationally designated, the rocky outcrops and intertidal areas will be insensitive to changes in waves, tides and sediment transport. The pocket beach within the bay itself will be more sensitive change although will have some capacity to recover from disturbance.

6.6.4.26 The magnitude of impact is predicted to be no greater than that anticipated for the construction phase (i.e. low) – see Section 6.6.2.37. This is because all impacts associated with cable removal activities will be of short-term duration and/or highly localised in nature.

6.6.4.27 The overall level of effect significance has been determined by combining the assigned rating for receptor sensitivity and impact magnitude, as shown in Table 6.7. The result is a **minor adverse effect**, and therefore not significant in EIA terms.

Additional Mitigation and Residual Effect

6.6.4.28 None of effects identified above are major or moderate adverse (significant in EIA terms). Therefore, no additional mitigation is required to reduce the significance to non-significant in EIA terms and the significance of residual effects remain as detailed above.

6.6.5 Effects on Human Health and Population

6.6.5.1 There will be no effects on population or human health in relation to marine and coastal processes. Potential effects on coastal water quality and any local bathing beaches via increased SSC are fully assessed in Chapter 7: Marine Sediment and Water Quality.

6.7 Additional Mitigation

6.7.1.1 No additional mitigation measures were identified within Section 6.6 in relation to potential effects during the construction, operation or decommissioning phases, in relation to marine and coastal processes.

6.8 Inter-Related Effects

6.8.1.1 Inter-relationships are considered to be the effects of different aspects of the proposed project on the same receptor. These are considered to be:

- Project lifetime effects: Assessment of the scope for effects that occur throughout more than one phase of the project (construction, O&M, and decommissioning); to interact to potentially create a more significant effect on a receptor than if just assessed in isolation in these three key project stages (e.g. subsea noise effects from piling, operational WTGs, vessels and decommissioning); and
- Receptor led effects: Assessment of the scope for all effects to interact, spatially and temporally, to create inter-related effects on a receptor. As an example, all effects on benthic ecology such as direct habitat loss or disturbance, sediment plumes, scour, jack-up vessel use etc., may interact to produce a different, or greater effect on this receptor than when the effects are considered in isolation. Receptor-led effects might be short-term, temporary or transient, or incorporate longer term effects.

6.8.1.2 The different marine and coastal processes studied are already inter-related; in particular, sediment transport is dependent on currents and waves and therefore these linked processes have already been considered within the assessment. In turn, this information on changes to marine and coastal processes has been used to inform other EIA topics such as:

- Chapter 7: Marine Seabed and Water Quality;
- Chapter 8: Offshore Designated Sites;
- Chapter 9: Marine and Coastal Ecology;
- Chapter 10: Fish & Shellfish Ecology;
- Chapter 11: Offshore Ornithology;
- Chapter 12: Marine Mammals; and
- Chapter 14: Offshore Archaeology and Cultural Heritage.

6.8.1.3 Assessments have been undertaken separately within these individual topic Chapters and are not reported here as additional inter-relationships.

6.9 Monitoring

6.9.1.1 The following monitoring is proposed to form part of the Environmental Monitoring and Mitigation Plan to be drafted in consultation with NRW prior to the commencement of works:

- MBES surveys of export cable corridor and/or array area to assess potential scour and bathymetric changes within the offshore consent boundary. These surveys would be conducted pre-construction (within 12 months of works) and then in years 1, 5 and 10 post-construction. The focus of the surveys would be on key areas, i.e. sandwaves along ECC and areas of cable protection near Turbot Bank, where it is likely increased coverage would be proposed as part of the surveys. However, the exact scope and extent of surveys would be developed in consultation with NRW and JNCC; and
- If open cut trenching is necessary it is proposed that beach profile monitoring will be undertaken to demonstrate that re-instated open cut trenching does not result in any morphological changes to the beach profile.

6.10 Cumulative Effects Assessment

6.10.1.1 A Cumulative Effects Assessment (CEA) has been made based on existing and proposed developments in the Study Area (Chapter 30: Cumulative Effects). The approach to the CEA is described in Chapter 30: Cumulative Effects. Cumulative effects are defined as those effects on a receptor that may arise when the development is considered together with other reasonably foreseeable projects.

6.10.1.2 The projects and plans selected as relevant to the assessment of effects on marine and coastal processes are based upon an initial screening exercise undertaken on a long list (see Chapter 30: Cumulative Effects). Each project, plan or activity has been considered and scoped in or out on the basis of effect–receptor pathway, data confidence and the temporal and spatial scales involved. The locations of these projects, plans and activities are shown in Volume 2, Figure 6.18, with summary details provided in Table 6.21.

6.10.1.3 It is noted here that the exact location of the Valorous offshore export cable corridor is presently unknown and is therefore not included in Volume 2, Figure 6.18. However, it is known that the minimum spacing between the Project and Valorous export cables will be 150 m.

Table 6.21 – Projects, Plans and Activities Considered within the Marine and Coastal Processes Cumulative Effect Assessment

Development Type	Project	Closest Distance	Impact/ Change	Justification
Maintenance Dredging	Milford Haven Maintenance Dredging	0.5 km (ECC)	Temporary cumulative increases in SSC and associated changes in bed level during construction (pathway)	Located within a spring tidal excursion ellipse from the array area and ECC (10-19 km) Precise details regarding construction/ operation timelines are not available for all projects listed here. However, for the purposes of the CEA, it has been assumed that with the exception of the Valorous export cable, all may be coincident with the Proposed Development.
Maintenance Dredge Disposal	Milford Haven Two Disposal Site	4.1 km (ECC)		
Offshore Wind Farm (Floating)	Valorous FLOW array	3.3 km (array area)		
Offshore Wind Farm (Floating)	Valorous FLOW export cable	150 m (ECC)		
Marine Energy (Wave power)	Bombora Demonstrator (East Pickard Bay)	3.0 km (ECC)		
Marine Energy (Wave power and FLOW)	Marine Energy Test Area (META) East Pickard Bay	1.4 km (ECC)		
Marine Energy (Wave power)	META Dale Roads	2.3 km (ECC)		

Development Type	Project	Closest Distance	Impact/ Change	Justification
Interconnector	Greenlink	(Overlaps ECC)		

6.10.1.4 The potential cumulative effects of the Pembrokeshire Demonstration Zone (PDZ) have not been considered at the time of writing due to the lack of detail with which to assess the effects of the proposed project. An EIA Scoping Report was produced and issued to NRW in 2018 for a proposed wave/floating wind project however based on discussions with Celtic Sea Power (the 3rd party agents for the PDZ) and recent public presentations by members of Celtic Sea Power, it is understood the PDZ will be repurposed as an offshore electrical hub. In the absence of an updated EIA Scoping Report and insufficient project information to allow the effects to be reasonably understood and a cumulative assessment undertaken, it has been omitted from this assessment.

6.10.1.5 For those reasons identified above, including the absence of EIA Scoping Reports, the potential cumulative effects of the recently announced Llyr 1, Llyr 2 and Whitecross FLOW projects are also omitted from this cumulative assessment.

6.10.1.6 As set out in PINS Guidance Note 17: Cumulative Effects Assessment, the Project proposed an assessment cut-off date of 1 October 2021 to allow the finalisation of the EIA and HRA assessments, even if project information came forward between the cut-off date and submission. This was agreed with NRW Marine Licensing, noting that in the absence of S.36/Marine Licence guidance the Project was drawing upon the best available advice. It is understood that should sufficient detail of these projects come forward following submission the Project may be requested to provide additional information during the determination period.

6.10.1.7 It is noted here that the potential for cumulative changes in waves, tides and associated patterns of sediment transport arising from the Proposed Development interacting with any of the developments set out in Table 6.21 is extremely low. This is due to the highly localised nature of blockage related change arising from the Project (see Section 6.6.3.1). Accordingly, this has not been assessed further here.

6.10.2 Construction

<u>Potential cumulative increases in SSC and associated changes in bed level during construction (pathway)</u>

Overview

6.10.2.1 All of the projects, plans and activities set out in Table 6.21 have the potential to cause localised temporary increases in SSC due to the installation or removal of structures on the bed and/or through the dredging and disposal of material. In theory, if these activities were occurring at the same time as construction (or decommissioning) works for the Proposed Development, there may be potential for cumulative increases in SSC and associated changes in bed levels. Although the likelihood of temporal overlap between activities is very low, the potential for this cumulative change is assessed further below.

Conceptual understanding of change

6.10.2.2 Sediment plume interaction generally has the potential to occur if the activities generating the sediment plumes are located within one spring tidal excursion ellipse from one another and occur at the same time. The tidal excursion distance is the approximate distance over which water (or a section of plume with elevated SSC) is advected during one flood or ebb tide. Under mean spring conditions, this is approximately:

- 10 km around the array area;
- 14 km around the middle of the ECC;
- 18 km in the approaches to Milford Haven; and
- Approximately 4 km within Milford Haven (estimated based on a representative 0.3 m/s peak current speed)

6.10.2.3 Areas beyond the tidal excursion distance and footprint are unlikely to experience any measurable change in SSC from a sediment plume. All the projects listed in Table 6.21 are within a spring tidal excursion ellipse from either the array area or ECC.

6.10.2.4 The interaction between sediment plumes generated by Project-related sediment disturbance activities and those from other nearby projects could theoretically occur in two ways:

- Where plumes generated from the two different activities meet and coalesce to form one larger plume; or
- Where sediment disturbance occurs within the plume generated by the Proposed Development construction (or decommissioning) activities (or vice versa).

6.10.2.5 For two or more separately formed plumes that meet and coalesce, the physical laws of dispersion theory mean concentrations within the plumes are not additive but instead a larger plume is created with regions of potentially differing concentration representative of the separate respective plumes. In contrast, where material is released into suspension within the footprint of an existing plume – for instance, plumes formed by a dredging vessel operating within the plume created during cable installation activities (or vice versa), the two plumes would be additive, creating a plume with higher SSC.

6.10.2.6 For the most part, the sediment disturbance activities associated with the Proposed Development are likely to involve the release of coarse-grained material, although it is acknowledged that drilling associated with the installation of mooring systems could potentially release some finer material into suspension. On the basis of the spreadsheet-based modelling (Section 0 and Volume 3, Technical Appendix 6.1: Marine and Coastal Process Assessment Technical Report), it is found that the sediment plumes associated with coarser grained material are expected to be spatially constrained as the material drops out of suspension more quickly. Elevated levels of SSC are therefore expected to return to background levels within a distance of hundreds of metres from the sediment disturbance location. The spreadsheet-based modelling also shows that any fine-grained sediment plume will be subject to rapid dispersion, both laterally and vertically, to near-background levels (tens of mg/l) within hundreds to a few thousands of metres at the point of release.

6.10.2.7 Given the above information and the fact that any two sediment disturbance activities are generally located several km apart, for the most part any cumulative increase in either the spatial footprint or peak concentration of sediment plumes are expected to be indistinguishable from background levels. Any associated changes in bed level can also be expected to be immeasurable.

6.10.2.8 A possible exception to the above is at the landfall where cable installation could (theoretically) be occurring at the same time as maintenance dredging around 500 m away. Given the very close proximity of the two activities, it is considered that both types of plume interaction could occur. However, it is noted that in line with UNCLOS (The United Nations Convention on the Law of the Sea) cable installation vessels typically request a 1 nautical mile (c. 1.85 km) vessel safety zone when installing or handling cables. Accordingly, whilst plume interaction may still occur, the potential for much higher concentration and more persistent plumes than that previously described in the project-alone assessments of SSC (Section 0 and Volume 3, Technical Appendix 6.1: Marine and Coastal Process Assessment Technical Report) is considered to be small.

Assessment of Significance

6.10.2.9 All of the identified marine and coastal processes receptors will be insensitive to elevated levels of SSC and localised changes in bed level. However, the potential for these changes to impact other EIA receptor groups are considered elsewhere within the ES, in particular:

- Chapter 7: Marine Seabed and Water Quality;
- Chapter 8: Offshore Designated Sites;
- Chapter 9: Marine and Coastal Ecology;
- Chapter 10: Fish & Shellfish Ecology;
- Chapter 11: Offshore Ornithology; and
- Chapter 12: Marine Mammals.

6.10.3 Operation

Overview

6.10.3.1 The Valorous offshore export cable is expected to be installed along a broadly similar route to the Project ECC although in no location would cables from the separate projects be closer than 150 m. In theory, sandwave levelling could therefore be undertaken within the ECC and along the Valorous export cable at a minimum spacing distance of 150 m. Because sandwave levelling activities would not occur simultaneously (as Valorous is currently planned to be constructed after the Project), there is no potential for the coalescence of sediment plumes and so further assessment has not been undertaken. However, the longer-term implications for any changes in sediment transport to down drift locations (including Turbot Bank) are considered in this section.

Conceptual understanding of change

6.10.3.2 As set out in Table 6.17, levelling of sandwaves within the ECC would be achieved by MFE or dredging. The requirement for any sandwave levelling along the Valorous offshore export cable corridor is unknown at this stage but should it be needed; it is expected that similar methods to that proposed for the ECC would be used. Importantly (and as noted in Section 6.6.2.17) for sandwave levelling in the ECC, any sediment removed from the seabed would, preferentially, be deposited in close proximity to the dredge location. Accordingly, no material will be removed from the local sediment transport system and as such, there will be very little potential for cumulative interaction with Valorous and associated morphological impacts to any nearby (downdrift) receptors.

6.10.3.3 In all locations, surficial sediments will continue to be mobilised at the natural ambient rate and direction under sufficiently energetic current and wave conditions, with the associated development and migration of smaller (e.g. ripple and mega-ripple) bedforms.

Assessment of Significance

6.10.3.4 The receptor under consideration is the Annex I sandbank within and around the ECC at Turbot Bank, and the seabed areas within the West Wales Marine SAC and the Skomer, Skokholm and the Seas off Pembrokeshire SPA (levelling of sandwaves is not proposed within the Pembrokeshire Marine SAC). Although internationally designated, the seabed in these areas is highly dynamic and is assessed to have some capacity to recover from disturbance associated with sandwave levelling. Accordingly, it is assessed to be of medium sensitivity.

6.10.3.5 The magnitude of impact to the seabed resulting from cumulative changes to sediment transport is considered negligible. This is because sand will be retained within the local sediment transport system and therefore the net movement of material will remain largely unaltered.

6.10.3.6 The overall level of effect significance has been determined by combining the assigned rating for receptor sensitivity (medium) and impact magnitude (negligible), as shown in Table 6.10. The result is a **minor adverse** effect, and therefore not significant in EIA terms.

6.10.4 Decommissioning

6.10.4.1 No potential cumulative effects were identified in relation to marine and coastal processes during the decommissioning phase.

6.11 Transboundary

6.11.1.1 No transboundary effects have been identified. This is because the predicted changes to the key marine and coastal process pathways (i.e. tides, waves, and sediment transport) are not anticipated to be sufficient to influence identified receptors at this distance from the Proposed Development.

6.12 Summary

6.12.1.1 This chapter has investigated potential changes to marine and coastal processes arising from the Proposed Development. The array area and ECC are situated to the southwest of Pembrokeshire, with water depths between 65 and 85 m below LAT in the array area and between 0 and ~70 m LAT along the ECC. Tidal currents are sufficiently energetic to mobilise the sandy sediments that characterise most of the array area and ECC and this results in the migration of the (often) large sandwave features which are mapped in several locations along the ECC and within central/northern parts of the array area. Large waves associated with Atlantic storms are expected to be capable of mobilising sand at the seabed, even at the greater water depths encountered in the array area.

6.12.1.2 The offshore export cable will make landfall at West Angle Bay at the entrance to Milford Haven. This is a small pocket beach surrounded by rocky headlands with available evidence suggesting that beach morphology has changed little over the past few decades.

6.12.1.3 The range of potential impacts and associated effects considered has been informed by Scoping responses and from subsequent discussions with stakeholders. It has also drawn upon reference to existing policy and guidance.

6.12.1.4 The assessment has been undertaken in three stages. These are:

- The determination of the RWC from the Chapter 4: Proposed Development Description;

- The determination of the baseline environment (including potential changes over the Proposed Development lifetime due to natural variation); and
- Assessment of changes to marine and coastal processes arising from the RWC both for the Proposed Development on its own and in conjunction with other built and consented projects.

6.12.1.5 In order to assess the potential changes relative to the baseline (existing) coastal and marine environment, a combination of complementary approaches have been adopted. These include analytical assessments of Project-specific/publicly available data as well as consideration of the evidence base of environmental change associated with carrying out similar activities to that proposed for Proposed Development. This includes sandwave levelling and the installation of the offshore export cable through intertidal areas.

6.12.1.6 A number of different assessments have been undertaken in this chapter, including:

- The extent and duration of sediment plumes associated with construction activities such as mooring system installation;
- Potential impacts to the coast at the landfall arising from installation of the offshore export cable;
- Consideration of likely seabed changes associated with sandwave levelling and the potential timescales over which recovery might take place; and
- Changes in wave, tides and sediment transport arising from the presence of semi-submersible floating platforms and their mooring systems.

6.12.1.7 However, even with RWC assumptions for the project design parameters, no impacts on identified receptors are found to be significant (Table 6.22). The assessment also finds that there is very low potential for measurable cumulative change to marine and coastal processes resulting from interactions with other planned projects across the Study Area (Table 6.23). Accordingly, no additional mitigation has been proposed to that already embedded in the existing Proposed Development Design.

Table 6.22 – Summary of Effects

Description of Effect	Significance of Potential Effect (assuming standard mitigation implemented)		Additional Mitigation Measure	Significance of Residual Effect	
	Significance	Beneficial/ Adverse		Significance	Beneficial/Adverse
Construction					
Potential increases in SSC and associated changes to seabed substrate.	[Potential pathway of effect for other topics]	N/A	N/A	[Potential pathway of effect for other topics]	N/A
Potential changes to sediment transport system by changes in wave and current climate.	[Potential pathway of effect for other topics]	N/A	N/A	[Potential pathway of effect for other topics]	N/A
Potential changes to the morphology of the seabed (including scour).	Minor	Adverse	N/A	Minor	Adverse
Potential changes in morphology of the coast.	Minor	Adverse	N/A	Minor	Adverse

Description of Effect	Significance of Potential Effect (assuming standard mitigation implemented)		Additional Mitigation Measure	Significance of Residual Effect	
	Significance	Beneficial/ Adverse		Significance	Beneficial/Adverse
Operation					
Potential changes to sediment transport system by changes in wave and current climate.	[Potential pathway of effect for other topics]	N/A	N/A	[Potential pathway of effect for other topics]	N/A
Potential changes to the morphology of the seabed (including scour).	Minor	Adverse	N/A	Minor	Adverse
Potential changes in morphology of the coast.	Minor	Adverse	N/A	Minor	Adverse
Decommissioning					
Potential increases in SSC and associated changes to seabed substrate.	[Potential pathway of effect for other topics]	N/A	N/A	[Potential pathway of effect for other topics]	N/A
Potential changes to sediment transport system by changes in wave and current climate	[Potential pathway of effect for other topics]	N/A	N/A	[Potential pathway of effect for other topics]	N/A
Potential changes to the morphology of the seabed (including scour).	Minor	Adverse	N/A	Minor	Adverse

Description of Effect	Significance of Potential Effect (assuming standard mitigation implemented)		Additional Mitigation Measure	Significance of Residual Effect	
	Significance	**Beneficial/ Adverse**		**Significance**	**Beneficial/Adverse**
Potential changes in morphology of the coast	Minor	Adverse	N/A	Minor	Adverse

Table 6.23 – Summary of Cumulative Effects

Receptor	Effect	Cumulative Developments	Significance of Cumulative Effect	
			Significance	Beneficial/ Adverse
Pathway – no marine and coastal processes receptors sensitive to changes in SSC	NA	Milford Haven Maintenance Dredging Milford Haven Two Disposal Site Valorous FLOW Bombara Demonstrator (East Pickard Bay) Marine Energy Test Area (META) Dale Roads Greenlink	NA	NA
Potential changes to the morphology of the seabed (Annex I sandbank within and around the ECC at Turbot Bank)	Minor Adverse	Valorous FLOW	Minor	Adverse

6.13 References

ABP R&C, 1996. Pembroke emulsified fuel conversion. Environmental Statement for the dredging and disposal works. ABP Research and Consultancy Ltd. Report R.565. August 1996.

ABPmer, HR Wallingford and Cefas. (2010). Further review of sediment monitoring data: ScourSed-09. COWRIE.

ABPmer & HR Wallingford (2009). Coastal Process Modelling for Offshore Wind farm Environmental Impact Assessment: Best Practice Guide. COWRIE

ABPmer, Met Office and SeaRoc UK Ltd. (2008a). Guidelines in the use of metocean data through the lifecycle of a marine renewables development. ABPmer, Southampton

ABPmer, Met Office and POL 2008b. Atlas of UK Marine Renewable Energy Resources: Atlas Pages. A Strategic Environmental Assessment Report, March 2008. Accessed on: 1/3/21. Available at: http://www.renewables-atlas.info/.

ABPmer, Cefas and HR Wallingford. (2007). Review of Round 1 Sediment process monitoring data - lessons learnt: Sed01. ABPmer, Southampton.

ABPmer, Met Office and POL (2008b). Atlas of UK Marine Renewable Energy Resources: Atlas Pages. A Strategic Environmental Assessment Report, March 2008. Produced for BERR. Report and associated GIS layers available at: http://www.renewables-atlas.info/.

ABPmer (2018a). Hornsea Project Three Offshore Wind Farm: Appendix 11 to Deadline I submission. Sandwave Clearance Clarification Note. November 2018. Available from https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010080/EN010080-001133-DI_HOW03_Appendix%2011.pdf

ABPmer, (2018b). Norfolk Vanguard and Norfolk Boreas Export Cable Route, Sandwave bed levelling, ABPmer Report No. R.2920. A report produced by ABPmer for Royal HaskoningDHV, April 2018. Available from https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010079/EN010079-001482-5.03%20Appendix%207.1%20ABP%20Sandwave%20study.pdf

Atkins 2016. Kincardine Offshore Windfarm: Environmental Statement. Atkins Ltd.

Belderson RH., Johnson MA., Kenyon NH. (1982). Bedforms. In: Stride AH (ed.) Offshore tidal sands, processes and deposits. Chapman and Hall Ltd, London, UK pp 27-57.

BERR (2008). Review of Cabling Techniques and Environmental Effects applicable to the Offshore Wind farm Industry Technical Report. Department for Business Enterprise and Regulatory Reform in association with Defra.

Blue Gem Wind (2021). Blue Gem Wind Project Erebus Ground Model Phase 1

Brooks, A., Whitehead, P., Lambkin D. (2018). Evidence Report No: 243 Guidance on Best Practice for Marine and Coastal Physical Processes Baseline Survey and Monitoring Requirements to inform EIA of Major Development Projects. Natural Resources Wales, Cardiff

BSI (2015). PD 6900:2015 Environmental impact assessment for offshore renewable energy projects - Guide. BSI Standards Ltd.

Carey, D. A., Hayn, M., Germano, J. D., Little, D. I. and Bullimore, B.2014. Marine habitat mapping of the Milford Haven Waterway, Wales, UK: Comparison of facies mapping and EUNIS classification for monitoring sediment habitats in an industrialized estuary. Journal of Sea Research, 100 (2015), pp. 99-119. September 2014.

Cefas (2016). Suspended Sediment Climatologies around the UK. Produced for the UK Department for Business, Energy & Industrial Strategy offshore energy Strategic Environmental Assessment Programme.

Cefas (2004). Offshore Windfarms: Guidance Note for Environmental Impact Assessment in Respect of FEPA and CPA requirements. Defra Marine Consents and Environment Unit, London.

Collins MB, 1987. Sediment transport in the Bristol Channel: A review. Proceedings of the Geologists' Association, 98, 367-383.

Cooper, B and Beiboer, F (2002) Potential effects of offshore wind developments on coastal processes. Department of Trade and Industry, London.

Coughlan, M., Guerrini, M., Creane, S., O'Shea, M., Ward, S.L., Van Landeghem, K.J.J., Murphy, J., Doherty, P. (2021). A new seabed mobility index for the Irish Sea: Modelling seabed shear stress and classifying sediment mobilisation to help predict erosion, deposition, and sediment distribution, Continental Shelf Research. doi: https://doi.org/10.1016/j.csr.2021.104574.

DECC (2011a). Overarching National Policy Statement for Energy (EN-1).Accessed on: 3/3/21 Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/47854/1938-overarching-nps-for-energy-en1.pdf

DECC (2011b). National Policy Statement for Renewable Energy Infrastructure (EN-3). Accessed on: 3/3/21 Available online at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/37048/1940-nps-renewable-energy-en3.pdf

Department for Business, Energy and Industrial Strategy (2016). UK Offshore Energy Strategic Environmental Assessment 3. Available at https://www.gov.uk/government/publications/uk-offshore-energy-strategic-environmental-assessment-3-supporting-documents

DTI, 2007. Impact assessment Strategic Environmental Assessment 8: supporting documents. Available online at: https://www.gov.uk/government/publications/strategic-environmental-assessment-8-supporting-documents

Dyfed Archaeological Trust, 2010. West Angle Bay, Angle, Pembrokeshire: Arfordir excavation, May 2010. Rep[ort produced for Cadw. Available online at: https://dyfedarchaeology.org.uk/projects/westangle2010.pdf

East Anglia Offshore Wind (2012). East Anglia ONE Environmental Statement Volume 2.

Environment Agency 2015. The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015.

Fairley, et al., (2017) An analysis of the wave climate in South Wales, UK. Proceedings of the 12th European Wave and Tidal Energy Conference 27th Aug -1st Sept 2017, Cork, Ireland

Fugro-Emu, 2014. Review of Environmental Data Associated with Post-consent Monitoring of Licence Conditions of Offshore Wind Farms. MMO Project No: 1031.

Gafeira, J., Green, S., Dove, D., Morando, A., Cooper, R., Long, D., & Gatliff, R.W., 2010. Developing the necessary data layers for Marine Conservation Zone selection - Distribution of rock/hard substrate on the UK Continental Shelf.

Geologists' Association (2020). Pembrokeshire Geology. http://swga.org.uk/. Accessed 29/04/2021

GEOxyz Ltd (2021). Erebus Floating OWF - Geophysical & Geotechnical Surveys Geophysical Survey Results Report. Document Reference UK4150H-723-RR-01-1.0

Greenlink (2019) Greenlink Marine Environmental Statement. P1975_R4484_RevF1

Halcrow, 2012. Lavernock Point to St Ann's Head Shoreline Management Plan SMP2. Accessed on 2/3/21: Available online at: http://www.southwalescoast.org/content.asp?id=58 [Accessed September 2019].

Howells, C., Kammer, T. (2014). A new crinoid from the Mississippian (Early Carboniferous) of South Pembrokeshire, Wales. Geological Journal 49(2), pp 207-212.

HR Wallingford et. al. (2007). Dynamics of scour pits and scour protection - Synthesis report and recommendations: Sed02. HR Wallingford, Wallingford.

Hughes, A.L.C., Gyllencreutz, R., Lohne, Ø.S., Mangerud, J., Svendsen, J.I. (2016). The last Eurasian ice sheets – a chronological database and time-slice reconstruction, DATED-1. Boreas, 45, 1-45

Intertek (2019). Erebus Stage 1 Floating Windfarm Geological Desk Top Study. P2324_R4791_Rev0

JNCC and Natural England (2011). 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

Judd A (2011). Guidelines for Data Acquisition to Support Marine Environmental Assessments of Offshore Renewable Energy Projects. Cefas, Lowestoft

King, E. V., Conley, D. C., Masselink, G., Leonardi, N., McCarroll, R. J., & Scott, T. (2019). The impact of waves and tides on residual sand transport on a sediment-poor, energetic, and macrotidal continental shelf. Journal of Geophysical Research: Oceans, 124, 4974–5002

Little, D. I.,(2009). Sediment contaminants and transport review. Report for Milford Haven Waterway Environmental Surveillance Group. June 2009.

Mackie, A.S.T., James, J.W.C., Rees, E.I.S., Darbyshire, T., Philpott, S.L. Mortimer, K., Jenkins, G.O. & Morando, A. (2007). The Outer Bristol Channel Marine Habitat Study. Studies in Marine Biodiversity and Systematics from the National Museum of Wales. BIOMÔR Reports 4: 1-249 & A1-A227

Marine Space (2019). Project Erebus' Floating Offshore Wind (FLOW) development: Environmental Impact Assessment Scoping Report

MMO (2014). Review of post-consent offshore wind farm monitoring data associated with licence conditions. A report produced for the Marine Management Organisation, MMO Project No: 1031. MMO, Newcastle.

Moore, J. (2021). West Angle Bay, survey of shallow subtidal habitats, 14 May 2021. A report to MarineSpace from Coastal Assessment, Liaison & Monitoring Ltd., Cosheston, Pembrokeshire. 12pp + i.

Moray Offshore Renewables Ltd (2012) Environmental Statement for Telford, Stevenson, MacColl Wind Farms and Associated Transmission Infrastructure.

National Tide and Sea Level Facility (2021). Water level data for Milford Haven. Accessed March 2021. Available at https://www.ntslf.org/

Natural Resources Wales (2020a). Marine Physical Processes Guidance to inform Environmental Impact Assessment (EIA). Natural Resources Wales, Cardiff

Natural Resources Wales (2020b). Project Erebus: Screening and Scoping Opinion under the marine works (environmental impact assessment) regulations 2007 (as amended) project Erebus, floating offshore wind farm. Natural Resources Wales

Navitus Bay Development Ltd (2014). Navitus Bay Wind Park Environmental Statement. Volume B – Offshore: Chapter 5 – Physical Processes. Document 6.1.2.5.

Ocean Ecology (2021) Erebus Floating Offshore Windfarm: Environmental Baseline Survey report. Ref:OEL_ROVERE0420_TCR_EBS_V03

Ocean Ecology (2020). Erebus Floating Offshore Wind Farm Habitat Report. REF: OEL_ROVERE0420_TCR_INT_V01

Ørsted (2018). Hornsea Project Three Offshore Wind Farm Environmental Statement.

Palmer, M., Howard, T., Tinker, J., Lowe, J., Bricheno, L., Calvert, D., Edwards, T., Gregory, J., Harris, G., Krijnen, J., Pickering, M., Roberts C. and Wolf J. (2018) UK Climate Projections Science Report: UKCP18 Marine report. Met Office Hadley Centre: Exeter.

Partrac (2020). Erebus project metocean survey. [In progress]

Pembrokeshire Coast National Park Authority. (2020). Pembrokeshire Coast National Park Local Development Plan 2 (Replacement) - end date 2031: Adopted Local Development Plan.

Pye K., Blott, S., Brown J. (2017). Evidence Report No: 208 Advice to Inform Development of Guidance on Marine, Coastal and Estuarine Physical Processes Numerical Modelling Assessments. Natural Resources Wales, Cardiff

RenewableUK (2013). Cumulative Impact Assessment Guidelines: Guiding Principles For Cumulative Impacts Assessment In Offshore Wind Farms

Rovco (2021). Blue Gem Wind Project Geophysical & Environmental Final Survey Report. ERE-ENG-RVC-REP-GEO-0010 A05

SEASTATES (2021). ABPmer metocean information service. Accessed April 2021. Available at https://www.seastates.net/

Soulsby, R. (1997). Dynamics of marine sands. Thomas Telford, UK

Tappin D.R., Chadwick R.A., Jackson A.A., Wingfield R.T.R., Smith N.J.P., 1994. United Kingdom offshore regional report: The Geology of Cardigan Bay and the Bristol Channel. British Geological Survey, Nottingham. 107pp.

Uncles R.J and Stephens J.A. (2007) SEA 8 Technical Report – Hydrography. Plymouth Marine Laboratory Applications Ltd. Document was produced as part of the UK Department of Trade and Industry's Offshore Energy Strategic Environmental Assessment programme.

UKHO (2021). Bathymetry data. Accessed April 2021. Available at https://seabed.admiralty.co.uk/

UKHO (2020). Admiralty TotalTide tidal prediction software. Accessed 19/04/2021

Van Rijn, L.C., (2007). Unified view of sediment transport by currents and waves, I: Initiation of motion, bed roughness, and bed-load transport. Journal of Hydraulic Engineering, 133(6), p 649-667.

Vattenfall Wind Power Ltd (2018). Thanet Extension Offshore Wind Farm Environmental Statement

WaveVenture (2019). Erebus Metocean analysis desk study. Simply Blue Energy. P98.01

Welsh Coastal Monitoring Centre (2021). LiDAR Data. Accessed April 2021. Available at: https://www.wcmc.wales/

Welsh Government (2019). Welsh National Marine Plan. Accessed on 2/3/21. Available at https://gov.wales/welsh-national-marine-plan-document

Welsh Government (2018). Planning Policy Wales. Accessed on: 1/3/21. Available at: https://gov.wales/planning-policy-wales

Whitehouse, R.J.S. (1998). Scour at marine structures: A manual for practical applications. Thomas Telford, London, 198 pp.

Williams, D. J. A. and Jolly, R., 1975. Milford Haven: survey of pollution and mathematical modelling of pollutant distribution and transport. Report from Department of Chemical Engineering, University College of Wales, Swansea.